Local Government Association
of South Australia

The Voice of Local Government

Guidelines For Developing a Climate Change Adaptation Plan and Undertaking an Integrated Climate Change Vulnerability Assessment

November 2012

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EXECUTIVE SUMMARY

South Australia has one of the most variable climates on earth as a result of a number of naturally occurring circulations in the atmosphere and oceans. In addition, as the planet warms as a result of the release of greenhouse gases into the atmosphere, there will be further changes to our climate.

Over the past 40 years there have already been measured increases in average temperature, evapotranspiration, the number and frequency of very hot days and nights, and the number of extreme fire danger days. Our rainfall patterns have changed and there has been a sea level rise of approximately 18 cm.

In the coming years as the global temperature continues to rise, the changes to the climate will very likely exceed those observed over the past century. In South Australia rising sea levels, a hotter, likely drier future, and other expected climate changes will affect water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health. To prosper into the future means we will need to adapt to these changes.

As part of implementing the Climate Change Adaptation Framework for South Australia, and building on the climate change risk assessments already undertaken for all Councils across South Australia by the Mutual Liability Scheme, this Local Government Association of South Australia (LGA SA) publication provides guidance on how to develop a climate change adaptation plan.

The guide is the second of two publications and follows the LGA SA *Guide for Councils Developing a Climate Change Action Plan, (*to view the publication see http://www.lga.sa.gov.au/site/page.cfm?u=15)*.*

The four steps for developing a climate change action plan are:

1. develop the necessary management structures and processes to successfully implement the plan;
2. identify mitigation actions (actions that reduce the emission of greenhouse gases into the atmosphere);
3. develop adaptation actions (actions that reduce the impact of expected climate changes); and
4. cost, prioritise, implement and communicate the actions.

This guide expands on step three of the climate change action planning process and provides clear, logical and implementable steps for developing a climate change adaptation plan. The aim of the adaptation plan is to increase the resilience (reduce the vulnerability) of our natural systems, productive landscapes, and communities by developing policy responses founded in active participation at all levels, strong partnerships and best scientific knowledge. Outputs of the process will be well developed, regionally specific climate change adaptation actions.

Because the expected climate change impacts will be interlinked with, and exacerbated by, changes in a range of other stressors that will occur at the same time (such as population increases, further demand for resources, an ageing demographic, and pressures on the natural environment from feral weeds and pests that may be more suited to the changed climate), it is important that the adaptation plan is develop with an integrated perspective. For these reasons, a methodology for undertaking a regional integrated climate change vulnerability assessment (IVA) has been developed and is described in detail in this guide.

The Intergovernmental Panel on Climate Change (IPCC) describes vulnerability as a function of impact and adaptive capacity and "*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 2007). The IVA methodology developed here builds on this description of vulnerability by examining the exposure (predicted changes in the climate), sensitivity (the responsiveness of a system to climatic influences) and adaptive capacity (the ability of a system to adjust to climate change) of a range of indicators in a region. The indicators are selected to represent the full range of dimensions in a region and describe the environmental, economic and social bottom line or environmental, financial, physical social and human capital.

The key outputs of the integrated vulnerability assessment are to:

- identify which, industries, communities, businesses, ecosystems, species are most vulnerable to climate change;
- determine why they are vulnerable – is it that they are more sensitive, more exposed, or have a low adaptive capacity; and
- identify actions can be taken to reduce this vulnerability.

By taking an integrated approach, the chances for maladaptation (actions that address one impact but cause problems elsewhere) are reduced. Integrated solutions might also identify win-win options that have more than one benefit. Solutions that cross sectoral boundaries such as town planning, monitoring and reporting processes can be identified and managed in a more efficient way, and the collaboration of numerous stakeholders required in the process builds community and professional networks, engages the key regional partners, and has the opportunity to raise awareness levels to result in more effective and efficient outcomes for the region that minimize duplication.

The six steps outlined here for developing a climate change adaptation plan are:

- **Scope:** Define the scope of the study in terms of geography (location, region) and sector (Council, industry, business) and identify key stakeholders;
- **General Climate Change Impacts:** Identify the relevant general climate change stresses that will occur and the likely impacts;
- **Key decisions:** Identify the detailed information required to make the key decisions or answer the key questions needed to respond to the general climate change impacts;
- **Climate change scenarios:** Source relevant downscaled climate change scenarios for the geographic area and timeframes required for detailed studies;
- **Detailed climate change impacts and vulnerabilities:** Quantify detailed climate change impacts and / or vulnerabilities relevant to the key decisions; and
- **Identify adaptation actions:** Identify adaptation actions based on outputs from the integrated climate change vulnerability assessment and prioritise.

The guide provides detailed instructions on how to undertake each step and gives a checklist at the end of each step so that practitioners can ensure that they have addressed the key points.

Appendix 1 provides a table of suggested vulnerability indicators for each of five capitals (environmental, physical, financial social, and human). The methodology can accommodate other indicators that may be chosen by the stakeholders in the study and so allows for the outputs to be regionally specific.

Appendix 2 describes the concept of uncertainty including climate complexity and sensitivity, the range of future greenhouse gas emissions, the sensitivity of systems to climate stressors and how to deal with uncertainty in assessing vulnerability.

Appendix 3 provides example climate change scenarios for South Australia and Appendix 4 provides a summary of the flow charts developed for quick reference. A glossary at the end of the document provides definitions of the terms used in the guide.

The steps described in this guide are designed to ensure Councils and participating regional stakeholders use a consistent approach when developing a climate change adaptation plan and undertaking the integrated climate change vulnerability assessment while still providing for regional input and indicators to the process.

Consistency is important for providing a degree of comparability across the different environmental, social and economic indicators assessed and between the different regions of the State so that priorities for action are easily identified.

BACKGROUND CONTEXT

The IPCC's Fourth Assessment Report (FAR) released in 2007 stated that the warming of the global climate system as a result of the release of greenhouse gas emissions into the atmosphere is now "unequivocal", and is "evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC 2007).

The warming of the planet has already caused changes in the climate and as a result South Australia has, over the past 40 years, experienced increases in average temperature, changes in rainfall (reductions in winter and spring, longer dry spells between rainfall events), an increase in evapotranspiration (the combined effects of evaporation and plant transpiration), an increase in the number and frequency of very hot days and nights, a reduction in the frequency of frosts, an increase in the number of extreme fire danger days and a sea level rise of approximately 18 cm.

In the coming years the global temperature will continue to rise for a number of reasons. First, much of the greenhouse gas emissions to date have been absorbed by terrestrial and ocean sinks but in recent years these sinks appear to have reduced in their capacity to extract the gases from the atmosphere. Secondly, aerosols from pollution have so far cooled the earth but their concentration in the atmosphere is now reducing because of clean air policies globally. And finally, global mitigation policies to date have not been enough to significantly curb the release of greenhouse gases into the atmosphere and so they will continue to increase over the coming decades. The resultant continuation of warming will bring changes to the climate that will very likely exceed those observed over the past century (IPCC 2007). Average temperature increases are expected to rise by more than 2^{o}C above 1990 levels in the next 30 years, a level of warming expected by many scientists to result in "dangerous" climate changes.

In South Australia rising sea levels, a hotter, likely drier future, and other expected climate changes will affect water resources, agriculture, forestry, fisheries and human settlements, ecological systems and human health. The impacts will be interlinked with, and exacerbated by, other stressors that will occur at the same time such as population increases, further demand for resources, an ageing demographic, and pressures on the natural environment from feral weeds and pests that may be more suited to the changed climate.

It is very likely that there will be shifts in the geographical distribution of agriculture for some regions. Conventional farming of marginal land in drier regions is likely to become unsustainable in the longer term due to water shortages. New biosecurity hazards and increased environmental degradation due to extreme events is also likely. However, in some areas it may be possible to grow new crops or those displaced from other regions. Ecosystems will need to be able to adapt or migrate in tandem with their suitable climatic zone or sea level, or will face extinction.

Hard physical infrastructure including roads, bridges, dams, buildings and other assets are likely to be affected by the increased extremes in the climate such as heat-waves, flooding, bushfire or extreme wind events.

Social disruption to existing communities and networks are possible as the impacts affect the economic sectors of agriculture, fishing, forestry, tourism and others.

As part of the LGA SA Climate Change Strategy, the Mutual Liability Scheme recently undertook a climate change risk assessment for all Councils across South Australia to identify key areas of local government business that are likely to be at risk from future climate changes. Risk assessments consider likely impacts from the perspective of likelihood and consequence of an event occurring and usually follow the Australian and New Zealand

Standard AS/NZS 4360 Risk Management Standard. Although risk assessments take into account preventative measures and corrective actions from outside the system to reduce the risk, they generally do not explicitly consider any intrinsic capacity from within a system to adapt to the impacts. As a result, the risk assessment may identify a system as at high risk of impact when in fact it may actually adapt quite well without external support, while others that appeared to be at low risk but do not have the internal capacity to adapt on their own are overlooked.

More recently, the tool used both internationally and in Australia to determine which geographic regions, ecosystems, economic sectors and social groups are most at risk from climate change is an integrated climate change vulnerability assessment (IVA) – a process that takes into account how sensitive something is to climate changes, how exposed it will be to the climate hazard / impact and its intrinsic capacity to adapt to the changes. In this way an IVA builds upon the risk assessment process.

In addition to identifying what will be most vulnerable, an IVA also aims to identify actions that will reduce vulnerability by either reducing the impacts of climate change or enhancing adaptive capacity. Actions to adapt to climate change may include: building sea walls, establishing early warning systems and improved responses to extreme events, improving water and energy efficiency, changing agricultural practices or variety / species selection, modifying planning or building codes and standards to withstand changes in the climate or to optimise energy efficiency.

New opportunities will also become available with adaptation actions in the form of renewable energy, carbon sequestration and business and government that meet the needs of the changing environment.

In 2012 the Government of South Australia released the state climate change adaptation framework entitled *Prospering in a Changing Climate*. The framework has four key objectives for climate change adaptation in the state:

1. to develop leadership and a strategic direction for building a more climate resilient state;
2. development of policy responses founded on the best scientific knowledge;
3. resilient, well-functioning natural systems and sustainable, productive landscapes; and
4. resilient, healthy and prosperous communities.

The four objectives of the climate change adaptation framework aim to increase the resilience (reduce the vulnerability) of our natural systems, productive landscapes, and communities by developing policy responses founded in active participation at all levels, strong partnerships and best scientific knowledge. The framework highlights the need for a regional approach to developing adaptation responses because of locally relevant issues, and encourages the inclusion of economic, environmental and social climate change impacts when determining adaptation actions. The tool identified in the framework for developing adaptation actions is a regional integrated climate change vulnerability assessment.

This guide provides a detailed methodology for developing a climate change adaptation plan, including the process of undertaking an integrated climate change vulnerability assessment is a supplement to the recently released LGA SA guidelines for Councils undertaking a Climate Change Action Plan (see http://www.lga.sa.gov.au/site/page.cfm?u=1544).

The methodology builds upon the Mutual Liability Scheme climate change risk analysis by considering not only the climate change impacts to Council business but also the sensitivity and adaptive capacity of the social, economic and environmental components of a larger region within which the Council operates. This approach will provide local government, business and other sectors state-wide with a more integrated view of the likely challenges posed by climate change and what adaptive actions will best improve the resilience of both their own business and that of the broader community.

The steps described in this guide are designed to ensure Councils and supporting stakeholders (Natural Resource Management Boards, Regional Development Australia, Zone Emergency Mangers, etc) in the process use a consistent approach when developing a climate change adaptation plan and undertaking an integrated climate change vulnerability assessment. Consistency is important so as to provide a degree of comparability across the different environmental, social and economic indicators assessed and between the different regions of the State.

Regional consistency and comparability is an important dimension for the LGA SA and state agencies working under the state adaptation framework. At the same time, the process allows for regional priorities to be included and a degree of flexibility in approach to ensure local needs are met. Outcomes of an IVA will be a set of adaptation options and action plan recommendations that are based on rigorous science, developed in consultation with a wide range of stakeholders at all levels of the community in an integrated way. Adaptation options and actions should then be easy to incorporate into Council and other stakeholder strategies and plans at a regional scale with support from the State Government where appropriate.

It is important to note that there is still much debate within the scientific community about how best to evaluate vulnerability and which tools are most suited to informing climate change adaptation policy decisions.

Within that context, these guidelines will remain a working draft and are designed to be updated in response to future changes in our understanding of climate change and adaptation assessment processes.

DEVELOPING A CLIMATE CHANGE ACTION PLAN

To provide Councils across South Australia with guidance on how to both reduce their greenhouse gas emissions and their vulnerability to the accelerating climate changes, the Local Government Association South Australia published *A Guide for Councils Developing a Climate Change Action Plan* that outlines four steps for developing a climate change action plan:

1. develop the necessary management structures and processes to successfully implement the plan;
2. identify mitigation actions (actions that reduce the emission of greenhouse gases into the atmosphere);
3. develop adaptation actions (actions that reduce the impact of expected climate changes); and
4. cost, prioritise, implement and communicate the actions (Figure 1).

An overview of how to undertake each of these steps is provided in the guide and expanded upon in more specific detail here where relevant. The full text of the LGA SA Climate Action Plan is available on the LGA SA website (see http://www.lga.sa.gov.au/site/page.cfm?u=1) and is recommended reading before using this guide.

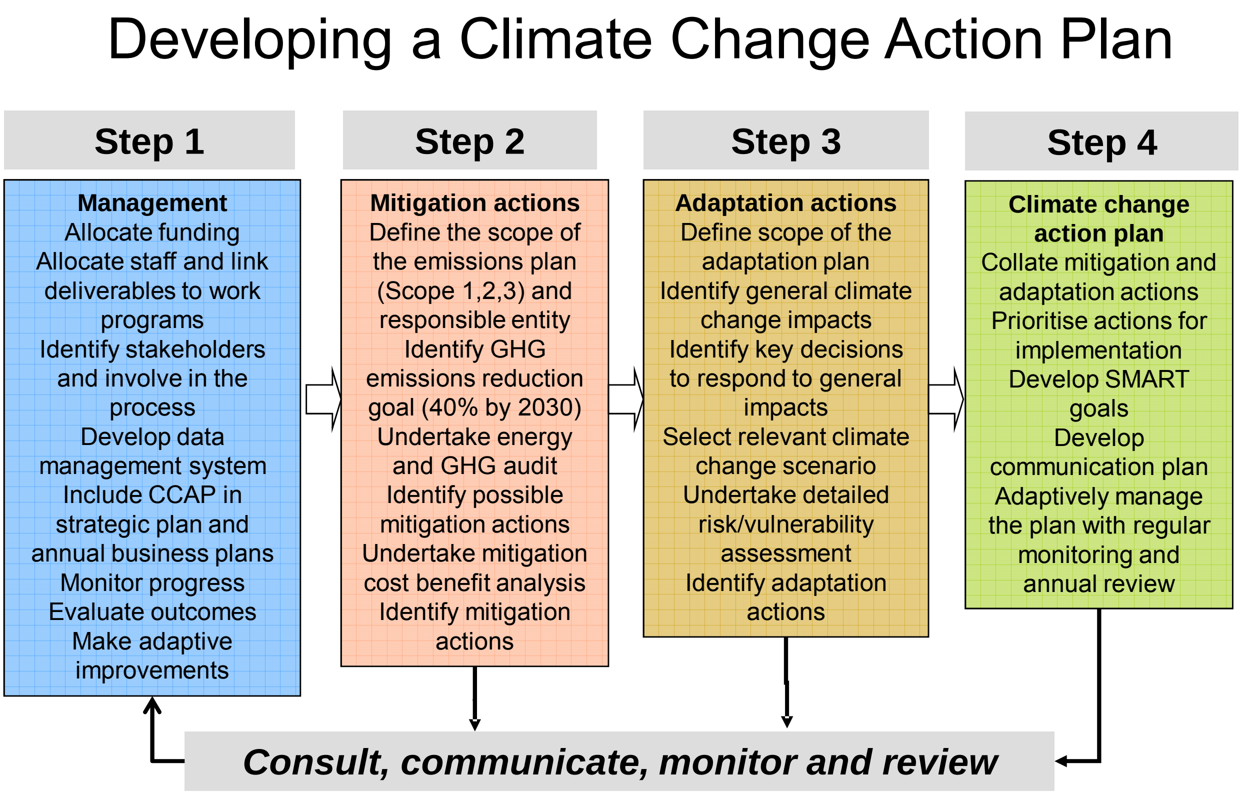

Figure 1: Steps for developing a climate change action plan from the LGA SA Climate Change Action Plan Guidelines.

Step one describes the management processes to be put in place prior to developing the climate action plan.

Step two describes the process of identifying greenhouse gas emissions and developing a mitigation plan.

Step three in the climate change action plan process is the development of a climate change adaptation plan and involves six steps:

1. define the scope of the study;
2. identify general climate change impacts to narrow the detailed analysis stage;
3. determine the information required to make decisions that address the likely impacts;
4. identify a relevant future climate change scenario that includes the climate change stressors and timeframes relevant to the decisions to be made;
5. quantify the detailed changes to the climate and resultant impacts and vulnerabilities using an integrated vulnerability assessment; and
6. identify adaptation actions that either reduce the associated impacts or build adaptive capacity.

Step three of the methodology for developing a climate change adaptation plan provides clear, logical and implementable steps for developing a regionally integrated climate change vulnerability assessment that delivers outputs to inform well developed, regionally specific adaptation options and is expanded on in this guide.

The final step involves implementing and communicating the options identified and the ongoing monitoring and review of the plan as part of the overarching climate change action plan.

If as a Council you are interested in developing a regional climate change adaptation plan, the preliminary actions identified by the City of Port Adelaide Enfield outlined below may be of value:

1. Investigate whether other Councils in your planning region are interested in collaborating on the project. The State's Adaptation Framework recommends that IVAs and resulting adaptation plans be undertaken wherever possible at the most meaningful scale, which in the context of climate change, is usually regional. In rural areas, this co-ordination may already be available or facilitated via the regional LGA organisations.

   The LGA SA and other network resources are available to assist Councils in a region to begin the collaboration process, if required. Contacting and discussing the process with other Council regions in SA who are currently undertaking Adaptation Planning projects may also be very valuable, and will provide insight into how a regional collaboration might be effectively managed and administered.

   The benefits of developing an adaptation plan jointly with similar adjacent Councils are:

   - the opportunity to share project and professional skills, resources, and information across the participating Councils – some of which may not always be available in individual Councils;
   - the opportunity to ensure that actions within, or as a result of the project, are planned and implemented at the most cost effective and beneficial scale;
   - the opportunity to engage the support and participation of the State Government in the project, via alignment with the State's Adaptation Framework; and
   - the greater likelihood of gaining funding via relevant programs, all of which recommend a regional approach wherever feasible.

2. As a group, investigate funding opportunities at the Commonwealth and State level – there are funding programs which support the undertaking of an integrated vulnerability assessment as part of the climate change adaptation planning process and related work. For example, the Commonwealth's Natural Disaster Resilience Program has recently amended its guidelines to include eligibility for regional proposals regarding climate change adaptation.

ADAPTATION PLANNING AND VULNERABILITY ASSESSMENTS

In 2006 the Department of Climate Change and Energy Efficiency (previously the Australian Greenhouse Office) released a set of guidelines entitled *Climate Change Impacts and Risk Management – A Guide for Business and Government* (Australian Greenhouse Office 2006). The guide outlined the steps for undertaking a climate change impact and risk assessment based on the Australian and New Zealand Standard for Risk management (AS/NZ 4360:2004) a standard that is widely used in public and private sectors to guide strategic and operational risk management. As such, the guide provides a familiar framework on which to examine and reduce the risks of climate change in a way that is well understood by a range of clients.

The framework is outlined in Figure 2 and involves five key steps:

- establishing the context;
- identifying the risks;
- analysing the risks;
- evaluating the risks; and
- then finding treatments or actions / recommendations to reduce these risks.

Risk is defined as a combination of the likelihood of an event and the consequence of that event - what can happen, and what are the odds of it happening. Treating the risk involves identifying options that manage or adapt to the risks and their consequences.

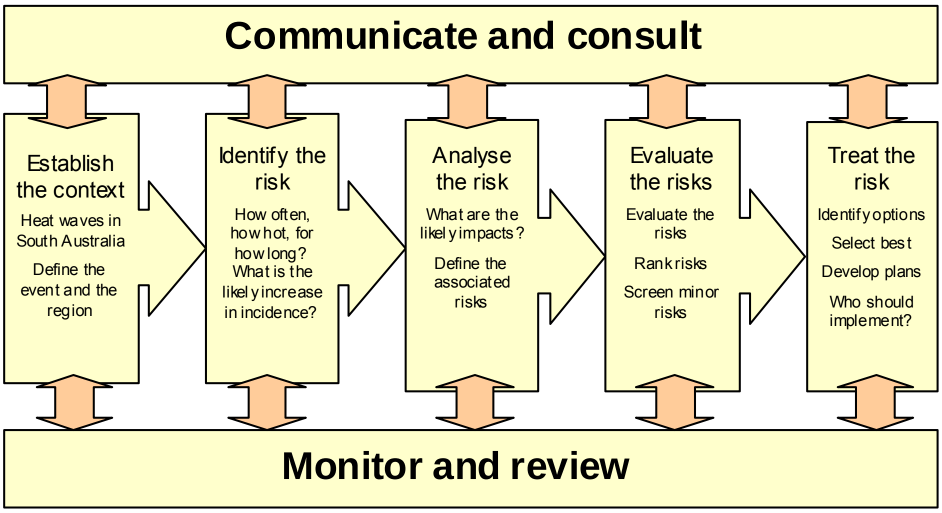

Figure 2: The framework for undertaking a climate change risk analysis (Australian Greenhouse Office 2006).

There are however, some limitations with the risk assessment process when determining likely impacts of and resilience to, climate change. Most critically, the likelihood of an event occurring is difficult to quantify as an understanding of past climate events will not provide an accurate picture of the future. Instead of considering likelihood and consequence, a climate change vulnerability assessment determines the impact of climate change by considering the sensitivity of the organism or system to the expected changes, and then how exposed the organism or system is to the expected changes. The assessment then builds upon a risk analysis by considering not only the impacts associated with climate change, but also the intrinsic capacity to overcome stress and adapt to changed conditions – adaptive capacity.

The IPCC describes vulnerability as a function of impact and adaptive capacity and “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 2007). The components of exposure, sensitivity and adaptive capacity are described below (IPCC 2007) and their relationship to vulnerability illustrated in Figure 3 (Allen Consulting Group 2005).

Exposure relates to the influences or stimuli that impact on a system. In this case, exposure is a measure of the predicted changes in the climate for the future scenario assessed.

Sensitivity reflects the responsiveness of a system to climatic influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes.

Adaptive capacity is 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. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system, the less vulnerable it is. Also defined as the property of a system to adjust its characteristics or behaviour in order to expand its coping range under existing climate variability or future climate conditions.

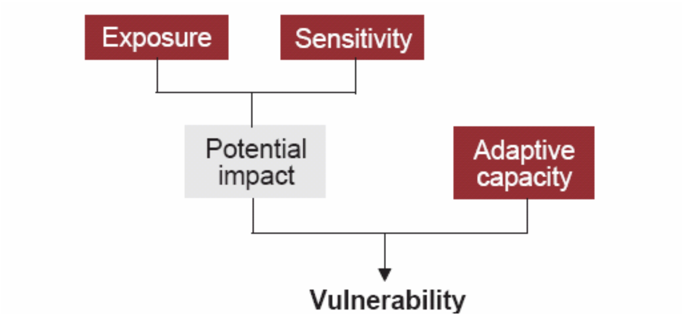

Figure 3: Exposure, sensitivity, potential impact and adaptive capacity are all considered in the evaluation of vulnerability to a defined climate change stressor such as temperature increases (Allen Consulting Group 2005).

There has been some confusion arising from these somewhat general definitions for exposure, sensitivity, adaptive capacity and vulnerability. For this reason, in the context of this methodology, each of the components of vulnerability is described in more detail as follows.

VULNERABILITY

An assessment of vulnerability can be defined as a "measure of possible harm" (Hinkel 2011). In this case harm to the environment would include such things as a loss of habitat or species diversity, disruption to food webs, reduction in ecosystem services or loss of ecosystem resilience and the capacity to bounce back from stresses, reduced water quantity or quality or an increase in habitat fragmentation.

For the human population, vulnerability would describe an increase in physical morbidity or mortality, increased mental illness, a reduction in the educational standards of a region, reduced access to medical care or increased suicide rates.

For social systems vulnerability would be seen as a disruption to social networks and communications, a reduction in the capacity of volunteer organisations or reduced productivity as a result of reduced access to the workplace. Occupational health and welfare policy that reduced working hours would also increase the vulnerability of social systems, as would reduced household incomes, reduced public services such as public transport, increased crime rates, an increase in the proportion of the population considered to be socially excluded or a reduction in the levels of engagement or trust with government.

Vulnerability of constructed physical systems would include the number or capital value of infrastructure assets that will be damaged or in need of increased maintenance modification or relocation / retreat from the climate stressors and will include transport networks (roads, rail, ports), communication networks, buildings, land and service related infrastructure (water and energy networks).

EXPOSURE

Exposure is the changes expected in the climate for a range of variables including temperature, heatwave, bushfire, sea level rise, frost, rainfall, carbon dioxide levels in the atmosphere, acidity of the oceans, storm surge and combinations of these. Systems may also be exposed to secondary changes as a result of these primary climate changes – such things as reduced income due to rainfall reductions / drought, or an increase in weed or pest pressure. If a system is protected from some of these changes (eg an irrigated crop is protected from drought, a chicken housed in a shed is protected from the cold) then exposure to the stressor is reduced.

SENSITIVITY

Sensitivity is the degree to which systems respond to the changes. Some systems will have a large reaction to a change in the climate while others will be less. For example, plants or animals that die in response to small changes in temperature or water availability are highly sensitive – physiologically they can't cope with the stress. Small changes in a household income that results in bankruptcy or mental illness are examples of a highly sensitive social system. Sensitive systems are often those that are close to a threshold or tipping point that means a small change in stress results in a large reaction. Systems that can endure significant changes would be considered to have a low sensitivity.

ADAPTIVE CAPACITY

Adaptive capacity describes how well a system can adapt or modify to cope with the climate changes to which it is exposed to reduce harm – does it bounce back? Is it resilient?

Examples of natural systems with low adaptive capacity are those with a limited gene pool and as a result a limited capacity to evolve, ecosystems affected by excessive land clearing, over extraction of ground or surface water, invasive species, soil erosion, salinity or environmental pollutants that do not have the resilience to adapt.

Economic systems that have a high debt to capital ratio or minimal opportunities to increase income would also struggle to adapt to climate changes.

Social systems that are disrupted, have poor communication networks, high crime rates or a prevalence of other socially dysfunctional behaviours such as domestic violence, suicide or drug addiction are also likely to be limited in their capacity to adapt.

When the adaptive capacity of a system is reduced, it is considered to be more vulnerable to the impacts of climate change. By considering adaptive capacity it is possible to avoid attending to impacts that may be reduced by the system itself with minimal outside help, or putting systems that have no capacity to adapt as a low priority with the result that more harm occurs than expected.

Putting this understanding of the components of vulnerability together in a few examples is helpful.

Example 1 – species vulnerability
When considering the vulnerability of a species to climate change, the assessment considers how exposed the species is to the changes (will it be impacted upon by sea level rise or heatwave?), how sensitive is it to the expected changes (is the species highly reactive to salt water inundation or heat events?) and how adaptable is it to the changes (can it migrate landward or move south or further up a slope to avoid extreme heat, or can it evolve to handle the changes while staying in the same place?).

Example 2 – ecosystem vulnerability
Coral reefs will be exposed to increased acidity in the ocean, are highly sensitive to the changes in pH, have no capacity to move away from the climate changes and are unlikely to be able to evolve quickly enough to cope – in other words they have high exposure, high sensitivity, low adaptive capacity and so are considered to be highly vulnerable to increased acidity of the oceans.

Example 3 – farming vulnerability
In contrast, a horticultural farming system that has the capacity to reduce exposure to heatwave with the use of shading, can reduce sensitivity through the selection of heat tolerant varieties, and has the capacity to adapt by changing species grown or management techniques used and so would be considered to have a low vulnerability to heatwaves.

Understanding the relationship between exposure, sensitivity, adaptive capacity and vulnerability enables the identification of specific adaption options that address the weakest link, and in doing so reduce exposure, reduce sensitivity or boost adaptive capacity.

In many cases boosting adaptive capacity will be achieved by reducing other non-climate related stresses. Social, economic and environmental systems that are already under stress from other changes will find it difficult to cope with the expected climate changes as well. Figure 4 illustrates the relationship between adaptive capacity and vulnerability to climate change for a number of key sectors identified in the Australia and New Zealand region over a range of future temperature increases.

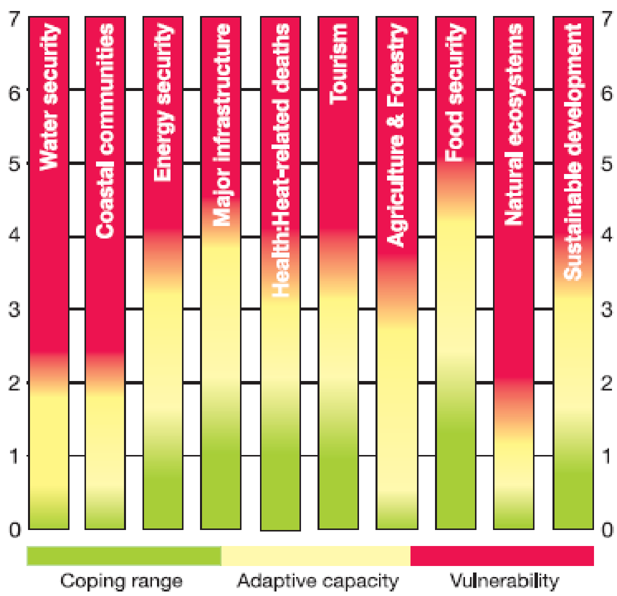

Figure 4: Vulnerability of key sectors in Australia and New Zealand to climate change (IPCC 2007).

INTEGRATED CLIMATE CHANGE VULNERABILITY ASSESSMENTS

Because of the complexity and interlinked nature of both climate and non-climate stresses, an integrated assessment that takes into account the breath of environmental, financial and social issues and other externalities is ideal. Integrated vulnerability assessments consider more than just one system and may involve a triple bottom line (environmental, social and economic factors) or five capitals approach (human, social, financial, physical and environmental dimensions).

The recommended five capitals approach within this methodology ensures that the sectors described in the State Climate Change Adaptation Framework (infrastructure and urban areas, agriculture, biodiversity, emergency management, bio-technology, water management, food supply, financial and consulting services and forestry) will all be included in an integrated way. As explained in our definition of exposure, an integrated vulnerability assessment will also usually consider a variety of stressors, not only those directly associated with the climate. For example when determining the vulnerability of a particular ecosystem to climate change the added pressures of pollution, land clearing, pests, diseases and weeds may also be taken into consideration as these things will affect the ecosystem's capacity to adapt to the added stress of changes in the climate.

In short, the key outputs of the integrated vulnerability assessment are to:

- identify which, industries, communities, businesses, ecosystems, species are most vulnerable to climate change;
- determine why they are vulnerable – is it that they are more sensitive, more exposed, or have a low adaptive capacity; and
- Identify actions can be taken to reduce this vulnerability.

In addition to providing an integrated perspective of climate change vulnerability that allows for comparison across variables and regions, an IVA has other benefits as well.

First, the process of undertaking an IVA will build climate change adaptation capacity within the stakeholders and organisations involved and provide key regionally specific data and knowledge about climate change impacts and adaptation options.

Secondly, the integrated approach ensures that maladaptation is avoided – actions that address one impact but cause problems elsewhere. For example, providing water to one area to irrigate a crop may well cause water shortage problems elsewhere in the landscape. Installing inefficient air conditioning systems that use more energy than necessary and put a strain on the electricity grid during heat waves would be another example. Integrated solutions might include win-win options that have more than one benefit such as the use of mulch for Council gardens (to reduce water use, recycle green waste, improve soil condition and sequester carbon dioxide from the atmosphere), or insulation of houses (to reduce extremes of heat and cold, recycle waste material in some cases, and reduce energy use and greenhouse gas emissions).

Thirdly, solutions that cross sectoral boundaries such as town planning, monitoring and reporting processes can be identified and managed in a more efficient way.

In addition, the collaboration of the numerous stakeholders required in the process builds community and professional networks, engages the key regional partners, has the opportunity to raise awareness levels to result in more effective and efficient outcomes for the region that minimise duplication.

Finally, the actions that are identified to reduce vulnerability (by reducing exposure to the climate stressor, sensitivity to the climate stressor or by enhancing adaptive capacity) can then be used to inform a climate change adaptation plan.

DEVELOPING A CLIMATE CHANGE ADAPTATION PLAN

The six steps for developing an adaptation plan from the Climate Change Action Plan model are shown below in Figure 5 and described in detail in the following sections. Remember that this apparently linear set of steps is part of the adaptive management circle of steps within the Climate Change Action Plan model (Figure 1) and that the outputs will be included in the Action Plan and regularly updated.

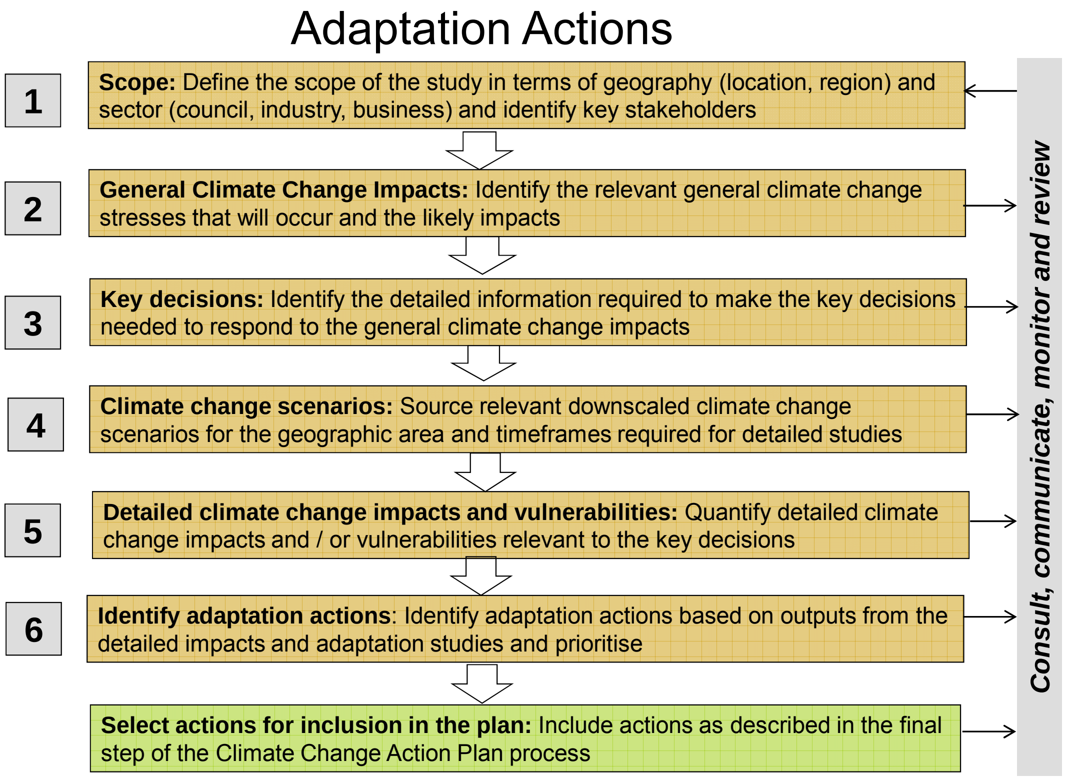

Figure 5: Steps for undertaking a climate change adaptation plan including an integrated vulnerability assessment as outlined in the Council Guidelines for Developing a Climate Change Action Plan.

Unlike a mitigation plan where the results of actions are relatively immediate (a reduction in electricity usage is measured and displayed in an energy audit at the end of each year), the results from an adaption plan will emerge more slowly. For this reason, an adaptation plan will probably only need to be updated every few years when recommended actions have been fully implemented, monitored outcomes of these actions are collated, and new knowledge about the climate system and climate related policy is available. The IPCC climate assessment reports are updated about every six years and provide a logical trigger for updating an adaptation plan. For each of the steps identified above, these guidelines provide a detailed description of the processes involved and a checklist of the key outputs that will be created.

STEP 1: DEFINE THE SCOPE OF THE STUDY

Scope: Define the scope of the study in terms of geography (location, region) and sector (Council, industry, business) and identify key stakeholders.

The first step in the adaptation planning process is for the stakeholders in the study to clearly identify the scope of the study. The scope should be guided by the goals for adaptation that in turn are developed to achieve the agreed vision for the region. The *Guide for Councils Developing a Climate Change Action Plan* describes the value of developing a vision in this context and should be read before starting this step in the process of developing an adaptation plan. The goal of adaptation as described in the State *Climate Change Adaptation Framework* are to increase the resilience (reduce the vulnerability) of our natural systems, productive landscapes, and communities by developing policy responses founded in active participation at all levels, strong partnerships and best scientific knowledge.

Because of the complexity involved in developing an integrated adaptation plan and undertaking a vulnerability assessment, it is particularly important to be very clear about exactly what will and what won't be included in the study and what the output will look like. Consider the context of the study (eg geographic boundaries, existing dimensions of the region), which sectors will be included (eg environmental, social, economic, industries, communities), and which stakeholders should be part of the study, what will be the final deliverable and how will the outputs align with existing processes that the stakeholders have for implementing the agreed actions.

STAKEHOLDER INVOLVEMENT

Stakeholders will include people who live in (or are dependent on) the region, sector or industry leaders, key decision makers, researchers and clients of the study. These personnel have a critical role in ensuring that the outcomes of the study are accurate for the region and that they will be useful and relevant. They will also bring to the table their values and beliefs about what they consider sustainable and what trade-offs they are prepared to make to adapt to the coming changes. Identifying and involving stakeholders early in the process ensures that they have an understanding of the process and ownership of the outcomes. When people are included in this way it is more likely that they will be advocates of the study and are inspired to lead and implement the recommendations. When people are not included in the development of action plans and the recommendations threaten their values there can be considerable resistance to the process. Without becoming unmanageable, an integrated study requires a range of stakeholders to ensure that the breadth of expertise and opinions needed are included in the assessment to avoid maladaptation and optimise efficiency.

Stakeholders should also have a clear understanding about how the process of developing an adaptation plan will unfold and what the final deliverable for the study will look like. Will there be a series of workshops for stakeholder involvement and if so who will be involved? Will the outputs align with their existing processes that will be used to implement the adaptation actions identified? What will the final report look like – does it need to include images, graphs, tables that easily communicate the outputs to their colleagues and those who will be making the decisions about who will implement the plan.

Once the scope and deliverables for the study are clearly defined and agreed on by all parties the details should be written down in detail so there is a common understanding of what will be covered and what won't, who will do what and by when it will be done. It is important at this stage that each of the stakeholders is clear about what their roles and responsibilities are - both within the study and when it comes to implementing the adaptation options identified. Writing a scoping document including the methodology of how the study will be undertaken is also a great way to include stakeholders from the beginning and can mean that any obstacles or barriers to completing the study are identified early on in the process.

CONTEXT OF THE STUDY

In consultation with the stakeholder group the context the study is then determined. The first step is to define the geographical area of the study and what within the area is to be assessed. Is the study going to consider a single business (a farm enterprise or manufacturing business), an industry (agriculture or viticulture, manufacturing or tourism) or a larger geographic region (local government area, group of regional Councils in the case of a regional climate change vulnerability assessment)? Where are the boundaries on a map? Also, what are the obvious networks of infrastructure, and flows of materials, people, and money in and out of the study area? For example, if water resources are piped into the area from elsewhere (Murray River) then it is important to consider the likely impact on the source of that supply. Or if a port facility outside the region is essential to the economy for exporting or importing goods to the region then the likely impacts of climate change on that facility should be considered too.

It is useful to realise that vast amounts of valuable data have already been collected by a number of key agencies (eg the Australian Bureau of Statistics (ABS), Australian Bureau of Agricultural and Resource Economics (ABARE), Department of Primary Industries (PIRSA in South Australia), Department of Natural Resources (DENWR in South Australia), the Natural Resource Management Boards (NRM Boards), the Regional Development Associations (RDAs) and LGA SA) and that the information that they can provide to the study will be geographically bounded by their collection areas. It is much easier to use existing data than to collect or generate new data sets and for that reason where the boundaries of an assessment are set will affect the cost and time associated with collecting information. For example, it may be better to change the boundaries of the study area to include a complete ABS data collection area than try to work out statistics for half an area. In some cases there will not be a perfect alignment with the data sets required and so assumptions will need to be made. In these cases it is important that those who are involved in the study are aware of the assumptions and the limitations of the data sets before the analysis stage.

INDICATORS TO INCLUDE

To achieve an integrated approach, the effects of climate change on a range of indicators that describe the sectors, industries and communities in the study region needs to be assessed. Indicators may include the proportion of the population over the age of 70, a measure of the primary income earning industries, productivity of key crops, outputs and number of people employed in the major manufacturing enterprises, education of the population and their capacity to access information, or availability of health care facilities. To simplify the process, indicators are usually grouped together to describe either the triple bottom line or five capitals depending on the approach taken.

The triple bottom line approach

The “Triple Bottom Line” is a term coined by John Elkington in his book “Cannibals with forks: the triple bottom line of 21st century business” (Elkington 1998) and is an expanded criteria for measuring organisational and societal success that includes not only the financial, but social and environmental dimensions of performance as well. Also known as “People, Planet, Profit” or “the three pillars”, the approach consists of measuring performance against the goal of sustainability by placing a dollar value on each of the three dimensions - financial capital, social capital and environmental or natural capital. The triple bottom line is now defined and recommended by the United Nations and is the dominant approach to public sector full cost accounting (Wikipedia 2010).

Human capital refers to the stock of competences, knowledge and personality attributes embodied in the ability to perform work to produce economic value. It includes the skills accumulated by a worker through education and experience (Smith 1776). Human capital is defined by the United Nations as "the productive wealth embodied in labour, skills and knowledge".

Natural or environmental capital includes the biotic and abiotic, renewable and non-renewable resources of the earth and includes plants, animals, minerals, gases, water and the interrelated systems of a healthy ecosystem such as recycling, pollution extraction, water collection and management of soil erosion. Environmental capital can be defined as the "total of renewable and non-renewable natural resources" (The Business Directory 2011).

The economic or financial capital is the real economic value of an organisation and is defined as the profit "after deducting the cost of all inputs including the cost of the capital tied up" (Wikipedia 2010).

The five capitals approach

More recently a five capitals approach developed as a rural livelihoods analysis framework (Ellis 2000) has been used as an extended version of the triple bottom line and is considered to encompass **all** the resources or capitals that an individual or community may be able to access. The five capital approach splits the original social capital into human and social capitals and the original financial capital into physical and financial capital. The five capitals are defined as:

- **Human capital** – the skills, health and education of individuals that contribute to the productivity of labour;
- **Social capital** – reciprocal claims on others by virtue of social relationships, the close social bonds that facilitate cooperative action and the social bridging, and linking and networks though which ideas and resources are accessed;
- **Environmental / Natural capital** – the productivity of land, and biological actions to sustain productivity, as well as the water and biological resources;
- **Physical capital** – the value of capital items produced by economic activity from other types of capital and can include infrastructure, equipment and improvements in genetic resources (crops, livestock); and
- **Financial capital** – the level, variability and diversity of income sources, and access to other financial resources (credit and savings) that together contribute to wealth.

When it comes to adapting to climate change, the total resources available to a community are those described by these five capitals. To increase one capital means reducing another. For example, an increase in horticultural food production results from using more of the available environmental capital in the form of soils, fertilizer and water. So the resources of a region will flow from one capital to another as people make choices based on their values and priorities for sustainability as a region.

For comprehensiveness it is recommended that the five capitals approach is used to assess the existing stock of the region. However, stakeholders may wish to combine the results of the human and social capitals into an expanded social bottom line, and the physical and financial capitals to produce the economic bottom line if that framework better suits their management approaches.

Each of the five capitals is described by a number of primary indicators that in turn are described by a more extensive selection of secondary indicators. The selection of indicators to describe each capital needs to take into account a number of key properties. First, the indicator needs to be a measure of something that will be affected by climate change and that is within the scope of the assessment (eg average crop yield of the region as a measure of agricultural production). It is useful if the indicator has been measured in the past (in other words there is a baseline against which to compare) and will continue to be measured into the future for ongoing monitoring of its condition over time. Also, the data that is collected should be available to the assessors at a reasonable cost.

Secondly, both the current condition of the indicator as well as a measure of its direction of change needs to be determined as the indicator is dynamic and will change over the period of time selected for the assessment (the climate change scenario). Understanding how the indicator is changing is important because the impact of climate change on the indicator in the future might be quite different to what it would be now. For example, the total kilometres of roads in the region, their current condition, and whether that length and condition is increasing or decreasing would need to be considered to get an accurate picture of what the likely vulnerability of roads to climate change will be in the future.

Finally, the spatial location of the indicator is important because depending on where the indicator is in the landscape its exposure and sensitivity to various climate changes will vary. Homes along the foreshore are both exposed to sea level rise and more or less sensitive depending on their construction type compared to homes inland that are not exposed at all.

Each of the recommended primary indicators (five for each of the five capitals) is shown in Table 1. A full list of secondary indicators for each of these primary indicators is given in Appendix 1.The secondary indicators selected for the study should reflect the needs of the region and the key decisions they are hoping to inform. Additional secondary indicators identified by the stakeholders in the region may also be added as well to provide a regionally specific analysis of each of the primary indicators. Once the relevant indicators to describe the capitals in the study region are selected, and the quantifiable data has been collected, the assessor can then quantify the exposure, sensitivity and adaptive capacity of each capital to climate change.

Table 1: Primary indicators for each of the five capitals recommended for consideration in an integrated climate change vulnerability assessment.

Capital	Primary Indicator				
Environmental	Landscape fragmentation	Vegetation communities	Biodiversity	Water	Land condition
Physical	Transport networks	Service networks	Communications	Buildings	Land assets
Financial	Primary industries excl. agriculture	Agriculture	Secondary industries	Tertiary industries	Quaternary sector
Social	Community Planning and Development	Existing Social Capital	Emergency Management	Governance	Social Inclusion/Exclusion
Human	Education	Physical Health	Age	Mental Health	

Checklist of outputs Step 1 - Scope:

□ Stakeholders - A list of people who make up the stakeholder group who will inform and direct the study, those that can provide required technical data and information, locally specific information, and value judgements for the study region.
□ An agreed deliverable for the end of the assessment that contains outputs that will align with existing processes that will be used to implement the climate change adaptation actions identified.
□ Context – A map of the study area that defines the boundaries of the region.
□ A project scope document that describes the roles of stakeholders and scope of the study.
□ Literature Review – and a review of the existing capital (financial, physical, human, social and environmental) within (and affecting) the region.
□ An agreed list of indicators that describe the five capitals that will be assessed for the study, and current data and expected trends for each of them.

STEP 2: CONSIDER GENERAL CLIMATE CHANGE IMPACTS

General Climate Change Impacts: Identify the relevant general climate change stresses that will occur and the likely impacts.

Because of the complexity and detail of data required for undertaking an integrated climate change vulnerability assessment, it is helpful to narrow down the amount of detailed analysis undertaken. For this reason the **second step** in the process is to consider the general climate changes that will be relevant to the location and scope of the study and identify the obvious impacts. For example, sea level rise will not be relevant for inland regions, changes in air temperature will not affect marine species (although sea temperatures would) and changes in bushfire frequency and intensity are probably not necessary to include in urban regions. In this way, the number of climate stressors and indicators for the detailed analysis can be reduced. It might be useful at this stage in the process to consider the primary and secondary indicators in the context of climate change as shown in Figure 6. Those climate stressors that are not relevant can be excluded from the study.

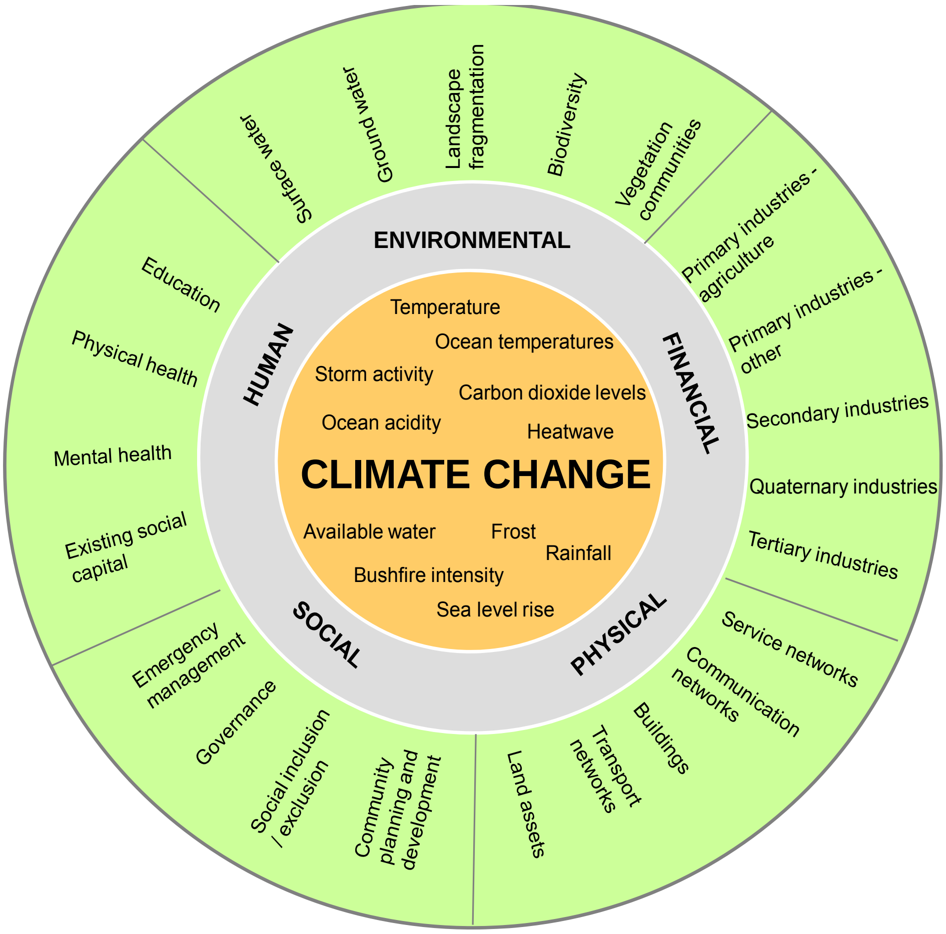

Figure 6: Climate change stressors in the centre of the circle will affect each of the five capitals (inner ring) as described by the primary indicators (outer ring) to be considered in an integrated vulnerability assessment. See Table 1 and Appendix 1 for more details.

An understanding of the likely general impacts of climate change on the selected region can be attained by undertaking a literature review of work that has been previously undertaken - a process that will also identify gaps in knowledge and limitations in the availability of more detailed data for further analysis. This step will provide assessors and stakeholders with an overarching understanding of the likely changes in the climate and the impacts from those changes in the study region without large amounts of data or detailed modelling.

Checklist of outputs Step 2 – General Impacts:
□ General impacts – An understanding of the general impacts that climate change will have on each of the indicators selected for the analysis in the study region. For example, sea level rise will inundate coastal property, reduced rainfall will likely reduce yield for many crops etc).

STEP 3: IDENTIFY KEY DECISIONS

Key decisions: Identify the detailed information required to make the key decisions or answer the key questions needed to respond to the general climate change impacts.

The **third step** considers what key decisions will need to be made about adapting to climate change. The key decisions that need to be made will be based on the scope of the study and are usually in the form of a question that arises in response to knowing the likely impacts to climate change. For example, what should we do to reduce the impacts of sea level rise on coastal infrastructure? Knowing what the key questions are and the decisions that need to be made identifies the timeframe over which actions need to be implemented and what detailed information will be required for the vulnerability assessment (Figure 7).

Some decisions have shorter lead times and short-term consequences and so are more flexible and can be implemented incrementally over time (eg planting annual crops). Other decisions have a longer lead time and long-lived consequences that may be hard to reverse and so are less flexible and need to be considered within in a more strategic time frame (eg construction of a dam or planned location of a coastal suburb). The changes in the climate over the short-term will not be as severe as those out to the end of the century and the levels of uncertainty about them will be less. For these reasons, determining the key decisions that need to be made at this stage in the process identifies the time lines that are important, and therefore the climate change scenario to select.

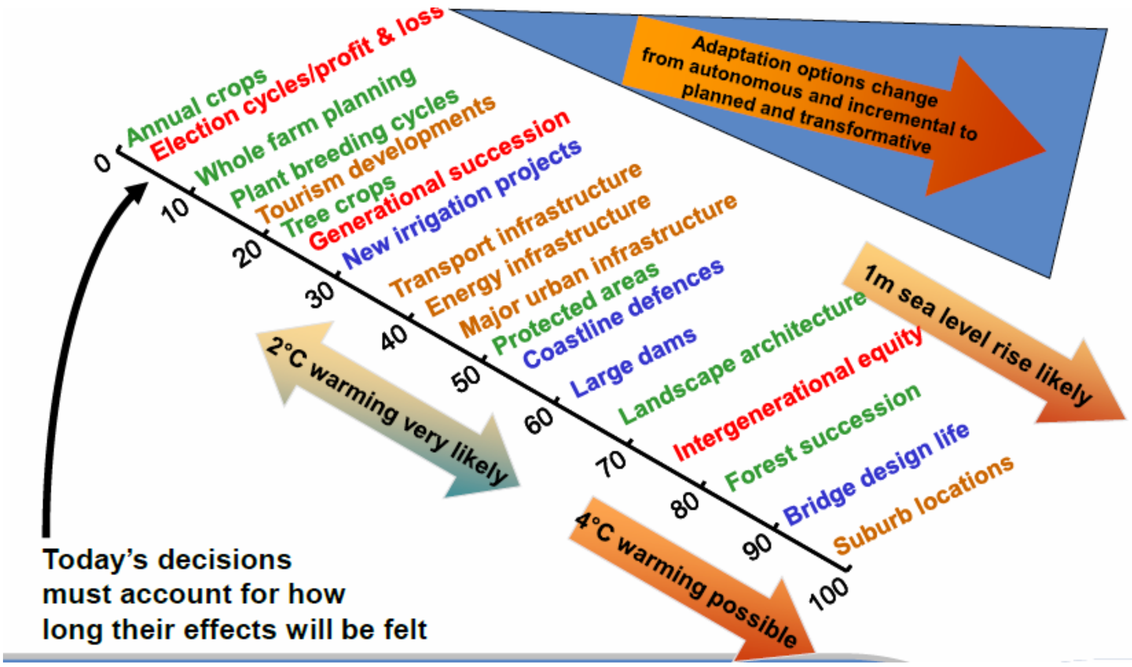

Figure 7: Climate change decisions and time lines (Stafford-Smith, Horrocks et al. 2011).

To inform the key questions and decisions identified may require additional data for more detailed assessments or modelling. For example: what is the likely yield reduction and therefore reduction in farm profits as a result of changes in rainfall? Or, how high will the sea level rise in this suburb between now and when coastal assets in the area are in need of replacement? Are there specific triggers or thresholds that need to be identified (eg when sea level rise reaches 80 cm these houses will be affected; when rainfall drops below a particular threshold some crops can no longer be grown).

Additional data and possibly modelling will be required to answer these questions or identify the thresholds, and can be a costly exercise. In reviewing the number and type of indicators to be assessed, the availability of the necessary data to undertake a detailed modelling exercise should be considered. One of the first pieces of information needed to model these problems is how the climate will change over the period of time identified by the decision. The next step in the process discusses the selection of a climate change scenario.

Checklist of outputs Step 3 – Key decisions:

□ Decisions – An understanding of the key questions and decisions that are needed to be made. For example, what should we do about sea level rise on existing coastal assets?

□ Data – the necessary information and detailed data required to answer the key questions and inform the decisions is clear including the spatial scale required and whether additional modelling is required.

□ Timeframes – the timeframes relevant to the key decisions is defined based on the lead and consequence times of the decisions and resulting actions.

STEP 4: SELECT CLIMATE CHANGE SCENARIOS

Climate change scenarios: Source relevant downscaled climate change scenarios for the geographic area and timeframes required for detailed studies.

The **fourth step** is to decide which future climate change scenario needs to be considered to inform the decisions identified. Choosing the future climate scenario on the basis of key decisions narrows down the amount of work required and provides relevant outputs. First, consider the relevant timeframe for your climate scenario - 2030, 2050, 2070 or further? Second, consider which greenhouse gas emissions scenario you wish to use – high emissions (business as usual, runaway, A1FI, A2 or RCP 8.5), medium emissions (stabilisation, A1B, B2, RCP 4.5) or low emissions (recovery, A1T, B1, RCP 2.6). See Appendix 3 for details of these emissions scenarios. Because future emissions are unknown, climate models are run using a number of different emissions scenarios as described in the section on uncertainty. When making this decision bear in mind the following points: Running a future climate change scenario on a global climate model is a highly complex and computer hungry exercise and for that reason there are only a limited number of future years and future scenarios available so be sure to choose one that has been calculated.

Regardless of the future emissions scenario, changes in the climate out to the year 2030 are not expected to vary largely from each other or the changes we have seen in the climate over the past 10 years due to known “lags” in the climate system – the slow response of the climate to the increased greenhouse gases in the atmosphere (Figure 8). Decision requiring a scenario to the year 2030 will include those that have a high degree of flexibility and short-lived consequences and that are incremental. For example, crop plantings and livestock management, tourist ventures, farm planning and short-lived policy. Be aware that the impacts by 2030 may not appear too dramatic and can lead to a false sense of security when making decisions that have long-lived consequences and that should use a longer scenario.

By the year 2050 projected climate changes vary more dramatically from what we have seen over the past decades, and between emissions scenarios (as shown in Figure 8). Scenarios to 2050 are usually considered relevant to decisions relating to planting tree crops that take a long time to mature and bear fruit, irrigation networks, infrastructure with a 50 year life span, transport, energy and telecommunications networks.

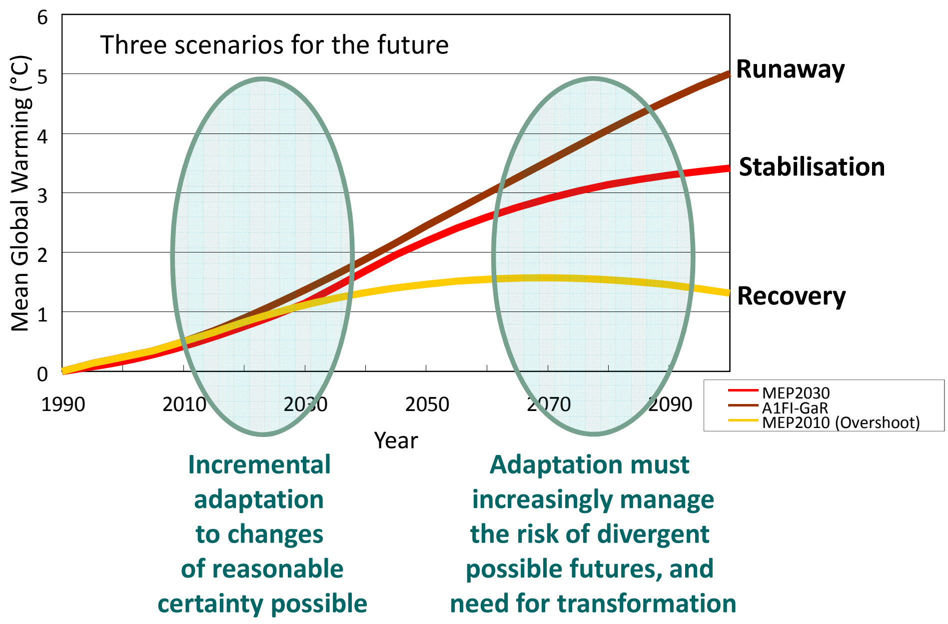

Figure 8: Climate change scenarios and time lines (Stafford Smith, 2012).

Longer scenario time-frames out to 2070 and 2100 will provide a vision of significant future changes (although with more uncertainty) and are important for long-lived decisions (construction of long-lived assets, planting of forestry lots, building a dam or planning the placement of a suburb for instance). Although scenarios along these timeframes may be beyond the concern of many politicians, managers and even leaders in the community, they are important to consider because of the large costs and possibly disruptive nature of making changes in the future.

The future climate scenarios chosen should include at a local scale a measure of all the climate variables that are going to have an impact on your business, industry or region at the relevant timescale. Climate variables might include local changes to temperature, rainfall, heatwave incidence and intensity, sea level rise, ocean acidity, bushfire incidence and intensity, carbon dioxide levels, storm surge height and frequency etc. See Appendix 3 for an example scenario for the year 2030.

DOWNSCALING

Climate scenarios from a global climate model (GCM) are usually at a large scale (they range from 160 to 800 km along each side of a square grid) and for that reason are not always useful for impact and adaptation studies that require a more locally relevant resolution. For these reasons the regional outputs from a GCM are usually "downscaled" using one of two methods – dynamical downscaling or statistical downscaling. The downscaling process improves the resolution of the projection outputs but may also introduce additional uncertainties (Figure 9). The limitations associated with downscaled climate change projections include the uncertainties described in the section on uncertainty (unknown sensitivity of the climate system to enhanced greenhouse gasses, unknown future emissions etc) and additional uncertainties associated with the downscaling process that include the degree to which the simulations are able to capture the relationship between local climate and the large-scale climate systems.

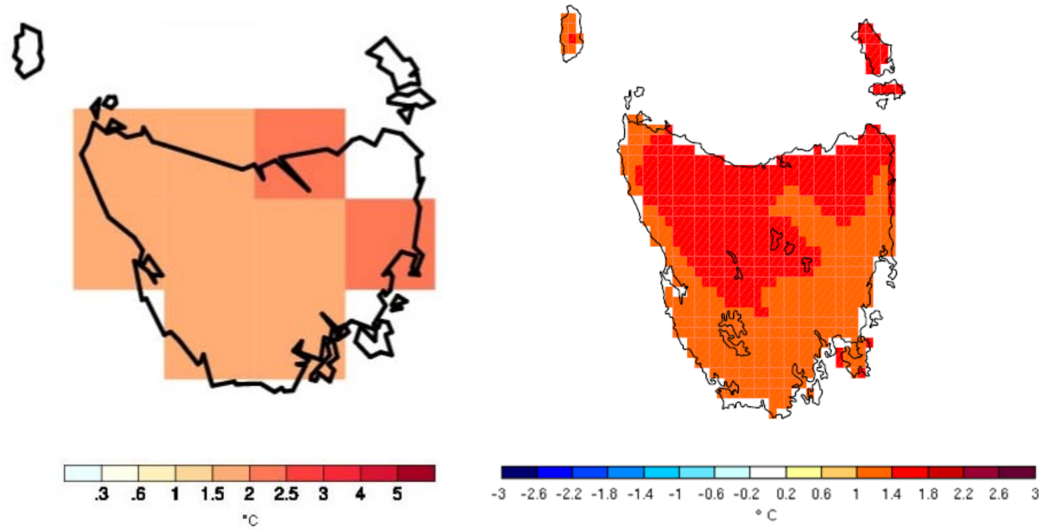

Figure 9: Climate change projections for changes to maximum temperature for Tasmania for the year 2050 under a high emission scenario compared to the 1990 baseline temperature. (Left) Climate Change in Australia report (CSIRO and BoM 2007) and (right) Climate Futures for Tasmania downscaled projections (Grose, Barnes-Keoghan et al. 2010).

Dynamical downscaling

Dynamical downscaling uses a high resolution, locally calibrated climate model that, like the GCM, uses physics to calculate the processes that are occurring in the atmosphere, but that runs at a finer regional resolution and uses outputs from the GCM to constrain the boundaries of the square. The grids in a downscaled model output are usually 5 to 50 km in length per side. These regional climate models (RCMs) are able to simulate the changes in the climate at the regional level but are expensive to run and require GCM outputs at a high temporal scale (3 to 6 hourly intervals) and so are not always readily available.

Statistical downscaling

Statistical downscaling uses regional historical data and GIS software to generate a high resolution surface for a range of climate parameters across the region that are then adjusted for future scenarios according to the projections from a GCM. The two models are tested against each other to ensure an accurate representation of historical and future climate using data averaged out over at least two decades to ensure a reasonable range of natural climate variability is included in the future climate scenario. However, unlike regional climate modelling, statistical downscaling assumes that the relationships between global and regional scale climate processes that have occurred in the past will remain the same into the future, an assumption that may not always be the case, particularly for rainfall. Statistical downscaling usually uses less computer time and for that reason is cheaper to generate than the dynamical RCMs.

It is important to note that although the outputs from a downscaled model may appear to have more accuracy because of the high spatial resolution, they are still subject to the same limitations of the original GCM and will include additional uncertainties associated with the process of downscaling.

When selecting which of the many GCMs to use to drive the downscaled model, it is best to use an average of a number of models, an approach that is considered to provide a more robust projection of future climate conditions than looking at the outputs from any single GCM. The CSIRO and BOM have already gone through the process of selecting the appropriate models for the Australian region based on a number of criteria including how well they model the historical climate in the region and how well they can model the range of variability and uncertainty associated with future climate sensitivity. An example of a climate change scenario for the full range of variables for the year 2030 is included in this guide as an example and is based on a review of previous studies and future climate projections for South Australia using the high emissions SRES scenarios (A1FI and A1B) (see Appendix 3). A summary of each of the key climate stressors and sources of the data for South Australia are described below.

Temperature

Projections for future temperature are given as, are a measure of the absolute change in the average annual, seasonal or monthly temperature compared to the 1990 baseline (the average for the years 1975-2004). Current projections expect a global average temperature increase of between 2^{o}C and 7^{o}C by 2100. An increase above 2^{o}C before the end of the century is considered on the basis of scientific consensus to be catastrophic for many ecological and human systems as it would exceed any change recorded over the past million years. Future temperature projections are available from the CSIRO OZCLIM online tool (http://www.csiro.au/ozclim/home.do). Downscaled projections at a higher resolution are currently for Tasmania and will be available for South Australia in the next year or two from two sources: the Bureau of Meteorology statistical downscaled data and the CSIRO dynamical downscaled simulations.

Rainfall

For projections of future changes to rainfall, outputs are usually presented as a percentage change or absolute change at an annual, seasonal or monthly scale compared to the 1990 baseline. Due to complex dynamics of climate systems that bring rain, projections of future changes in rainfall are usually more varied than the temperature projections. For South Australia, most models are predicting a reduction in the total amount of annual rainfall in the future (Suppiah, Preston et al. 2006). As for temperature, future projections for rainfall are available from the CSIRO OZCLIM online tool (http://www.csiro.au/ozclim/home.do). As for temperature, downscaled projections of rainfall at a higher resolution will be available in the coming years.

Changes in rainfall frequency and intensity

In addition to the changes in the amount of rainfall received, it is also important to consider the changes in how the rain falls – intensity, frequency and seasonality. The more intense the rainfall events, the more likely there will be floods, while if the frequency of the rain is reduced there may be the risk of drought. For many areas in the tropics and sub-tropics it is expected that the intensity of rainfall will increase. However, for South Australia, projections for rainfall intensity suggest only minor increases of perhaps only 2% above current levels (Darren Ray, BOM, Head Climatologist, South Australia, personal communication).

Heatwave

A heat wave is defined by the World Meteorological Organisation as "when the daily maximum temperature of more than five consecutive days exceeds the average maximum temperature by 5^{o}C". The frequency and intensity of heat waves is likely to continue to increase in the future under all global warming scenarios for most locations across South Australia. CSIRO have calculated the likely changes in heatwave frequency and intensity for a number of locations around Australia including Adelaide (Climate Change in Australia project and report 2007: http://climatechangeinaustralia.com.au/).

Sea level rise and storm surge

Sea level rise has been increasing at a rate higher than the worst case scenario predicted by the IPCC AR4 and is calculated for Australia as the sum of the expected increases on a global scale and regional isostaysis (movement of the ground) at key locations along the coast. The CSIRO sea level rise home page at http://www.cmar.csiro.au/sealevel/ describes the latest on sea level rise and provides average sea level rise projections for Australia for a range of scenarios each decade (http://www.cmar.csiro.au/sealevel/sl_proj_21st.html). Sea level rise along the South Australian coast can be assumed to be the same as the global projections (Murray Townsend, Coast Protection Board, Department of Environment and Natural Resources, personal communication.)

Projections of inundation as a result of sea level rise have been undertaken by the DCCEE for the whole Australian coastline at a medium resolution (http://www.ozcoasts.gov.au/). High resolution sea level rise inundation maps for limited areas have been undertaken by State agencies and some Local Governments and can be sourced in most cases direct from Council or the South Australian Coast Protection Board.

The intensity of low pressure weather systems is the primary driver of storm surge events in South Australia. GCM projections suggest that these storms may decrease in the future (pers. comm. Darren Ray, Climatologist, Bureau of Meteorology, 2011). However, despite minimal changes in storm events, the surge impacts will increase as a result of sea level rise.

Carbon dioxide

By the year 2030 the level carbon dioxide / greenhouse gasses is expected to increase to 450 ppm under the A1FI and A1B scenarios – an increase of 61% above 1990 baseline values. Depending on the chosen emissions scenario, concentrations to the end of the century range between 450 ppm CO_2e 1465 ppm CO_2e (IPCC 2007). Values for other climate scenarios and years can be read off the SRES graphs (See Figure 15 in Appendix 2).

Bushfire

The Forest Fire Danger Index (FFDI) is a measure of bushfire exposure and is a function of temperature, rainfall, humidity and wind speed. Modelling by the CSIRO for changes to the FFDI as a result of climate change calculated that a 1.0^{o}C increase in mean temperature would equate on average to a 25% increase in the number of extreme bushfire days, and that a doubling of CO_2 (to 560 ppm) would equate to a 100-300% increase (Lucas, Hennessy et al. 2007). Further information for bushfire incidence and intensity can be sourced from the Lucas, Hennessy et al 2007 report (see the bibliography for full reference details).

Carbon price

Although not a direct climate stressor, the inclusion of a price on carbon in the analysis takes into account the climate change mitigation actions that will have an impact on the economy and communities and so may be included where considered appropriate. The Clean Energy Futures package of legislation passed into law in November 2011 and is likely to increase the cost of fossil fuel based products and industries. An increase in the price of fuel and fertiliser would likely increase the costs of broad-acre crop production and travel costs for those in remote and rural areas. However, the opportunity to sequester carbon in the forest plantations and soil can provide an investment for those with appropriate land and skills. When compared to other price signals such as the exchange rate, in most cases a price on carbon is considered to be a minor stress (Balston, Billington et al. 2011). The Centre for Economic Studies in Adelaide can provide modelling of the impacts of a carbon price on various sectors of the South Australian economy.

Changes in available water

Although considered a climate change stressor in this study and so not included as an exposure score in Appendix 3, the amount of available water (both surface and groundwater) will be affected by climate change. Changes in water availability are a function of the amount, timing, seasonality and intensity of rainfall, the amount of evaporation and evapotranspiration (water losses through plants as they respire), the topography and slope of the region, surface cover on the ground the movement of water through rivers and underground aquifers. In most cases a reduction in the amount of rainfall will result in much greater reductions in the amount of available water as these other factors come into play.

For example, a 5% decrease in rainfall may represent a 20% decrease in run-off with a further compounding reduction in stream flow or dam yields. Likely changes in available water are calculated using complex computer models that input the change in rainfall across a catchment and return the likely changes in stream flow and ground water recharge. Outputs can be used to determine the sensitivity of ground water and surface water supplies to climate changes so that the vulnerability of these systems can be calculated. Modelling of changes to stream flow as a result of climate change has been undertaken for the Murray Darling Basin by CSIRO and some catchments within South Australia by SA Water.

Combined climate stressors

In some cases, it is not possible to pull apart the impact of only one climate stressor on a variable. For example, when crop yields are modelled a number of climate stressors are included in the crop growth model at a daily time-step and so the predicted yield would include the crop response to rainfall, temperature, heatwave, carbon dioxide levels and changes in rainfall timing and intensity. In these cases a combined climate stressor is described to capture a number of climate stressors working together on the indicator.

Secondary climate stressors

Finally, there are some climate stresses that could be considered as secondary stressors. For example financial hardship on a community as a result of climate change driven drought or the stress on natural ecosystems from weeds and pests that have evolved in a warmer and drier environment and so are likely to exert pressure in geographical areas where they have not been present before.

Checklist of outputs Step 4 – Climate change scenarios:

□ Select scenario year/s – Based on the key decisions that need to be made and therefore the relevant timeframe for the future scenario, choose a future climate year or years. Years for GCM calculated future years are usually 2030, 2050, 2070 and 2100.

□ Select emissions scenario – Select an emissions scenario from the IPCC SRES or RCP options to ensure global climate model projections are available.

□ Climate change stressors – select the relevant climate change stressors (temperature, rainfall, sea level rise etc) and source the projection data (eg Appendix 3).

STEP 5: UNDERTAKE AN INTEGRATED VULNERABILITY ASSESSMENT

Detailed climate change impacts and vulnerabilities: Quantify detailed climate change impacts and / or vulnerabilities relevant to the key decisions.

The **fifth step** is to take the climate change stressors from the selected scenario and use the data in conjunction with the findings of the literature review and stakeholder and technical input to inform an integrated vulnerability assessment. Vulnerability assessments can be undertaken in a number of ways. In this guide we recommend a relatively simple method of capturing information about exposure, sensitivity, impact and adaptive capacity that includes an allocation of a score to each and then calculating a score for vulnerability. A simple vulnerability assessment matrix to guide the process can be created as an Excel ® spreadsheet. A template is available for download from the LGA SA climate change website.

Other methods for undertaking vulnerability assessments involve more complex mathematical or statistical analysis of measured data, or spatially determined analysis that use GIS technology to identify vulnerable areas within the landscape. These complex quantitative methods are beyond the scope of a simple guide and usually involve research agencies with specialised computational and data storage facilities and software. However, simple qualitative analyses of vulnerability are common and still very useful. In many cases, the data for a more complex quantitative analysis does not exist (or may never exist), and the use of qualitative measures of vulnerability are considered to be just as scientifically rigorous.

With any assessment of this type either qualitative or quantitative, there will be uncertainties associated with the data or information that is available including the projections for future climate changes and how systems will respond to these changes. For more detail on uncertainty please see Appendix 2.

DETERMINING IMPACTS

The first step in the process is to consider exposure to climate change and the sensitivity of the indicator to those changes. This step in the analysis will provide an understanding of the potential impacts of climate change on the indicators selected (See Figure 10 on the following page).

Columns A and B
The first column (A) contains each of the primary indicators. A selection of secondary indicators identified as relevant to the study area and scope are then listed in column B (See Appendix 1).

Column C
The current status and existing trend for each indicator is described in the column C.

Column D
The next column (D) contains the list of climate change stressors. To be able to quantify the effects of climate change on the selected indicators, the climate change scenario selected needs to be described as a selection of climate change parameters (or “stressors”) each with an associated description and a score to evaluate the relative measure of intensity. Climate change exposure is a measure of how much of a change is expected in the climate. Relevant climate parameters to include in the assessment would be temperature, rainfall, rainfall intensity, carbon dioxide increases, sea level rise, ocean acidity, storm surge events, incidence of heat waves, bushfire exposure etc.

The change in the climate parameter is described on the basis of rigorous science for the study area and an exposure score between one and five allocated as shown in the scales in Table 2.

In each case a score of one indicates very little change in the climate with minor impacts, and a score of five represents a change that is considered to be severe and likely to result in serious economic impact, species loss, or social impacts.

A B C D E F

Primary Indicator	Secondary Indicator	Description of indictor including current status ad future trends	Climate exposure	E Score	Sensitivity description	S Score	Potential Impacts	I Score
Health	Access to medical care	Given increased climate change related climatic changes/lifestyle related stress, medical care becomes more important. Distribution of healthcare is important, as is the ability to actually travel to healthcare providers. Single person, older, financially disadvantaged and socially isolated persons all find access more challenging. C3Some of these individuals are also more exposed to some climate change stressors as well and so may have greater need for medical care. (For example older people who are reluctant to use air-conditioning may also find travelling to health care difficult).	Winter May - Oct temp increase of 0.8°C: Southern Flinders					
			Winter May - Oct temp increase of 0.66-0.76°C: Mid-North, Yorke Peninsula and Barossa					
			Summer Nov - Apr temp increases of 0.87-0.81°C for the Southern Flinders and Mid-North	3.00	Increase in summer heat impacting on physical health, productivity, and morale.	3.00	Increase in negative health effects, decrease in productivity, increase demand for air-conditioning and water. Increase in vector borne diseases with concomitant loss in productivity and drain on healthcare resources.	6.00
			Summer Nov - Apr temp increase of 0.69-0.75°C for the Yorke Peninsula and Barossa	2.00	Increase in summer heat impacting on physical health, productivity, and morale.	3.00	Increase in negative health effects, decrease in productivity, increase demand for air-conditioning and water. Increase in vector borne diseases with concomitant loss in productivity and drain on healthcare resources.	5.00
			Winter May - Oct rainfall decrease of 10.4% for the Southern Flinders					
			Winter May - Oct rainfall decrease of 8.4-8.8% for the Mid-North, Yorke Peninsula and Barossa	2.00	Floods present an immediate threat to the wellbeing of individuals.	1.00	Increase in the dislocating effects of flood events (social, physical, financial).	3.00
			Summer Nov - Apr rainfall decrease of 3.3-3.7% across all sub-regions	1.00	Drought conditions leading to higher dust levels in the atmosphere, possibly more frequent dust storms. Air pollution (particulate matter, increased ozone etc) has deleterious effects on lung function and can increase the prevalance of asthma.	1.00	Increase in asthma and other respiratory conditions related to increased airborne particulate matter.	2.00
			Increased inundation (15-20cm) and coastal erosion (10-20m) from sea level rise and storm surge					
			Increased ocean temperatures by 0.92°C					
			Increased ocean acidity by a pH ranking of 0.13					
			Increased CO_2 in the atmosphere to 450ppm					
			Minor reduced frost incidence					
			Increased heatwave frequency (52%) and intensity	3.00	Increase in health related effects of prolonged or intense heatwaves not present yet, but anticipated.	2.00	Increased demand on the health system as a result of those who succumb to the physical and mental effects of increased heat.	5.00
			Increased bushfire frequency (55% for extreme FFID) and intensity	3.00	Bushfires present an immediate threat to the wellbeing of individuals - the young and old are less able to respond to disaster situations.	3.00	Increase in the dislocating effects of bushfire events (social, physical, financial).	6.00
			Price on carbon	1.00	Increased costs in fuel etc leads to service reduction. Less accessibility. Greater distances between service providers.	2.00	Increased fuel costs.	3.00
			Combined climate change stresssor score	3.00	The very young and the very old are more vulnerable to climate change stressors.	3.00	More ambulance transfers, greater draw on medical resources, potential loss of life.	6.00
			Secondary climate change impact score	1.00	Possible increase in vector borne diseases due to increased mosquito populations (i.e. dengue fever). Food spoilage due to heat can lead to gastroenteritis and other health issues.	2.00	Increased demand on the health system as a result of those who succumb to the physical effects of disease and gastroenteritis. Potential ongoing health issues as a result.	3.00
Average Score for Indicator				2.11		2.22		4.33

Figure 10: Example template for undertaking the first step in the integrated climate change vulnerability assessment. column A names the primary indicator to be assessed; column B names the secondary indicator selected to describe the primary indicator; column C contains a description and current status of the indicator; column D the list of climate change stressors shown in Appendix 3 and corresponding exposure scores (E score) – note that irrelevant climate stressors to the indicator being assessed are crossed out; column E describes the sensitivity of the indicator to the climate stressor and the allocated score (S score); column F describes the potential impact of the climate stressor on the indicator and calculated score (E score + S score).

Table 2: Scale for the allocation of climate exposure scores for the vulnerability assessment. Each category is a measure of the change in the climate variable compared to the 1990 baseline climate (as described in studies and calculated by Global Climate Models). Qualitative descriptors are provided as defined by the IPCC Third Assessment Report.

Scale (exposure and sensitivity):	**1**	**2**	**3**	**4**	**5**
Description for qualitative data	**Very low**	**Low**	**Medium**	**High**	**Very high**
Description for qualitative data	**Rare**	**Unlikely**	**Possible**	**Likely**	**Very likely**
General description for quantitative data (%)	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**
Absolute change in temperature (^{o}C)	**0.01-0.4**	**0.41-0.8**	**0.81-1.2**	**1.21-1.6**	**1.61-2.0**
change in rainfall from baseline (%)	**1-5%**	**5-10%**	**10-15%**	**15-20%**	**20-25%**
Increase in sea level (m)	**0.0-0.1**	**0.11-0.2**	**0.21-0.3**	**0.31-0.4**	**0.41-0.5**

In many cases, the indicator that is assessed will not be exposed to all of the climate stressors and so the redundant ones can be crossed out. Where there are case specific reductions to a climate exposure (eg livestock that are housed indoors and so not as exposed to heat) the exposure score may be reduced to account for the current adaptation that has already occurred.

Column E

The next column (E) allows for a description of the sensitivity of the indicator to each of the climate stressors and a score between one and five for sensitivity as described in Table 3.
Species sensitivity is a measure of how responsive a species is or how likely it is to be affected by the climate changes as described in the first section in this guide that describes adaptation and vulnerability assessments.

The allocation of a score for sensitivity is in most cases qualitative and will be the result of key technical input, research identified in the literature review and local knowledge. As the process is subjective, different individuals will choose to allocate different scores based on their understanding of the indicator and its response to climate change. For this reason, it is best to involve a number of stakeholders in the discussion on what score to allocate each indicator - a process that can be undertaken as part of a workshop or similar process and then validated by technical experts if required. A steering committee of personnel involved in vulnerability assessments across the state is available to provide input to the process as part of the State Climate Change Adaptation Framework and the LGA SA to support operators undertaking the assessment.

In some cases the sensitivity of an indicator to climate change might be able to be modelled (eg for predictions of yield and pasture productivity, estimates of financial flow on effects to other sectors of the economy from a reduction in agricultural production or the likely change in freshwater availability in response to changes in rainfall and temperature). Sensitivity modelling when it is done should be undertaken using the same climate change scenario and climate stressors used in the IVA so that the results are congruent with the rest of the vulnerability assessment. The specific details of each of these modelling exercises should be provided in the assessment report for transparency.

Scores for sensitivity including water quality and quantity have been defined and are shown in Table 3. As for exposure, if the sensitivity of an indicator is reduced due to current management techniques these influences can be noted and the score allocated accordingly. The vulnerability of the indicator will then be dependent on the continued reduction in sensitivity and this should be noted in the result to ensure current practices that reduce vulnerability are not removed.

Table 3: Scale for the allocation of sensitivity scores for the vulnerability assessment.

Scale (sensitivity):	1	2	3	4	5
Description for qualitative data	Very low	Low	Medium	High	Very high
Water quantity sensitivity	Water allocations not restricted. Where no licensing occurs water users have no water restrictions in place; available water can meet full requirements of uses, including water dependent ecosystems. Additional water sources are not required.	Water allocations restricted to 80% of licence allocation. Where no licensing occurs users have first stage water restrictions in place; available water can support productivity, but in a slightly diminished way; minor damage to water dependent ecosystems, where full recovery could be expected. Additional water required only in isolated cases.	Water allocations restricted to 50% of licence allocation. Where no licensing occurs users have 2nd stage water restrictions in place; available water can meet basic requirements (i.e. stock water, irrigation to sustain life of plants), but can't support optimal productivity; moderate damage to water dependent ecosystems, where recovery would have minor long term effects. Moderate quantities of additional water are required.	Water allocations restricted to 30% of licence allocation. Where no licensing occurs users have severe water restrictions in place; available water can meet basic requirements (i.e. stock water, irrigation to sustain life of plants), but can't support productivity; major damage to water dependent ecosystems, where recovery would have significant long term effects. Major quantities of additional water are required, but does not require additional major interbasin transfers.	Water allocations restricted to 5% of licence allocation. Where no licensing occurs users have the highest level of water restrictions in place; available water can't meet basic requirements (i.e. stock water, irrigation to sustain life of plants); irreversible damage to water dependent ecosystems. Major quantities of additional water are required, which can not be sourced from within the region.
Drinking water quality sensitivity	Minimal modification to normal operation required No discernible human impact	Modification to normal operation with some increase in operating costs Potential for short term minor water quality incident No discernible human impact	Additional operational procedures considerably increasing costs (eg PAC, UV, enhanced coagulation)otential for short to medium termminor water quality incident Increased monitoring required Potential risk to human	Additional operational procedures significantly increasing costs (eg PAC, UV, enhanced coagulation). Boil water notice issued. Potential for significant water quality incident Continual monitoring required Likely risk to human	Failure of system requiring notice not to ingest water even after boiling Potential for significant water quality incident Probable risk to human health resulting sickness lasting up to 30 days, chronic health issues and possible death
Ecosystem water quality sensitivity	No discernible human impact	Minor damage to water dependent ecosystems, where full recovery could be expected	Moderate damage to water dependent ecosystems, where recovery would have minor long term effects	Major damage to water dependent ecosystems, where recovery would have significant long term effects	Irreversible damage to water dependent ecosystems

Together the exposure to climate changes and the sensitivity of the indicator to those changes gives us a measure of impact.

Column F

The next column in the matrix (F) allows for a description of the potential impacts from the climate stressor when the exposure and sensitivity of the indicator is taken into account. The potential impact score is simply the sum of the exposure and sensitivity scores (Table 4). The Excel template will calculate the scores automatically.

Table 4: Scale for impact used in the climate change vulnerability assessment. Impact is calculated as the sum of the exposure and sensitivity scores.

Impact = exposure + sensitivity

	Sensitivity				
Exposure	**1**	**2**	**3**	**4**	**5**
1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10

Impact	
9-10	**Very high**
7-8	**High**
5-6	**Medium**
3-4	**Low**
1-2	**Very low**

The second stage in the assessment process is to consider the adaptive capacity of the indicator to the impacts identified (Figure 11).

G H I J K

I Score	Adaptive capacity	AC Score	V Score	Adaptation options	Adverse implications / Maladaptation	Potential to benefit / Opportunities
6.00	Greater use of air-conditioning, greater draw on water supplies. Improved and targeted local health care systems. Monitoring of known vectors, control programs where appropriate, and public education systems regarding the relevant diseases .	7.00	9.00	Greater energy consumption and water usage- increase in household running costs. State water availability drops. Heightened public awareness can cause fear.	Less impact on public health and therefore demands on the health system drop. Greater public awareness can lead to changed practices that minimise the potential effects.	
5.00	Greater use of air-conditioning, greater draw on water supplies. Improved and targeted local health care systems. Monitoring of known vectors, control programs where appropriate, and public education systems regarding the relevant diseases .	7.00	8.00	Greater energy consumption and water usage- increase in household running costs. State water availability drops. Heightened public awareness can cause fear.	Less impact on public health and therefore demands on the health system drop. Greater public awareness can lead to changed practices that minimise the potential effects.	
3.00	Creation and implementation of flood management systems, creation and implementation of disaster (flood) response systems.	5.00	8.00	The process would be expensive to implement.	Greater public awareness can mean people are aware of the warning signs in advance and able to remove themselves from the situation or minimise the impact.	
2.00	Improved local health care programs. Monitoring and public warning program for air particulate matter.	6.00	6.00	Heightened public awareness can cause fear. Less time spent outdoors-this could affect other sectors, such as sport and recreation, and social inclusion (less networking in the community).	Greater public awareness can lead to changed practices that minimise the potential effects. Awareness can lead to early detection of symptoms and lessen the extent of the impact.	
5.00	Improved and targeted local health care systems.	4.00	11.00	Costly and could divert spending away from other priority areas.	Health care systems are better equipped to deal with localised issues and able to respond efficiently.	
6.00	Implementation of bushfire response systems.	7.00	9.00	Emergencies can be anticipated as likely to occur, but their scale, timing and location are unknown. Costly process.	Emergency response systems can respond more efficiently and effectively in times of disaster. Local hazards can be identified early and mitigation measures put in place.	
3.00	Potential for subsidy of fuel costs. Public transport options made available.	8.00	5.00	Depending on the health issue, public transport could infect others with their condition. Few volunteers available to drive public transport- would have to be a paid position, which could prove costly.	Greater and cheaper access to medical facilities. Allows household income to be spent in other priority areas. Potential for networking and bonding on public transport	
6.00	Improved local health care systems.	4.00	12.00	A costly process and will not be effective if people cannot access.	Health care systems are better equipped to deal with localised issues and able to respond efficiently.	
3.00	Improved management of the food transport cold chain. Improved food hygiene practices. Improved management and contagious disease. Education programs for households.	4.00	9.00	Increased business costs- businesses are already more likely to be 'struggling' with other increasing prices.	Businesses and individuals are more aware of the potential dangers and can put measures in place to mitigate the effects.	
4.33		5.78	8.56			

Figure 11: Example template for undertaking the integrated climate change vulnerability assessment. Column G describes the adaptive capacity of the indicator to the climate stressors and the allocated score (A score); and column H is the calculated vulnerability score (V); column I lists the adaptive actions to take; column J the possible adverse implications of implementing the actions (maladaptation); and column K the potential benefits or opportunities identified with implementing the adaptive action.

DETERMINING ADAPTIVE CAPACITY AND VULNERABILITY

Column G

The next column (G) in the vulnerability assessment template allows for a description of the adaptive capacity of the indicator to the climate stressors and a score between one and ten is allocated according to Table 5. Note that the scores for adaptive capacity are reversed as a low adaptive capacity will result in high vulnerability and vice-versa. The adaptive capacity of the indicator describes the intrinsic capacity of the indicator to cope with the impacts described in the potential impacts column.

For ecological species, adaptive capacity is determined by the size of the species genetic pool (how common or endangered it may be) and its own genetic resilience and physiological capacity to respond to the changes. The more individuals within a species the more genetic diversity there is within the population and so the species has a greater capacity to genetically evolve to the changes expected. Species that are already low in number and have low genetic diversity within the population have less capacity to evolve beneficial traits that will enhance their capacity to survive and so are most vulnerable. Adaptive capacity of a species in a particular location may also be affected by external influences such as the construction of barriers to adaptation (roads, sea walls etc). Adaptive capacity does not include potential external human intervention that is yet to occur such as species relocation or reductions in exposure.

The adaptive capacity of a particular industry or community is the capacity of the enterprise or township to adapt to the climate changes using their own internal resources. As was the case for sensitivity and exposure, if the adaptive capacity of the indicator has already been enhanced by external influences (eg external grants, protection policies or aid), then these factors should be noted and the score adjusted accordingly. Again, it is important to note that the vulnerability of the indicator as scored will then be dependent on the continued provision of that support and it risks becoming more vulnerable if the support is removed. New actions that may or may not occur in the future are not considered as part of the adaptive capacity of the indicator. Table 5 provides a guide for the allocation of adaptive capacity scores.

Table 5: Scale for the allocation of scores for adaptive capacity.

Scale (adaptive capacity):	1 to 2	3 to 4	5 to 6	7 to 8	9 to 10
Description for qualitative data	Very low	Low	Medium	High	Very high
Description for qualitative data	Rare	Unlikely	Possible	Likely	Very likely
Species adaptive capacity	Engangered	Very rare	Rare	Threatened	Common
% for quantitative data	81-100%	61-80%	41-60%	21-40%	0-20%
Vegetation communitites	Vegetation community type primarily found in relictual landscapes <10% remaining	Vegetation community type primarily found in Fragmented landscapes 10-30 % remaining	Vegetation Community type primarily found in fragmented landscapes 30-60% remaining	Vegetation Community type primarily found in variegated landscapes 60-90% remaining	Vegetation Community type primarily found in intact landscapes >90% vegetation remaining

Column H

The final column contains the vulnerability score (H in the template) and is calculated as potential impact minus adaptive capacity (plus ten to ensure the number is positive). The vulnerability score will be between two and twenty as per Table 6. The Excel template automatically calculates the vulnerability score.

The final sensitivity, potential impact, adaptive capacity and vulnerability score for each indicator is an average of the scores allocated against each climate stressor (bottom row of the template example in Figures 10 and 11). Averaging the scores allows for an assessment of the overarching response of the indicator to climate change, although individual stressors may have a more or less severe effect.

Table 6: Scale of scores for vulnerability as calculated from the potential impact and adaptive capacity scores.

Vulnerability = (impact - adaptive capacity)+10

Impact	Adaptive capacity									
	10	9	8	7	6	5	4	3	2	1
2	2	3	4	5	6	7	8	9	10	11
3	3	4	5	6	7	8	9	10	11	12
4	4	5	6	7	8	9	10	11	12	13
5	5	6	7	8	9	10	11	12	13	14
6	6	7	8	9	10	11	12	13	14	15
7	7	8	9	10	11	12	13	14	15	16
8	8	9	10	11	12	13	14	15	16	17
9	9	10	11	12	13	14	15	16	17	18
10	10	11	12	13	14	15	16	17	18	19

Vulnerability	
16-19	Very high
12-15	High
8-11	Medium
4-7	Low
2-3	Very low

Outputs from the vulnerability matrix assessment will be the tables of indicator descriptions and tends, climate stressors that affect the indicators, sensitivity, potential impact, adaptive capacity, adaptation options and potential for adverse implications or opportunities for implementing actions as well as the scores for exposure, sensitivity, potential impact, adaptive capacity and vulnerability for each indicator that may be tabulated, plotted or otherwise presented (examples in Figure 12).

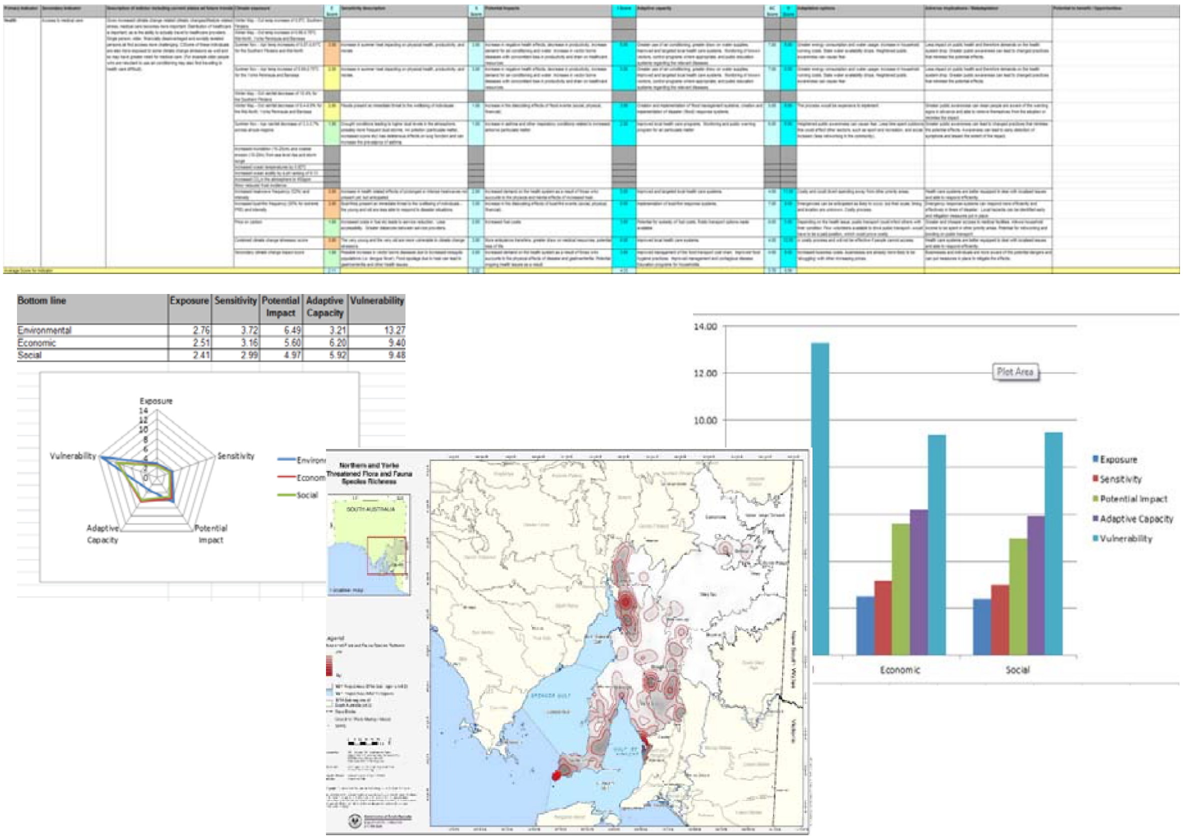

Figure 12: Example outputs from an integrated climate change vulnerability assessment include the vulnerability assessment matrix of sensitivity, potential impact, adaptive capacity and vulnerability including descriptions and scores, (top) scores plotted in a bar chart, (bottom right) hot spots of vulnerability mapped across the region, (bottom centre) scores plotted as a spider diagram (bottom left).

The vulnerability assessment matrix provides a framework within which to describe each of the components of exposure, sensitivity, impact, adaptive capacity and vulnerability to climate change for each of the indicators selected for the analysis. It is important to realise that the scores are in most cases subjective in nature and indicators may be allocated different scores on another occasion even by the same group or by other individuals replicating the process. In addition, limitations in knowledge and the complexity of interrelationships between various variables means that nobody has a complete understanding of the full ramifications of climate change across such a diverse geographical area.

In addition, it is not possible at a regional scale to identify isolated spatial areas of high or low variability within the same indicator. For example, buildings generally have a low sensitivity to climate change. However, if the building is sited close to an erosive cost then its sensitivity to sea level rise will be very high. It is important therefore when considering the results of the IVA process to bear in mind that within the same indicator there will be some spatial areas that are more vulnerable than others. Likewise, within an economic sector or vegetation community, there will be some specific industries or species that will be more vulnerable than others, both because of their spatial location within the region but also because of the sensitivity and adaptive capacity to the climate change stressors. For these reasons it is important to report on the notes that are included against each indicator as well as the score.

Finally, although providing a description of vulnerability for each indicator, the matrix assessment also does not provide a measure of the importance the stakeholders and community in the region puts on each of the indicators considered – indicators are not weighted. As a way of determining priorities for action and expenditure, an assessment of stakeholder priorities and community values for each of the indicators should also be undertaken – a process that is described in the following section of this guide.

Checklist of outputs Step 5 – Integrated vulnerability assessment:

□ Vulnerability Assessment matrix / tables – using the vulnerability assessment matrix template provided for the analysis (see the Excel® attachment provided with this guide for use or example).
□ Check indicators – check that the indicators selected are relevant to the scope of the study and will describe the key decisions that need to be made.
□ Screen climate stressors – cross out those climate stressors against each indicator that are not relevant. Check that each remaining climate stressor has a description of how the stressor is expected to change for the future climate scenario selected and that an exposure score from 1 to 5 as described in Table 2 has been allocated.
□ Describe and score sensitivity– describe the sensitivity of each indicator to each of the climate stressors and score from 1 to 5 according to Table 3.
□ Describe impact and calculate score – describe the likely impact of each climate stressor on each indicator and calculate the impact score from 2 to 10 (sensitivity plus exposure) as described in Table 4.
□ Describe and score adaptive capacity – describe the likely adaptive capacity of the indicator to each climate stressor and score from 1 to 10 as per Table 5.
□ Calculate vulnerability – calculate the resulting vulnerability score between 1 and 20 as shown in Table 6.
□ Outputs – generate relevant outputs on the basis of stakeholder requirements. Outputs should include tables of descriptions and may include maps, graphs and tables of scores allocated.

STEP 6: IDENTIFY ADAPTATION ACTIONS

Identify adaptation actions: Identify adaptation actions based on outputs from the integrated climate change vulnerability assessment and prioritise.

Once the vulnerability of the indicator has been assessed then a range of adaptation options can be identified and included in column (I) of the template.

Adaptation options will either reduce exposure or sensitivity or boost adaptive capacity and will be specific to each indicator and perhaps each climate stressor as well. For example, options to reduce heatwave impacts on vineyards will be different to those needed to address increased bushfire risk. Actions will also depend on the timeframe and climate scenario considered and should be steps towards achieving the goals for adaptation set in the first step.

Actions to address **short-term** changes in the climate (because lead times are shorter and consequences are short-lived) will probably involve existing coping mechanisms that involve improving efficiencies and small, iterative changes and adjustments to current practice to cope with the expected changes. In some cases these types of actions may have already been implemented over the historical record (in times of drought for example). Decision making for these changes is at the more tactical level.

Actions required to deal with **long-term** changes in the climate (because of longer lead times and or longer consequences) will more likely involve transformative changes and so will require new habits, enterprises, investments and long-term adjustments. In many cases these actions may not have been implemented in a region before, although they may be in use elsewhere, and so creative problem solving and thinking outside the square is required. Decision making and the implementation of actions at this scale requires more strategic thinking.

When identifying possible adaptation options, it is important to gather ideas from a wide range of stakeholders that understand each of the indicators assessed for the study area. At this stage, it should also be noted whether there are any potential adverse effects or maladaptation outcomes from implementing the action (column J in the template) or potential benefits or opportunities from implementing the action (column K).

The term maladaptation usually refers to the implementation of adaptation options that cause problems elsewhere, such as the installation of refrigerant air-conditioning in homes that then causes unserviceable levels of electricity demand during heatwaves and results in blackouts across a region, or construction of a sea wall that causes flooding in other areas. The more stakeholders that review the actions identified the less likely it is that maladaptive responses will be implemented.

For all adaptation options identified there will be a flow of resources from one capital to another. In other words to enhance one capital will require input from another (eg to build a sea wall will use natural materials and cost money; to increase mining output in a region will use water, cost money and take jobs from other sectors; to enhance intensive agricultural production in a warmer, drier environment will require more water and possibly cooling infrastructure such as shade cloth or air conditioning for animals etc). For this reason a community needs to be very clear about what it values and what it believes is sustainable.

When identifying adaptation actions it may also be of benefit to consider grouping the actions on the basis of a number of other qualities that will help with identifying priorities (Hallegatte 2009; The Pew Center on Global Climate Change and the Pew Center on the States n.d.).

No regrets actions
No regrets actions that make sense regardless of expected changes in the climate. These actions usually are beneficial for other reasons as well as those related to climate change and include actions that save money / energy or provide resilience to vulnerable systems from other non-climate threats such as pollution. For example, protecting native ecosystems from weed and pest invasion, or improving the energy efficiency of buildings are all no regrets actions.

Profit / opportunity actions
Profit / opportunity actions are those that are likely to be profitable in the face of climate changes or provide a new opportunity for a sector or region. For example, investing in renewable energy or trialling new crops in a region would be profit / opportunity actions and would be a priority to implement.

Win-win actions
Win-win actions are those that will provide more than one positive benefit across social, environmental or economic outcomes if implemented. For example, improving internet may access in a region will reduce travelling emissions, enhance education and uptake of adaptive strategies, and build social bonds across the wider community illustrates a wealth of win-win outcomes.

Low regret actions
Low regret actions incur relatively low costs and that provide a high benefit in their capacity to reduce climate change impacts or vulnerability. For example, installing insulation and window shading in rented accommodation are both low regret actions.

Reversible actions
Reversible actions that are reversible and so allow for flexibility in the face of future uncertainty. For example, insurance and early warning systems that can be easily updated or changed, low cost investment in infrastructure that can be moved at a later date would be reversible actions.

Safety margin actions
Safety margin actions build in a safety margin to account for future changes. For example, designing the foundations of a sea wall to allow for future height increases is an example of a safely margin action.

Soft strategies
Soft strategies include institutional or financial tools that can be implemented. For example, changes in the planning guidelines, implementation of adaptive management that includes regular monitoring and updates, insurance for extreme events and tax and financial tools to reduce uncertainty of income in highly variable climates (such is the case in agriculture). These options are usually reversible as well.

Short consequence actions
Short consequence actions reduce the length of the consequences of decisions. For example design of short-lived or relocatable assets, or planting of short-lived tress that can be replaced with others that are more suitable to the climate as it changes are both short consequence actions.

Preventative
Preventative actions avoid unsustainable investments such as policies or other measures that prevent new investment in areas that are already, or highly likely to become, at high risk from climatic events. For example, prohibiting the construction of homes in flood-prone areas that are likely to be subjected to even higher flood risks due to sea level rise or increased rainfall intensity is a preventative measure.

Avert catastrophic risk
These are policies or actions that will avert potential or eventual catastrophic events with incalculable costs and so require action regardless of the uncertainties. For example, moving low-lying coastal settlements away from the impact of a catastrophic storm surge is usually considered necessary despite a low probability of occurrence.

Once a list of adaptation actions have been identified, limitations in time and finances will no doubt mean that there will not be the resources to implement them all at once and so there will be the need to prioritise them. Factors to consider when prioritising adaptation actions will include the vulnerability of the indicator (will the impact of not responding be large in scale or catastrophic in nature, will the impacts be irreversible, how important is the indicator to the community (is it valued)) and the capacity there is to implement the actions (cost, timing, availability of data, availability of resources).

The process of weighing up all these factors to determine priorities for action can be a complex task and requires that the stakeholders who are involved have the capacity to implement the identified actions. The State government is supportive of the development of Climate Change Adaptation Plans under the State climate Change Adaptation Framework and it is expected that there will be resources available to help stakeholders develop these plans.

In addition, there is current research underway that aims to develop decision pathways to optimise the timing and implementation of climate change adaptation options including the legal and financial implications of each. It is hoped that the outcomes of the research will be available soon and can be developed into a rigorous methodology for developing climate change adaptation plans. In the meantime, the selected measures for determining priorities can be simply ranked from low to high and then totalled to provide an overall priority score. Table 7 provides an example of a ranking table that in this case considers possible mitigation outcomes as well as adaptation and that might be adapted to suit the study.

Table 7: Example of a ranking scale to determine priorities for actions in the climate change plan.

Priority Score:	**3 (LOW)**	**2 (MEDIUM)**	**1 (HIGH)**
Potential greenhouse gas emissions / reduction (% of total target)	0-33%	34-66%	67-100%
Logical flow of actions / timing	Action requires outputs from two or more other actions	Action requires outputs from another action	Action can be undertaken immediately
Availability of data	Data does not currently exist and will need to be measured and collated	Relevant data currrently available but needs to be collated/updated/altered	Relevant data currently available in a useable format
Community response	Community rank the action as a low priority	Community rank the action as a medium priority	Community rank the action as a high priority
Resources / capacity to implement	Resources capacity to implement the action do not currently exist and will need to be sourced from both internal and external revenue / areas	Resources capacity to implement the action do not currently exist and will need to be sourced from other internal revenue / areas	Resources / capacity to implement the action currently available
Win-win (mitigation + 1)	Single benefit action	Action has two benefits	Action has three or more benefits

Once priorities have been given to each of the actions, a timeframe and measurable is allocated to each action and a responsible staff member appointed to ensure it is implemented. Actions should be specific and include a clear measurable that can be checked at the end of the reporting period.

It is important to remember that because of the ever changing nature of the climate, of social, financial, economic and political pressures, that the climate change action plan and resulting documents should be considered to be a working paper that is regularly reviewed, updated and modified on the basis of new information and the learning from both your own organisation and that of others. For that reason the adaptation actions outlined here sit within the Climate Change Action framework that has been designed as part of an adaptive management process that will be continually updated as new information is sourced (Figure 4).

Checklist of outputs Step 6 – Adaptation actions:

□ Adaptation actions - A list of adaptation actions that either reduce the exposure or sensitivity of an indicator or increase its adaptive capacity is developed.

□ Maladaptation – Adaptation actions have been reviewed by a range of stakeholders that represent each of the five capitals in the region to reduce the possibility of maladaptation.

□ Priorities – actions are prioritised against a suite of measurables and allocated to a responsible agent / officer to implement.

IMPLEMENTING, COMMUNICATING, MONITORING AND REVIEWING THE CLIMATE CHANGE ADAPTATION PLAN

The final steps in the Climate Change Action Planning process are relevant to mitigation actions as well as adaptation actions and also form part of any adaptive management framework. Continuous monitoring, evaluation and adjustment to the process of considering climate change impacts and adaptation will ensure that updated information and experience is included in the ongoing management of a project. There are a number of slightly different adaptive management models available but each have the similar stages of implementation, monitoring, evaluating and feedback of learnt information to the process (Figure 13).

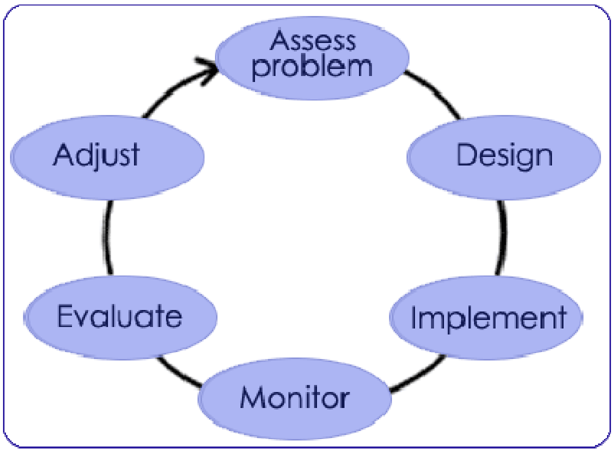

Figure 13: The adaptive management framework.

In the case of a climate change adaptation plan, implement refers to the implementation of the plan by the relevant organisations and partners, monitor is the process of regularly assessing the progress of the adaptation actions over a number of years; evaluation is the process of determining how effective the adaptation actions have been in reducing climate change vulnerability (actions should be able to show a measurable or qualitative improvement in the vulnerability of the indicator compared to the baseline when the first vulnerability assessment was undertaken) and adjust is the process of updating the plan on the basis of the monitoring and evaluation programs, new information and experience.

In addition to communicating and consulting throughout the planning process, each of these steps will need to be implemented for each action identified as part of the adaptation plan. Responsibility to undertake them will be assigned to the stakeholder who has responsibility for implementing each action. Because a climate change adaptation plan will be implemented at multiple levels (national, state, regional, sectoral and community) it is important the stakeholders communicate on progress regularly and that the adaptation plan itself is updated regularly. An appropriate engagement strategy may need to be developed to ensure that implementation of the plan continues with full stakeholder support. Council and stakeholders involved in the study have a great opportunity to lead by inspiring the wider community to play a role in climate change mitigation and adaptation. The development of a communication or education plan will provide public access to the knowledge and results gained by developing and implementing the plan.

The steps for developing a climate change action plan and climate change adaptation plan are summarised in Appendix 4.

APPENDIX 1 – SUGGESTED VULNERABILITY INDICATORS

The table below shows each of the five capitals and recommended primary and secondary indicators for each.

Environmental Capital

Primary Indicator	**Landscape fragmentation**	**Vegetation communities**	**Biodiversity**	**Water**	**Land condition**
Secondary Indicator	% or area of native vegetation cover	% or area of native vegetation cover by vegetation type/community	Proportion of terrestrial fauna species that are threatened (regional, state,	Surface water quantity and flows	Dryland salinity
	% or area in National Reserve System	Vegetation communities that are predisposed to climate change impacts (narrow range of physiological tolerance to factors such as temperature, water availability and fire)	Proportion of terrestrial flora species that are threatened (regional, state)	Surface water quality	Erosion
	% or area of native vegetation cover by IBRA region/subregion	Area/proportion of coastal vegetation communities prone to inundation	Proportion of marine fauna species that are threatened (regional, state)	Water for human consumption quanity and quality	
			Proportion of marine flora species that are threatened (regional, state)	Groundwater quantity and recharge	
				Groundwater quality	

Physical capital

Primary Indicator	**Transport networks**	**Service networks**	**Communications networks**	**Buildings**	**Land assets**
Secondary Indicator	Kilometers of roads and condition	Condition of electricity networks	Extent of telecommunications infrastructure and condition	Numbers / value and condition of housing	Area of farmland
	Kilometers roads at risk of sea level rise / coastal threats	Level of energy demand and constraints	% telecommunications networks at risk of sea level rise / coastal threats	Number of houses at risk of sea level rise / coastal threats	Area and condition of council owned land
	Kilometers of roads at risk from bushfire	Kilometers of energy networks at risk from bushfire	% of telecommunications networks at risk from bushfire	Number of houses at risk from bushfire	Area and condition of state owned land
	Kilometers of rail and condition	Condition of traditional energy assets		Numbers / value and condition of public buildings (schools, hospitals, libraries etc)	Area and condition of federal owned land
	Kilometers rail at risk of sea level rise / coastal threats	% traditional energy assets at risk of sea level rise / coastal threats		Number of public buildings (schools, hospitals, libraries etc) at risk of sea level rise / coastal threats	
	Kilometers of rail at risk from bushfire	% of traditional energy assets at risk from bushfire		Number of public buildings (schools, hospitals, libraries etc) at risk from bushfire	
	Number of ports and jetties and condition	% of renewable energy production		Numbers / value and condition of emergency flood, fire and heat refuges	
	Number of ports at risk of sea level rise / coastal threats	Condition of renewable energy assets		Number of emergency flood, fire and heat refuges at risk of sea level rise / coastal threats	
		% of renewable energy assets at risk from bushfire		Number of emergency flood, fire and heat refuges at risk from bushfire	
		Water networks and condition			
		% water networks at risk of sea level rise / coastal threats			
		% of water networks at risk from bushfire			

Financial capital

Primary Indicator	**Primary industries excl. agriculture**	**Agriculture**	**Secondary industries**	**Tertiary industries**	**Quaternary sector**
Secondary Indicator a measure of the gross regional production and/or financial value of each of the following:	Mining	Broad acre crops -cereals production	Manufacturing	Wholesale sales	Intellectual activities
	Forestry	Broad acre crops - legumes production	Construction	Retail sales	Government
	Aquaculture	Broad acre crops - oil seed production	Engineering	Tourism	Culture
	Wild commercial fisheries	Forage and seed production	Metal working and smelting	Transport and distribution services	Libraries
		Wool production and quality	Vehicle and machinery production	Banking	Scientific research
		Rangelands grazing sheep and beef	Aerospace manufacturing	Entertainment	Education
		Improved pasture grazing sheep and beef	Ship building	Restaurants	Information technologies
		Intensive livestock (pigs, chickens)	Processing (food and other)	Clerical services	Gross regional income from government support or aid
		Horticulture and tree crops	Textile production	Media	
		Viticulture production and quality	Chemical industries	Banking	
		Packaging and processing of agricultural raw materials	Energy utilities	Health care	
			Breweries and bottlers	Law	
			Oenology (wine making)		

Social capital

Primary Indicator	**Community Planning and Development**	**Existing Social Capital**	**Emergency Management**	**Governance**	**Social Inclusion/Exclusion**
Secondary Indicator	Internet usage patterns	Sense of belonging to community	Rates of Volunteerism	Perceived effectiveness of local government	Populations of aboriginal and other minority cultural groups
	Employment	Links with neighbours	Changes in the community being served, and the services provided.	Voter participation	Divorce rate
	Regional occupation and industries	Perceived level of crime	Resourcing	Trust in government processes	Single parent families
	Household income	Actual level of crime	Governance	Number and nature of services provided to the community	Households dependent on government support
	Household size	Political involvement			% Sole occupant houses
	Public transport usage patterns	Membership/participation in local groups and clubs			% Population not fluent in English
		Leadership			% Low income households
					% Rented households

Human capital

Primary Indicator	**Education**	**Physical Health**	**Age**	**Mental Health**	
Secondary Indicator	% secondary education	Self assessed health	% Age 0-4 young children	Self assessed health	
	% population with a non-school qualification	Access to medical care	% Age 5-19 school age youths	Access to medical care	
	Access to further education	Activity/outputs	% Age 20 - 29	Activity/Outputs	
	Access to libraries	Doctors visits	% Age 30 - 39	Doctors visits	
	Internet access	Admissions rates	% Age 40 - 49	Admissions rates	
	% participating in an education process in the past 12 months	% requiring assistance with daily activities	% Age 50 - 59	Suicide Rate	
			% Age 60 - 69		
		Note - the age brackets to the right correspond with ABS segregations but have been condensed.	% Age 70 - 79		
			% Age 80 +		

APPENDIX 2 - DEALING WITH UNCERTAINTY

When undertaking an integrated climate change vulnerability study it is important to realise that although we have a wealth of knowledge in many areas there are some uncertainties in the process too. Our lack of perfect knowledge in understanding how the climate system works, how individual species and systems will respond to the impacts of climate change, how dependant systems will respond to primary changes, the level of future greenhouse gas emissions, and the complexities of economic repercussions all contribute to the uncertainty when determining vulnerability. It is important to realise that many of these uncertainties may have little effect on the final outcomes of a qualitative assessment such as integrated climate change vulnerability assessment. However, for clarification the common uncertainties are explained in more detail here. An extended definition of uncertainty as described by the IPCC is included in the glossary.

CLIMATE COMPLEXITY AND SENSITIVITY

The first level of uncertainty is a result of our imperfect knowledge of the climate system. Projections of future changes in the climate are made by using global climate models that calculate changes in the big-picture aspects of the atmosphere using the laws of physics to describe the transfer of heat and moisture through the atmosphere for thousands of grids across the surface of the earth, up into the atmosphere and deep into the ocean (Figure 14). The models take into account changes in solar radiation from the sun, volcanic eruptions and changes in aerosols (including smog and clouds), natural climate variability (for example as a result of the El Nino climate cycle), ocean and atmospheric circulations and feedback from ice sheets, and have been tested for accuracy against historical data.

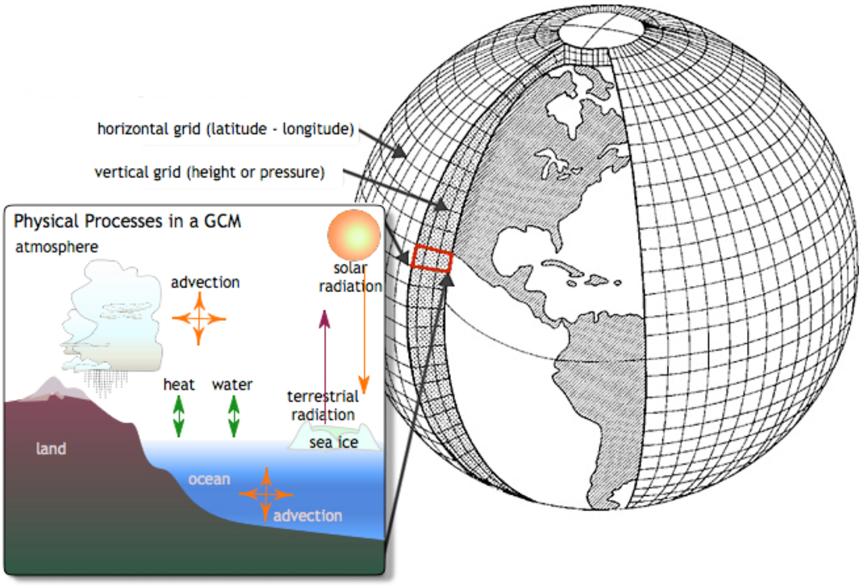

Figure 14: Schematic showing how global climate models work (Source: Centre for Multiscale Modelling of Atmospheric Processes 2011).

By changing some of the parameters in the models (eg the concentration of greenhouse gases in the atmosphere) outputs describe how the climate will change on the broad scale. As the models are not calculating the day-to-day weather, but instead the changes in the underlying trends of the climate, they do not estimate short-term changes but instead provides a projection of how the climate will change over decades. Only when greenhouse gas emissions from human activities are included in the models do they accurately calculate the changes that have been observed over the past century of historical records, a result that confirms that it is human released greenhouse gas emissions that are the cause of the changes we are now recording in the climate. Once scientists know that the model is performing well on the basis of historical data, it can be run into the future to provide estimates of future climatic conditions.

However, as the climate projections are run further into the future, there will be uncertainties that will affect how accurate the projections will be. Uncertainties within the models include how much aerosols and clouds will influence future temperatures, and how sensitive the climate is to additional greenhouse gases. In 2007, the IPCC estimated that the global average temperature was likely to rise by approximately 3°C in response to a doubling of greenhouse gases in the atmosphere – an estimate that has since been confirmed by more recent research. The Fifth Assessment Report will also provide measures of confidence around uncertainties associated with climate change model calculations.

FUTURE GREENHOUSE GAS EMISSIONS

Another uncertainty is that we don't know how many tonnes of greenhouse gases will be emitted by human activities in the future. For these reasons projections of the climate are expressed as a range of different emissions scenarios – possible futures. In the IPCC Forth Assessment Report (AR4) in 2007, climate projections made by global climate models were based on future emissions scenarios in the Special Report on Emissions Scenarios (SRES) used in previous assessments (Figure 15 top). For the upcoming IPCC Fifth Assessment Report (AR5), new emissions scenarios to be known as "Representative Concentration Pathways" (Figure 15 bottom) will be used instead (Moss, Edmonds et al. 2010).

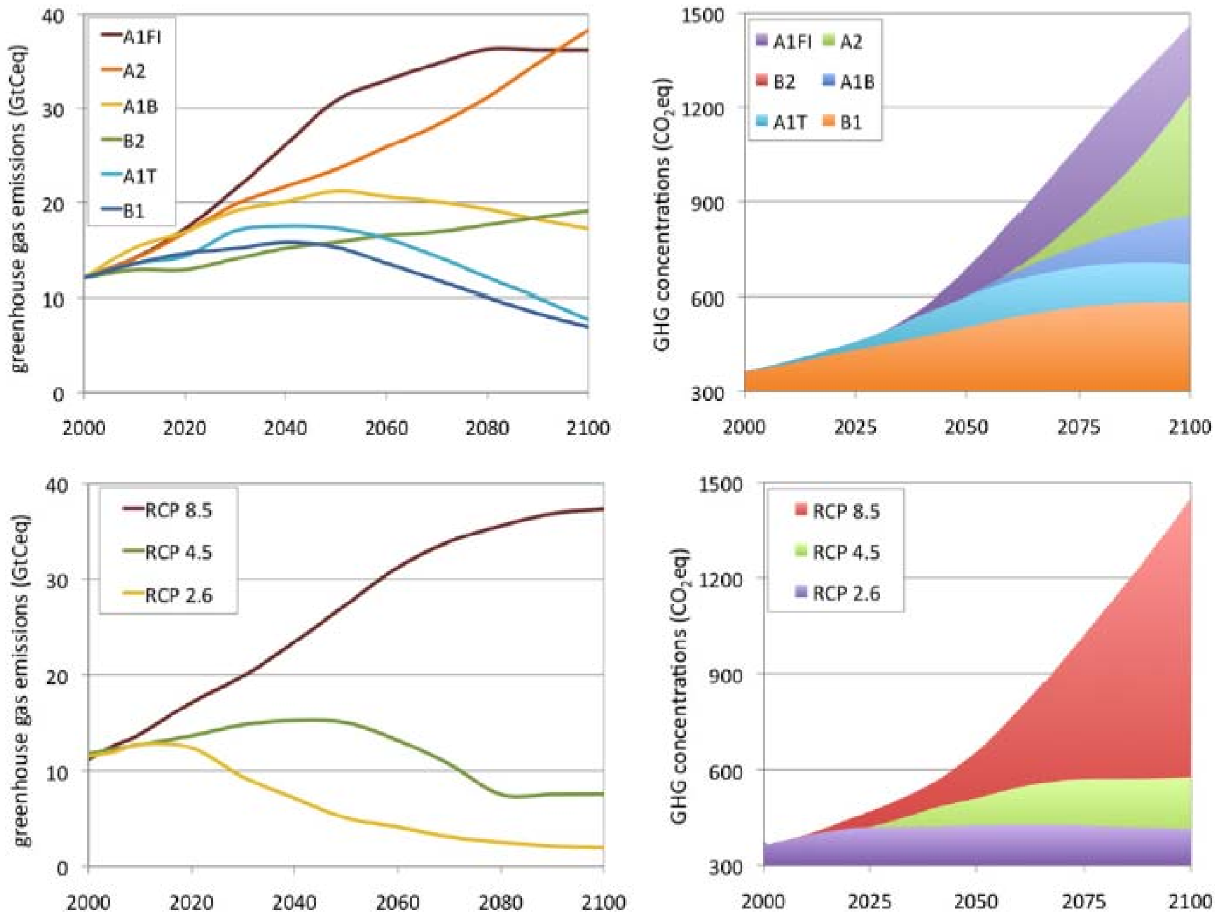

Figure 15: (Top) IPCC AR4 future climate scenarios expressed as greenhouse gas emissions in gigatonnes of CO_2 equivalents (left) and total greenhouse gas concentrations in the atmosphere in parts per million out to 2100 (right). The two plots at the bottom of the figure show the AR5 representative concentration pathways (Source: Moss, Edmonds et al. 2010).

The four pathways will represent the full range of greenhouse gas emission concentrations that may occur in the atmosphere by the year 2100 and will range from 450 ppm up to 1300 ppm CO_2 equivalents. The scenarios are named according to the level of radiative forcing in W/m^2 by the year 2100, for example, RCP 8.5 represents the emissions pathway that will result in 8.5 W/m^2 by the year 2100. The climate projections from these scenarios are expected to be released in 2013. Figure 15 compares the two scenarios out to the year 2100.

The two sets of future climate scenarios align somewhat. The highest RCP 8.5 (1465 ppm CO_2e by 2100) in the new set of scenarios corresponds closely to the SRES A1FI emissions scenario (1360 ppm by 2100). This scenario sees greenhouse gas emissions continue to rise beyond the end of the century. The mid-low RCP 4.5 (600 ppm by 2100) corresponds most closely to SRES B1 (640 ppm by 2100). As is the case with the RCP 6.0, these two mid-range scenarios describe a stabilisation of greenhouse gas emissions not long after 2100. The lowest RCP 2.6 projects a future where emissions are significantly lower than even the lowest SRES scenario, as although CO_2e concentrations in the atmosphere rise to nearly 500 ppm, they then fall to 450 ppm by the end of the century.

In addition to uncertainty about future emissions, it is also difficult to accurately quantify the size of future sinks. Carbon dioxide is sunk (or extracted) out of the atmosphere as a result of natural processes in the deep and shallow oceans, terrestrial systems such as forests and other components of the natural carbon cycle. Although we have a good estimate of how much of the greenhouse gases these natural sinks have absorbed already, it is difficult to accurately predict how quickly and how much they will be able to continue to extract from the atmosphere in the future.

SENSITIVITY OF SYSTEMS TO CLIMATE STRESSORS

Due to the complexity of the natural world and our social and economic systems that sit within it, there are gaps in our knowledge about the severity of future climate change impacts because we don't readily understand how sensitive things are to changes in the climate. Species and systems will respond not only to the magnitude of the climate changes but also the rate of change. Mobile species will be able to move more easily and so reduce their exposure to changes, while plants, particularly long-lived tree species, will be more exposed because they are immobile. Many species will not have experienced changes in the climate as rapidly or as great over the coming century than at any other time in their evolutionary history and so knowing how they may respond is impossible. Additionally, our understanding of the species on the planet is very limited. It is now estimated that there are about 8.7 million species on earth and yet we have only identified and named 1.2 million (or about 11%) of these. We also don't know how complex ecosystems will respond when one or more species within it is removed. And finally, we can't accurately predict how future human actions (eg land clearing, population growth, irrigation, pollution) will change in the future and so how these changes will affect the climate and the natural systems that we live in – we may enhance or reduce the adaptive capacity of other species by our actions.

HOW TO DEAL WITH UNCERTAINTY IN ASSESSING VULNERABILITY

As can be seen from the above discussion, there is what is called a cascade of uncertainty that gets greater the more steps one is away from the measurable level of greenhouse gases in the atmosphere. Other uncertainties that we haven't considered here also exist such as the uncertainties that arises when communicating the process with a range of different stakeholders and their individual understanding of the concepts involved. Again, the presence of uncertainty does not prevent us from undertaking the assessment, we just need first to understand them and their impact they may have, if any, on the analysis.

Once we are clear what uncertainties exist, we need to explain what assumptions we have made and which methods we have used to deal with the uncertainty so the process is transparent and comparable to other assessments. For example, what measurements or models did we use, what assumptions did we make when assessing the impacts?

Next, can we give a measure to the degree of uncertainty? In other words, can we define whether we are confident in the outcome or not on the basis of the levels of uncertainty involved in the assessment? The IPCC in its publications defines uncertainty by providing tables of scale ranging from very low to very high aligned to a measure of the uncertainty. We use this approach here in this methodology to provide a standard framework for the assessment so that outputs will be relatively consistent across the state.

Finally, we can consider more than one future climate scenario to be sure that we cover the range of uncertainty that may occur in the future. This is especially important when undertaking long-term studies that consider vulnerability beyond 2030 when future scenarios diverge significantly.

As described above, the IPCC provides a number of future scenarios and it is recommended that the scenarios selected are one of these. Be aware that uncertainty in climate change will continue into the future and what we thought we were quite certain about today may not be the case in the coming years. At the same time, uncertainty is no excuse for inaction – there are plenty of examples where we make decisions and manage systems in the face of uncertainty today such as those associated with financial markets and disaster planning.

It is also important to remember that the full process of determining vulnerability to climate change and identifying adaptation should be part of an adaptive management process where outcomes are monitored and improvements in knowledge are reintegrated into the plan over time.

APPENDIX 3 – EXAMPLE CLIMATE CHANGE SCENARIOS

This example shows the climate changes and scores (as defined in Table 2) associated with an A1FI SRES climate scenario for the year 2030 in the Central Local Government Region of South Australia (Balston, Billington et al. 2011).

Variable	Description	Exposure score
May - Oct temp increases: Southern Flinders	May - Oct temperature predicted by the four models to increase by an average of 0.81°C for the Southern Flinders sub-region by 2030 compared to 1990 (CSIRO 2011)	3
May - Oct temp increases: Mid-North, Yorke Peninsula and Barossa sub-regions	May - Oct temperature predicted by the four models to increase by an average of 0.76, 0.66, 0.72°C for the Mid-North, Yorke Peninsula and Barossa sub-regions respectively by 2030 compared to 1990 (CSIRO 2011)	2
Nov - Apr temp increases: Southern Flinders, Mid-North sub-regions	Nov - Apr temperature predicted by the four models to increase by 0.87 and 0.81°C for the Southen Flinders and Mid-North sub-regions respectively by 2030 compared to 1990 temperatures(CSIRO 2011)	3
Nov - Apr temp increases: Yorke Peninsula, Barossa sub-regions	Nov - Apr temperature predicted by the four models to increase by an average of 0.69 to 0.75°C for the Yorke Peninsula and Barossa sub-regions respectively by 2030 compared to 1990 temperatures (CSIRO 2011)	2
May - Oct winter rainfall: Southern Flinders	May - Oct rainfall predicted by the four models to decrease by an average of 10.4% below 1990 levels by 2030 (CSIRO 2011). Globally there is an increased chance of intense precipitation although for South Australia GCM calculations of rainfall increase are very low - perhaps only 2% (*pers.comm. Darren Ray, Climatologist, BOM, 2011*).	3
May - Oct rainfall reductions: Mid-North, Yorke Peninsula, Barossa sub-regions	May - Oct rainfall predicted by the four models to decrease by an average of 8.8%, 8.7 and 8.4% for the Mid-North, Yorke Peninsula and Barossa sub-regions respectively below 1990 levels by 2030 (CSIRO 2011). Globally there is an increased chance of intense precipitation although for South Australia GCM calculations of rainfall increase are very low - perhaps only 2% (*pers.comm. Darren Ray, Climatologist, BOM, 2011*).	2
Nov - Apr rainfall reductions: All sub-regions	Nov - Apr rainfall predicted by the four models to decrease by an average of 3.3% to 3.7% below 1990 levels by 2030 (CSIRO 2011). Globally there is an increased chance of intense precipitation although for South Australia GCM calculations of rainfall increase are very low - perhaps only 2% (*pers.comm. Darren Ray, Climatologist, BOM, 2011*).	1
Increased inundation and coastal erosion from sea level rise and storm surge	Sea level has been rising at about 4.5 mm/year in South Australia since the 1990s. Levels by 2030 are projected to be between 15-20 cm above the 1990 levels at the high end of the IPCC AR4 predictions. This equates to 10 - 20 m recession of a sandy shore as a result of erosion. The frequency of storm surge events will increase as a result of increased sea levels and possible increased intensity of storm driven wind events (DCCEE 2009), although changes in the frequency and intensity of low pressure systems (the primary weather pattern producing storm surge events in South Australia) may decrease in South Australia (*pers.comm. Darren Ray, Climatologist, BOM, 2011*) and so most of the storm surge effect will be a result of sea level rise.	2
Increased ocean temperatures	Sea surface temperatures in the Spencer Gulf have risen by about 0.11°C per decade since 1950 (0.66°C to 2010). By the year 2030 sea surface temperatures in the region are expected to increase by up to 0.92°C compared to 1990 levels (Ozclim 2011).	3
Increased ocean acidity	The pH of the oceans has already dropped by 0.1 from pre-industrial levels and represents an increase in acidity of 30%, the most acid in 25 million years. It is expected that by 2030 that average ocean pH will have dropped by 0.13 and be close to levels that are unfavourable for coral formation in some parts of the world.	5
CO_2 increases	Increase in CO_2 from 280ppm in 1900 up to 450ppm in 2030 - a 61% increase (IPCC 2007).	4
Reduced frost incidence	The incidence of frost has not been modelled for the A1FI scenario for the year 2030 but is is expected to decrease as temperatures increase. However, the reduction in frost risk across southern Australia is not expected to happen as quickly as the increase in minimum temperature increases (CSIRO 2010). Across the region there is expected to be a reduction in frost risk in every season except autumn (*pers.comm. Darren Ray, Climatologist, BOM, 2011*).	1
Increased heatwave frequency and intensity	In Adelaide the number of days above 35°C will increase from 17 in 1990 to 26 in 2030 under a high emissions scenario - a 52% increase (CSIRO 2007).	3
Increased bushfire frequency and intensity	Bushfire exposure is based on the projected increases in the number of high, very high and extreme fire danger days. For Adelaide there is expected to be a 22% increase in the number of very high fire days and a 55% increase in the number of extreme fire days by 2030 (Lucas et. al. 2007).	3
Combined climate change impacts	This score considers stress due to all the factors of climate change rolled into one and is used for some varialbes where it is not possible or there is not enough information to separate out the individual components of climate change. The score is calculated as the average for all the other exposures.	1 to 5
Price on carbon	It is likely that a Carbon Trading Scheme or tax will be introduced to reduce carbon emissions in the near future. The policy would to increase jobs in green energy technologies and decrease jobs in fossil fuel intensive industries. The cost of fuel, electricity and carbon intensive products and services would be expected to increase. Carbon sequestration from forest plantations and other relevant agricultural practices would be increasingly viable (OCC 2009). However, the price signal from the cost on carbon is not expected to be significant when compared to other price signals such as exchange rates etc.	1
Secondary Climate Change Stressors	Secondary climate change stressors are relevant to the social, economic and agricultural areas and describe changes that incorporate a number of different climate variables (e.g. reduced rainfall and increased temeratures together) or secondary flow on effects (e.g. increased drought incidence leading to financial stress that then flows onto social and health impacts). In each of these cases the variable will be listed, described and given an exposure score unique to the defined stressor.	1 to 5
Exposure to weed invasion	Exposure to weed invasion (secondary exposure): Based upon expert opinion on whether the vegetation community is likely to be exposed to increased levels of weed invasion or incursion of new weeds as a result of changing climatic conditions. Score as per qualitative indices (very low, low, moderate, high, very high).	1 to 5
Exposure to feral animals	Exposure to feral animals (secondary exposure): Based upon expert opinion on whether the vegetation community is likely to be exposed to increased levels of feral animals as a result of changing climatic conditions. Score as per qualitative indices (very low, low, moderate, high, very high).	1 to 5

APPENDIX 4 – SUMMARY FLOW CHARTS

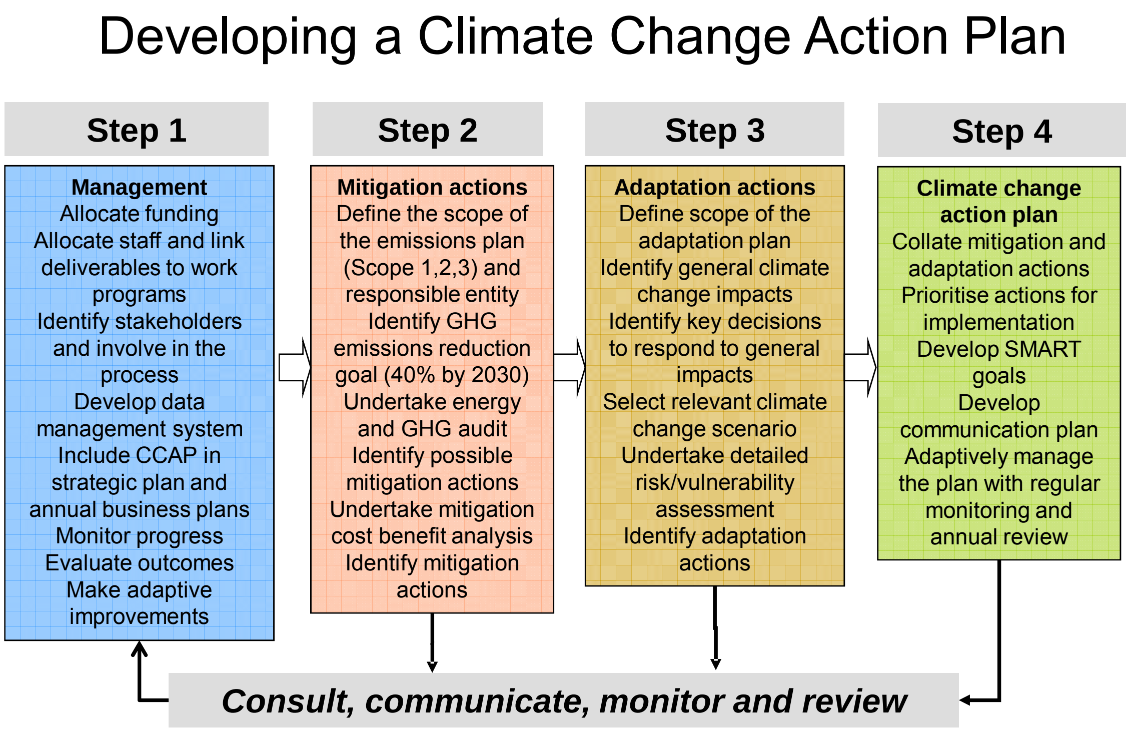

Figure 16: Steps for developing a climate change action plan from the LGA SA Climate Change Action Plan Guidelines (see http://www.lga.sa.gov.au/site/page.cfm?u=15).

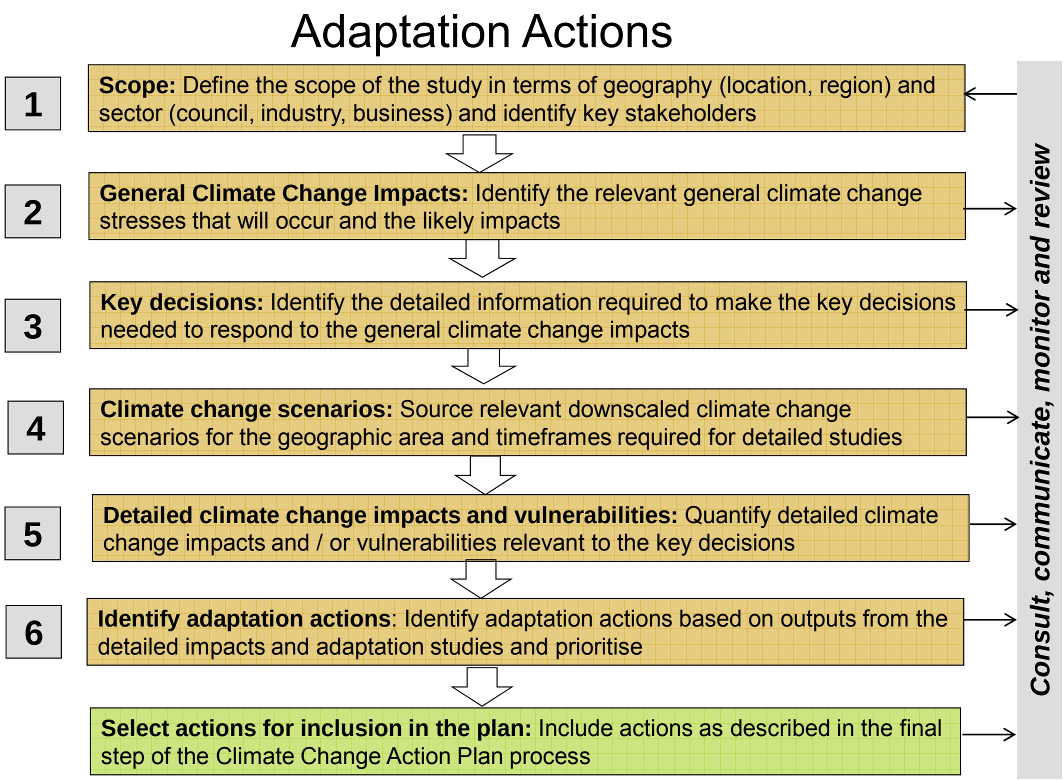

Figure 17: Steps for undertaking a climate change adaptation plan including an integrated vulnerability assessment as outlined in the Council Guidelines for Developing a Climate Change Action Plan.

GLOSSARY

ABS
Australian Bureau of Statistics.

ABARE
Australia Bureau of Agricultural and Resource Economics.

ADAPTATION
Adaptations are actions taken to help communities and ecosystems moderate, cope with, or take advantage of actual or expected changes in climate conditions.

ADAPTIVE CAPACITY
Adaptive capacity is 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. The adaptive capacity of a system or society describes its ability to modify its characteristics or behaviour so as to cope better with changes in external conditions. The more adaptive a system the less vulnerable it is. Adaptive capacity is also defined as the property of a system to adjust its characteristics or behaviour to expand its coping range under existing climate variability or future climate conditions.

AR4
The IPCC Fourth Assessment Report.

BDBSA
Biological database of South Australia.

BOM
Bureau of Meteorology.

CLIMATE
Climate summarises the average, range and variability of weather elements, e.g. precipitation, wind speed, air temperature, humidity, and sunshine hours (solar radiation), observed over many years (typically > 30 years) at a location or across an area.

CLIMATE VARIABILITY
Climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. Examples of climate variability include extended droughts, floods, and conditions that result from periodic El Niño and La Niña events.

CLIMATE CHANGE / GLOBAL WARMING
Anthropogenic or human induced climate change otherwise known as global warming refers to shifts in the mean state of the climate or in its variability, persisting for an extended period (decades or longer) as a result of changes to the composition of the atmosphere via the addition of greenhouse gases form human activities.

CPRS
Carbon Pollution Reduction Scheme.

CSIRO
Commonwealth Scientific and Research Organisation.

DEH
Department of Environment and Heritage.

DROUGHT
Drought in general means acute water shortage. When dry conditions are not relieved by equally wet periods over a number of years, or when a shorter period of dry is exceptional, it is commonly called drought.

DWLBC
The Department of Water, Land and Biodiversity Conservation, South Australia.

ECONOMIC CAPTIAL / BOTTOM LINE
Economic or financial capital is the real economic value of an organisation and is defined as the profit “after deducting the cost of all inputs including the cost of the capital tied up” (Wikipedia 2010).

ENVIRONMENTAL CAPITAL / BOTTOM LINE
Natural or environmental capital includes the biotic and abiotic, renewable and non-renewable resources of the earth and includes plants, animals, minerals, gases, water and the interrelated systems of a healthy ecosystem such as recycling, pollution extraction, water collection and management of soil erosion. Environmental capital can be defined as the “total of renewable and non-renewable natural resources” (The Business Directory 2011).

EPA
Environment Protection Authority.

EPBC
Environmental Protection and Biodiversity Conservation Act 1999.

EXPOSURE
Exposure relates to the influences or stimuli that impact on a system. In this study, exposure is a measure of the predicted changes in the climate for the year 2030.

FINANCIAL CAPITAL
Financial capital is the level, variability and diversity of income sources, and access to other financial resources (credit and savings) that together contribute to wealth.

GRP/GSP
Gross Regional/State Product: A measure of the net economic contribution of an economic activity to the region in question. It represents the value of output less the costs of goods and services used in producing the output.

HUMAN CAPITAL / BOTTOM LINE
Human capital refers to the stock of competences, knowledge and personality attributes embodied in the ability to perform work to produce economic value. It includes the skills accumulated by a worker through education and experience (Smith 1776). Human capital is defined by the United Nations as "the productive wealth embodied in labour, skills and knowledge" (United Nations 2010).

MDB
Murray Darling Basin.

NRM
Natural Resource Management.

NRM Board
Natural Resources Management Board.

GCM
Global Climate Model.

IPCC
Intergovernmental Panel on Climate Change.

NATURAL / ENVIRONMENTAL CAPITAL
Natural capital is the productivity of land, and biological actions to sustain productivity, as well as the water and biological resources.

NPWA
National Parks and Wildlife Act, 1972.

PHYSICAL CAPTIAL
Physical capital is the value of capital items produced by economic activity from other types of capital and can include infrastructure, equipment and improvements in genetic resources (crops, livestock).

PWRA
Prescribed Water Resources Areas.

RISK
Risk is the product of consequences and likelihood - what can happen, and what are the odds of it happening. Both of these factors are important in determining whether and how we address specific risks.

SAGR
South Australian Government Region.

SENSITIVITY
Sensitivity reflects the responsiveness of a system to climatic influences, and the degree to which changes in climate might affect that system in its current form. Sensitive systems are highly responsive to climate and can be significantly affected by small climate changes.

SOCIAL CAPITAL
Social capital reciprocal claims on others by virtue of social relationships, the close social bonds that facilitate cooperative action and the social bridging, and linking though which ideas and resources are accessed.

TRIPLE BOTTOM LINE
The triple bottom line is an expanded criteria for measuring organisational and societal success that includes not only the financial, but social and environmental dimensions of performance as well.

UNCERTAINTY
As per the IPCC treatment of Uncertainties in the AR4 Report (Box T.S.1).

Uncertainties can be classified in several different ways according to their origin. Two primary types are “value uncertainties” and “structural uncertainties”.

Value uncertainties arise from the incomplete determination of particular values or results, for example, when data are inaccurate or not fully representative of the phenomenon of interest. Structural uncertainties arise from an incomplete understanding of the processes that control particular values or results, for example, when the conceptual framework or model used for analysis does not include all the relevant processes or relationships.

Value uncertainties are generally estimated using statistical techniques and expressed probabilistically. Structural uncertainties are generally described by giving the authors' collective judgment of their confidence in the correctness of a result. In both cases, estimating uncertainties is intrinsically about describing the limits to knowledge and for this reason involves expert judgment about the state of that knowledge.

The uncertainty guidance provided for the Fourth Assessment Report draws, for the first time, a careful distinction between levels of confidence in scientific understanding and the likelihoods of specific results. This allows authors to express high confidence that an event is extremely unlikely (e.g., rolling a dice twice and getting a six both times), as well as high confidence that an event is about as likely as not (e.g., a tossed coin coming up heads). Confidence and likelihood as used here are distinct concepts but are often linked in practice.

The standard terms used to define levels of confidence in this report are as given in the IPCC Uncertainty Guidance Note, namely:

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Note that "low confidence" and "very low confidence" are only used for areas of major concern and where a risk-based perspective is justified.

The standard terms used in this report to define the likelihood of an outcome or result where this can be estimated probabilistically are:

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

The terms "extremely likely", "extremely unlikely" and "more likely than not" as defined above have been added to those given in the IPCC Uncertainty Guidance Note in order to provide a more specific assessment of aspects including attribution and radiative forcing.

VULNERABILITY
Vulnerability to the impacts of climate change is a function of exposure to climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes. The IPCC defines vulnerability as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change.

WEATHER
Weather describes atmospheric conditions at a particular place in terms of air temperature, precipitation, wind speed, pressure, and humidity.

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