Authors: Kieren Moffat, Anne-Maree Dowd*, Barton Loechel and Jane Hodgkinson
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
**Corresponding Author: Anne-Maree Dowd, Anne-Maree.Dowd@csiro.au*

Title: Risk, responsibility and relevance: Contextually framing adaptation governance for the mining sector and other stakeholders

Theme: The framing of adaptation problems and goals

Session: Friday 23rd March 9.00am - 11.30am

Introduction

One clear aspect of innovative governance is the inclusion of business and civil society stakeholders in the process of developing and implementing policy in order to create unitary action and compliance on an issue. The process is less effective if only a narrow, limited perspective approach is adopted which can lead to practical options being omitted and wider issues not addressed: often the result of a 'top-down' approach. According to Nelson et al. (2008), to create governance that is responsive to regional issues, it is essential to integrate local knowledge and communicate outcomes that effect livelihoods which are relevant to both governments and rural communities. A key issue facing industries and regional communities across the world is climate change. The question of how to develop appropriate governance responses is still yet to be fully explored. If we are to take a regionally responsive approach to managing this issue, then inclusion of multiple perspectives is fundamental in aiming for achievable and feasible outcomes and ensuring agreement and uptake.

Climate change is an issue of potentially great significance to the minerals sector and its associated communities. Climate change has the potential to significantly impact multiple points of the mining value chain as well as mine community wellbeing. Thus adaptation planning will be critical for this sector. The mining industry is a large and important part of Australia's economy and generates substantial economic and social benefits across the country. The industry also generates significant social and environmental impacts, but like many natural-resource dependent industries can also be strongly affected by environmental conditions (QRC 2011). In particular the industry contributes to greenhouse gas emissions directly and indirectly thus feeding into the drivers of climate change. This aspect is increasingly being addressed through policy mechanisms and won't be dealt with here.

At a global level, the mining industry has demonstrated that it can operate across a broad range of climatic extremes; however, it is also clear that mining operations are vulnerable to extreme weather events and changing climatic conditions globally (Ford et al. 2009, 2011; Pearce 2009, 2010). The communities associated with mining operations are also vulnerable to extreme weather events and changing climatic conditions, including to the indirect impacts that flow through from extreme weather events on mining operations (Miles et al. 2007; DERM 2009). Climatic change is expected to exacerbate these types of events in Australia (CSIRO & BOM 2007), and can be expected to pose increasing challenges to the industry and related communities and the surrounding environment. Therefore, it is imperative that the mining industry and communities adapt to address climate change and be supported by regionally-relevant governance in which they have been an active partner in developing.

Currently, adaptation activities by regional mining stakeholders (e.g., mining companies, local government authorities, communities) are disparate and disconnected, where they exist (Loechel, Hodgkinson & Moffat, forthcoming). This may lead to adaptation strategies by mining companies, for example, that have no benefit for regional 'neighbours' or may exacerbate the impacts of future climate or weather impacts for other stakeholders. The flooding of the Ensham mine in Queensland in 2008, for example, demonstrated that mine design that does not adequately plan for extreme weather events may lead to downstream community impacts through the release of contaminated water in local water courses. Hence, there is a call for a process that allows for all stakeholders to articulate their contextual framing about climate change impacts while at the same time collaboratively working towards an outcome that aims to address adaptive change. This paper provides results of a recent study that offered an opportunity for multiple stakeholders to use a framework to assess risk as well as establish clear guidelines around identifying responsibility of action and relevance of approach against the backdrop of specific local contextual issues. This framework allows for multiple regional perspectives to be articulated and 'heard' in the context of climate adaptation to establish points of tension, alignment and resources available to adapt successfully. The results of this type of collaborative, participatory approach to assessing future weather and climate risk also provide clear direction for the development of governance frameworks and intuitions that enable and support mutually beneficial adaptive behaviours. It may also address present power imbalances inherent in existing governance structures that advantage resource rich, high power groups (i.e. mining companies) over resource constrained, low power groups (e.g. local government bodies).

Theoretical framework

Centralised governance approach: Barriers in addressing local issues

Traditionally Australian governance of natural resources have stemmed from a centralised expert management approach. This approach consists of a top-down design with little to no involvement of stakeholders beyond scientific experts and policy advisors, creating a centralised institutionally driven governance system (Dietz et al, 2003; Nelson, 2008; Ostrom, 1999). According to Nelson et al. (2008) the fundamental risk of this approach is the exclusion of other important sources of information that can provide contextual knowledge.

> *Human-environment systems are inherently complex and unpredictable because of their nonlinear and open nature, making it impossible to build a complete body of scientific knowledge that allows full prediction and control (Brunner & Steelman, 2005, Dietz et al., 2003, Jiggins & Roling, 2000). They are complex systems with diverse components interacting at multiple scales, differing subtly between amyriad of local contexts and continuously changing under the influence of social, economic and environmental pressures (Dietz et al., 2003, Holling, 1978, Ostrom, 1999). The complexity of natural resource management systems means that narrowly disciplinary and reductionist study of individual system components provides few insights into the emergent properties of whole resource systems (Holling, 1978)* (Nelson et al., 2008: 589).

On the other hand, a more responsive or adaptive governance approach provides for a developing and locally context-specific balance and integration of multiple stakeholders through a process that engages discussion between governments and communities facilitated by the integration of local and scientific knowledge (Nelson et al., 2008). Therefore, many researchers (e.g. Dietz et al., 2003, Nelson et al., 2008; Ostrom, 1999) recommend that a combined top-down bottom up approach be used to address governance for natural resource management using a complimentary process that meets both government and local needs in a continual responsive manner.

What is lacking in the current literature is how this framing could be used to meet climate change adaptation governance requirements in the mining sector. Globally, little work has been performed on ascertaining the impacts of changing climate risk for the mining industry and its associated communities. Of the few reports available (e.g. Pearce et al 2009; UK Met office 2010), all have identified a general lack of awareness and action within the mining industry in relation to adaptation to future changes in climate risk. Therefore, the aim of this research is to investigate the effectiveness of a responsive governance approach in an Australian mining region in order to begin discussions regarding adaptation required to meet future climate risks.

What is clear with respect to mining is that community expectations regarding the impacts and benefits from mining, particularly as they relate to regional and remote Australia where most mining tales place, have changed. It is no longer the case that mining companies need only meet the formal regulated conditions to operate to be acceptable to a majority of their stakeholders, they must also now meet the conditions of what may be called a social licence to operate. This construct is broadly defined as ongoing acceptance or approval of an operation by those local community stakeholders affected by it (Joyce & Thomson, 2000; Kurlander, 2001; Nelson & Scoble, 2006; Thomson & Boutilier, 2010; Thomson & Joyce, 2008; Parker et al., 2008) and other stakeholders who can affect its profitability (Graafland, 2002). Critically, a social licence is conceived as being intangible, impermanent, and ostensibly 'granted' by a set of stakeholders based on the degree of match between their expectations of a corporation's behaviour and the company's actual behaviour (Salzman, et al, 2005).

The consequences for mining companies that do not hold or lose their social licence can be as damaging as if they were to lose their formal regulatory licence. Communities have real power to impact negatively on the reputation of companies through negative publicity, product boycotts, and high profile legal challenges which may, for example, reduce the flexibility of companies to operate in political and regulatory contexts, and therefore reduce their competitiveness (Gunningham et al, 2004). In 2008, for example, the Ensham coal mine in Queensland flooded during an extended period of heavy rain. This led to the emergency release of large amounts of untreated water into local water courses which then flowed to communities downstream. These communities were forced to boil drinking water before consumption leading to public discussion of local water resources and management practices in the aftermath. Community pressure flowed to state government who then tightened water release regulations. As a consequence, after heavy rain in early 2011 coal mines in the region were unable to release water to get operations back up and running as quickly as they would have preferred because of these new conditions (see DERM, 2009 for an overview of regulatory changes following this period).

It is therefore in the interests of mining companies to understand the contexts in which they operate and the issues that are important to local communities and other stakeholders, and to develop strategies for dealing with similar issues that take these interests into account. With respect to governance approaches, a top down approach allows for the formal 'rules' that determine how those regional neighbours affected by climate change may approach the task of adaptation to be defined. However, without a process to explore and understand the issues, concerns and needs of local stakeholders, and then to facilitate collaborative approaches to adaptation, it is more likely that the interests of local stakeholders will not be reflected in mining adaptation planning and may even lead to greater impacts on these stakeholders than may otherwise have been the case. As in the Ensham mine example, this may lead to reputational damage, restrictions on future operational activities and in extreme cases outright rejection of the social licence to operate.

Model for assessing vulnerability and adaptive capacity

In order to conceptualise how an integrated top-down, bottom-up process could be practically applied, we used the Garnaut (2008) model for assessing vulnerability and adaptive capacity (see figure 1). Climatic change may bring opportunities and benefits as well as risks, and both need to be considered. However, most analyses tend to only take a vulnerability assessment approach. Climate vulnerability is generally expressed in terms of 'potential impact' (derived from exposure and sensitivity), which, when combined with 'adaptive capacity', leads to an estimation of vulnerability.

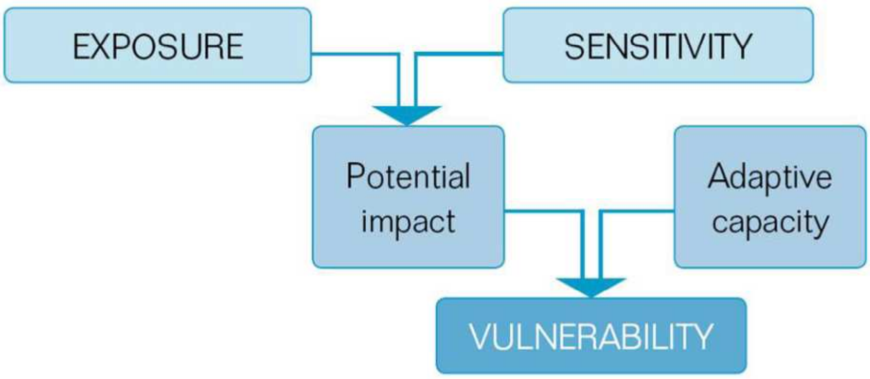

Figure 1. Model for assessing vulnerability (Garnaut 2008 p. 125)

Exposure refers to the types of environmental stimuli or changes that represent a potential threat, such as heat waves, more frequent and/or intense storm events, rainfall decline and so on. *Sensitivity* refers to how great the impact will be on a system for a given change in condition. For example a 1°C increase in average temperatures may reduce production efficiency or increase dust output by a certain percentage.

Adaptive capacity refers to the ability of a system to respond constructively to these changes in order to manage their situation so that detrimental effects are minimised, and any opportunities for improvement are exploited. Adaptive capacity tends to be mainly understood in terms of social, economic and technological characteristics, although biophysical characteristics such as alternative natural resources (e.g. water supplies) can also be important. These factors are sometimes referred to in terms of resource capacity, as expressed in the sustainable livelihoods model developed by Ellis (2000). This model identifies five types of capital available for adaptation: human, social, financial, physical (infrastructure, technology) and natural (biophysical). However, any final assessment of adaptive capacity requires an assessment of adaptation options and strategies utilising these resources (see for example, Nelson et al. 2007; Nelson et al. 2010; Park et al. 2009; Preston & Stafford Smith 2009).

Finally, while assessments of potential impacts and adaptive capacity will produce a calculation of (net) vulnerability, converting this to an assessment of climate risk requires consideration of the probability or likelihood of the various components that make up the model (Preston & Stafford Smith 2009).

It is apparent from the overview above that there are potential implications of future climate variability and change for the mining industry for a broad range of people, professions, organisations and groups. Furthermore, there are likely to be inter-connected outcomes as the effects on one party (such as increased costs of energy and transmission infrastructure) potentially have implications for many others. For this reason it is important that any approach to climate adaptation, including vulnerability assessment and governance development, be undertaken at both the individual organisational level and at the broader integrated community and/or regional level.

There for e, the aim of this research is to investigate the effectiveness of a collaborative process which tries to combined the risk, issue and concerns form both a top-down and bottom-up perspective. In order to achieve this aim, the following process is proposed:

1. Provide information and concepts to a range of stakeholder participants in relation to climate variability and change, and strategies for adaptation.
2. Explore the implications of this data for each of the stakeholder groups represented and across the mining value chain through structured discussions.
3. Develop a network of stakeholders in the research site region to engage in collaborative adaptation planning in the future which actively contributes to governance development and implementation.

Methodology

Research context

The research was conducted in Western Australia's Goldfields-Esperance (GE) mining region (see figure 2) which contributed over $10 billion in 2006-07 to Gross Regional Product (DLGRD 2010) and is an important mineral province for Australia. The regional population of around 60,000 also includes a significant Indigenous population, throughout and around the towns of Kalgoorlie-Boulder, Esperance, Kambalda and Ravensthorpe. There is considerable mining infrastructure across the region, from actual mines, through mineral processing, utilities and transport infrastructure. The GE region is likely to experience changes resulting from variations in climate and climate change, which will affect stakeholders in the mining industry, including mining companies, infrastructure providers, local government agencies and local communities. The region is home to a significant Indigenous population, particularly in its northern shires of Ngaanyatjarraku, Laverton, Leonora and Menzies. Nearly 10% of the region's population are of Aboriginal descent, which is a substantially higher proportion than for the state as a whole. Many groups reside in small remote community settlements and warrant culturally sensitive approaches to addressing issues that affect them.

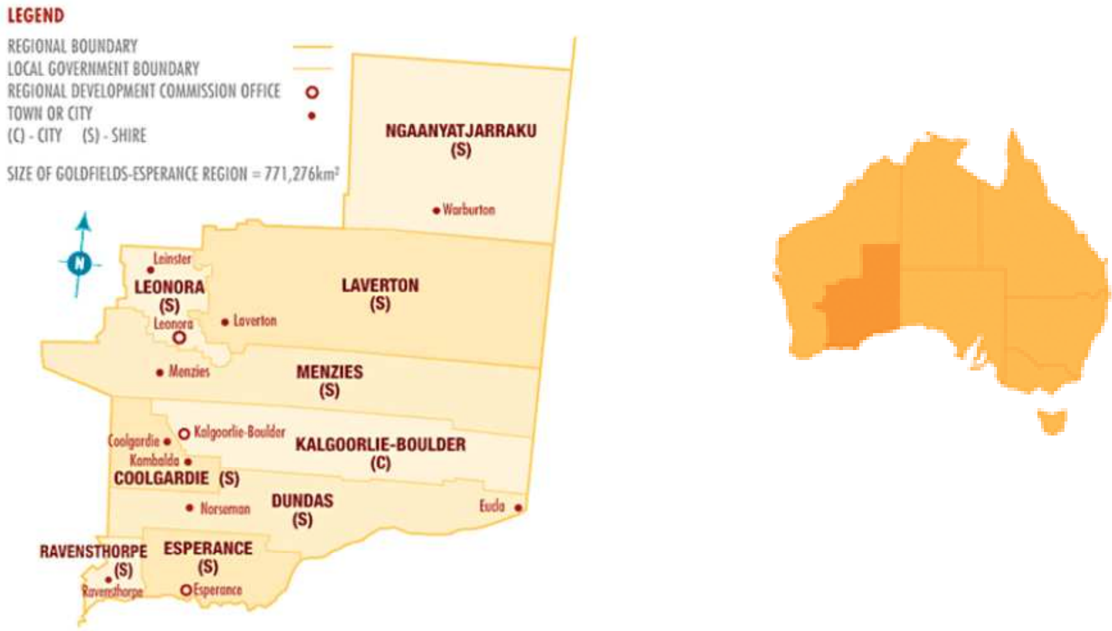

Figure 2. The Goldfields-Esperance region of Western Australia (Source: GEDC 2010)

Climate change projections for the research site

Climate projections (changes in monthly temperatures and rainfall) have been developed by CSIRO for 2030 and 2070 for key Australian mineral provinces using novel statistical downscaling methods (Kokic et al. 2010). Figure 3 shows the various mining regions within Australia (including region 4 - corresponding to the WA Goldfields), for which these climate projections have been developed.

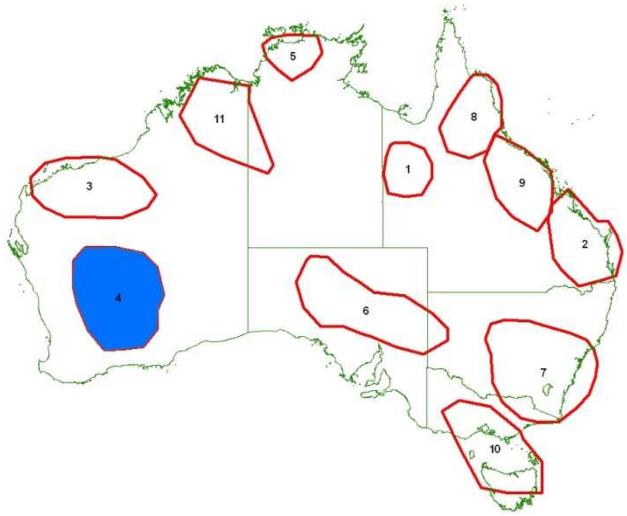

Figure 3. The 11 Australian mining regions for which CSIRO has developed climate projections out to 2030 and 2070 showing WA Goldfields (Region 4) highlighted in blue.

Current climate. Region 4 experiences two main seasons: namely a hot and dry summer (October to March) and a cool and dry winter. During the summer, this region can experience in excess of 10 days above 40°C and 38 days above 35°C with mean summer temperatures around 26°C. Over the winter, average temperatures are around 17°C and the lowest around 7°C occasionally falling below freezing at night. Rainfall is fairly evenly distributed throughout the year and averages about 264mm per annum, although annual figures can vary considerably. The most reliable rains occur in winter and June is typically the wettest month with approximately 29mm. Summer rainfall occurs usually as a result of thunderstorms. At such times, annual rainfall can exceed 500 mm (Bureau of Meteorology 2010).

Future climate. By 2030 future climate conditions for Region 4 are predicted to be between 0.6 to 1°C warmer and 5 to 7% drier (Table 1). This will have significant effects on extreme events with the number of days above 35°C increasing from its present mean of 38°C to between 43 to 53 days. This in turn has significant ramifications for evaporation and water availability.

Table 1. Projected change scenarios for temperature and rainfall in Region 4 according to four of the best performing climate models available [NCAR = National Centre for Atmospheric Research; ECHAM = Max Planck Institute for Meteorology; GFDL = Geophysical Fluid Dynamics Laboratory; HADGEM = Hadley Centre Global Environmental Model]. (Source: http://www.csiro.au/ozclim/home.do).

Projected changes in temperature and rainfall REGION 4								
SOURCE:	NCAR Temp °C	NCAR Rain (%)	ECHAM Temp °C	ECHAM Rain (%)	GFDL Temp °C	GFDL Rain (%)	HADGEM Temp °C	HADGEM Rain (%)
November to April 2030	1.09	4	1.09	-1	1.16	-5	0.93	-4
May to October2030	1.14	-6	1.09	-6	1.02	-5	0.76	-5
November to April 2070	2.96	10	2.96	-2	3.13	-14	2.52	-12
May to October 2070	3.07	-16	2.46	-15	2.76	-47	2.07	-13

Future issues likely to have a major influence on the prosperity and wellbeing of the region include those specific to the region (DEC 2010) and those applicable to the resources sector more generally (Giurco et al. 2009). For example:

- the duration of current mines and success of exploration for new mining ventures (linked to the issue of 'peak minerals')[1], and development of minerals processing
- mining investments elsewhere that compete for finite resources (e.g. finance, labour, energy, water)
- skills shortages resulting from the competition for labour
- commodity prices linked to global economic conditions
- corporate globalisation, mergers and acquisitions
- geopolitical events and shifting economic and political relations
- government taxation and regional investment regimes
- climate change affects, and mitigation and adaptation responses including the shift to a less carbon dependent economy
- energy costs and development of renewable resources
- changing social expectations that influence government regulation, especially those related to environmental and cultural heritage (e.g. Native Title) issues.

The future climate scenarios presented here generally point towards a hotter, drier climate for the WA Goldfields (Region 4), which is already described as hot and dry for most of the year. Where water is already at a premium, reduced rainfall and increased evapotranspiration will put additional stress on the water resources available, suggesting that both mining companies and the local community will need to

[1] Peak minerals refers to the point in time when the highest amount of production of a mineral occurs, with production declining in subsequent years

adapt their practices to use less water and cope in the hotter extremes. What this information does not show, but is projected more generally across Australia and relevant for region 4, is greater incidence and severity of extreme weather events or storms, including high winds (10 to 15% increase by 2030) and intense rainfall (20 to 30% increase by 2030).

In summary, this region is likely to experience changes resulting from variations in climate variability and change which will affect stakeholders in the mining industry, including mining companies, infrastructure providers, local government agencies and local communities. Developing a greater understanding of the potential impacts of climate variability and change on a range of interdependent stakeholders in the mineral extraction value chain, and strategies to adapt collaboratively to these potential impacts, is therefore an important issue to explore in a systematic manner.

Research participants

In association with the Goldfields-Esperance Development Commission (GEDC), the CSIRO conducted a workshop with a range of regional stakeholders to present climate change data, adaptation concepts and provide discussion topics in order to ascertain the industry's perceptions of climate change and requirements for adaptation. Participating organisations (n = 23) included mining companies (n = 6), mining industry services (n = 3), utility providers (n = 3), research organisations (n = 3), and state and local government agencies (n = 8).

Procedure

The workshop format was adapted from previous CSIRO research in Australian broad acre agriculture exploring adaptation issues for rural communities (Nelson et al. 2010) and in the Pacific exploring adaptation issues with island nations (Park et al. 2009). These research approaches used environmental vulnerability, based on climate projections, and social assessment tools to generate a holistic understanding of community adaptive capacity.

The broad structure of the workshop process is laid out in Figure 4. There were four main components of the process: pre-engagement interviews with attendees, a desktop regional climate vulnerability assessment, the half-day workshop itself, and a follow -up feedback survey to gauge satisfaction with the workshop. The first two components were undertaken prior to conducting the workshop to gain an understanding of the region and issues relevant to the workshop topic to ensure its relevance for attendees. Pre-engagement interviews were undertaken with a representative range of those who had accepted an invitation to attend the workshop (about half those accepting an invitation were interviewed). Additionally, the workshop content was guided by a desktop Regional Vulnerability Assessment (Loechel et al. 2010) a copy of which was provided to participants on the day. This comprised research and analysis regarding the characteristics of the region, prior research on likely impacts of climate change on mining, including the outputs of an earlier workshop conducted with CSIRO mining experts, and an overview of climate projections and potential implications for the regional mining community.

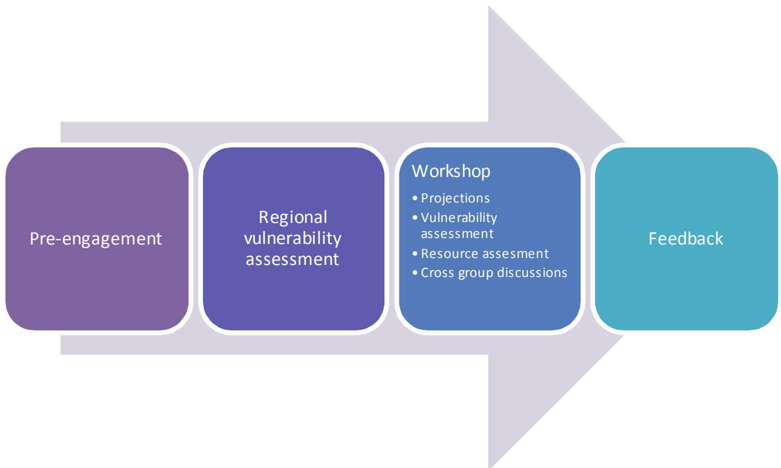

Figure 4. Broad structure of process undertaken in this study

The third component of the process was the half-day workshop itself. Workshop participants were assigned to their respective stakeholder or sectoral group as defined in Figure 5. Each group was guided by a CSIRO or GEDC facilitator. The workshop included four main stages. First, information regarding past and future climate of the GE region that was developed by CSIRO scientists was presented to participants. The information included global, national and regional climate trend analyses and climate projections for key Australian mineral provinces, including the WA Goldfields. The second stage of the workshop involved examining the likely vulnerability of the mining industry and community to climate change based on the information provided on regional climate projections. Sessions were structured to allow for sector-specific discussion around key issues before engaging in cross-group discussion to explore the interconnections between sectors.

The third stage of the workshop guided participants through an assessment of the resources available to their organisation and sector for adapting to climate change. The assessment was based on the sustainable livelihoods model developed by Ellis (2000), which defines five main resources for adaptive capacity in terms of human, financial, social, physical and natural capital. Finally, the workshop concluded with a sector presentations of their resource maps or 'spider diagrams' and a cross-sectoral discussion of interconnections between groups.

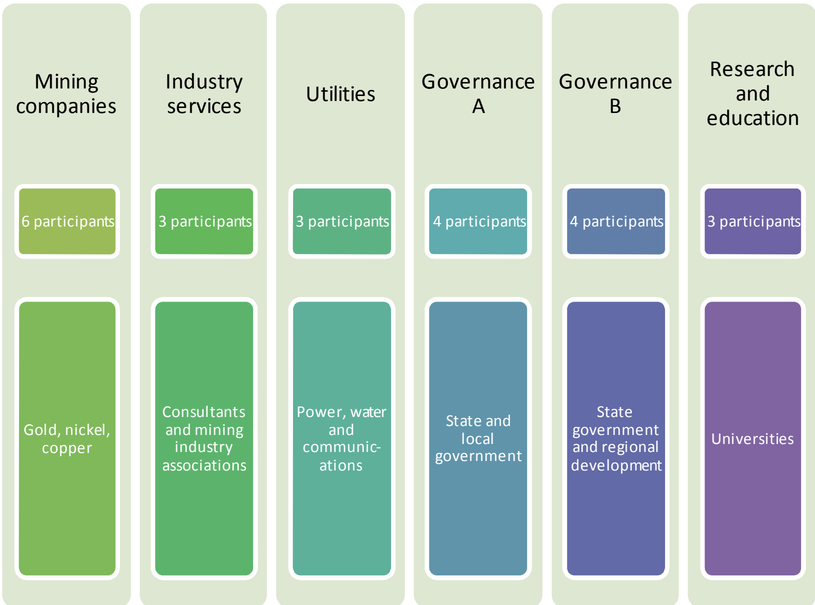

Figure 5. Group type definitions and participants present for each group type

Measures

Drawing upon the research aims and past research by Preston and Stafford Smith (2009), which stated that when investigating community climate adaptation planning has suggested that any approach needs to consider a range of dimensions (see Figure 6), the following questions were used in the workshop:

1. What are the key drivers of change or future prosperity for your operation/sector group?
2. What are the implications of the climate projections for your operation/sector group?
3. What types of factors will influence the vulnerability of your operation/sector group to a changing climate?
4. What are the measurable indicators for each area of climate vulnerability in your operation/sector group?

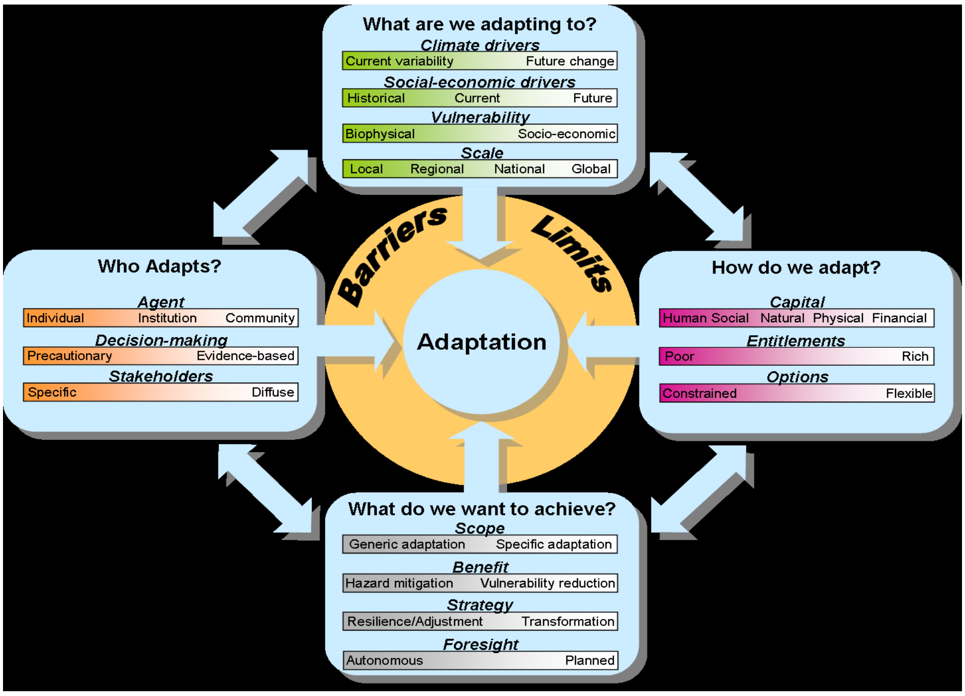

Figure 6. Dimensions of adaptation (Source: Preston and Stafford Smith 2009)

In addition to these considerations, lessons for community assessment from various vulnerability- capacity and adaptation studies (Hay & Mimura 2006; Ziervogel et al. 2006; Fussel 2008) suggest that broader, integrated assessments are required that:

- consider a range of major related variables or issues that are likely to affect the area's future; for example, demographic shifts, land-use changes, new technologies, industry trends;
- are integrated into on-going/ pre-existing community development and risk management processes, structures and pathways, and
- help assess not only community vulnerabilities and capacities, but also include risk planning (risk management/mitigation options).

Therefore, these additional considerations were included in our research.

Results

Pre-workshop engagement

Prior to the workshop 11 participants were interviewed to ascertain why they were attending the workshop and their expectations of it, the major factors or drivers they perceived to be important to the future of their sector, and vulnerabilities, opportunities, adaptation options and strategies they believed to be important in responding to a changing climate.

The resulting comments provided a means to tailor the workshop to their needs and expectations. Common themes that arose during the interviews centred on the mining process, technical issues, utilities, social and environmental issues, governance, information and decision-making, and general observations and other general comments.

Rainfall variability and groundwater resources were raised as mining process issues: flooding and lack of water caused by changes in patterns of precipitation will require thought and adaptation. Impacts by heat were raised in relation to the mining process as both human and technical resources will be subjected to more intense temperatures and potential failures; this also led on to a question of infrastructure integrity including the ability to transmit power and water effectively to what may be an increased population under more demanding conditions. Such conditions may reduce 'liveability' in the area, causing stress of the local population. It was suggested that the availability of credible and situation specific data together with a supportive political environment would be crucial to successful adaptation.

Workshop findings

Question 1: "What are the key drivers of change or future prosperity for your operation/sector group?"
Following presentation of the climate projections, participants were asked to list the key drivers for their operation or sectoral group. The aim of this question was to explore the broader context within which climate adaptation will take place for each sector group, to understand how these drivers related to climate change, and to explore any differences and similarities across groups.

Across all of the groups, the most common drivers mentioned related to:

- the economics of doing business and the costs of adaptation,
- certainty around government policy on climate change, and
- societal pressures.

Other drivers mentioned related to workforce availability, infrastructure costs and regulatory requirements of utilities providers, climate change adaptation and technology. There was considerable overlap in the drivers discussed, as reflected in Figure 7 (each coloured area represents a sector group while the numbers represent the various drivers of change identified within each group - the positioning of the numbers thus indicates which drivers were common to which groups).

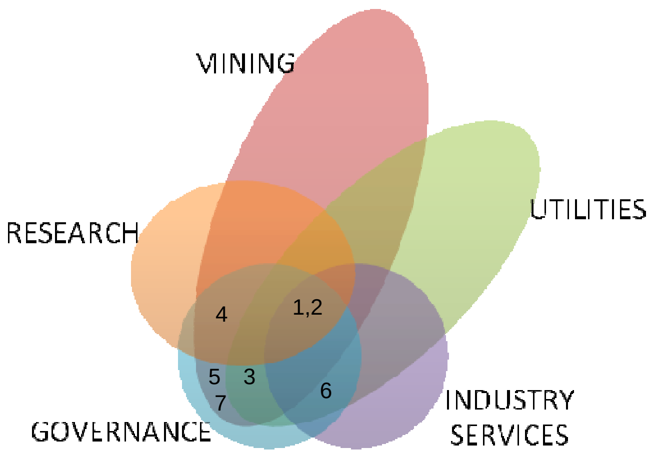

Figure 7. Key Drivers of change or future prosperity by sector group. [1=Economic factors; 2=Policy; 3=Society; 4=Workforce; 5=Adaptation challenges; 6=Infrastructure; 7=Technology (See also Appendix D)]

Economic issues: for the mining sector, this driver related to future commodity demand and prices, in addition to resource input costs (water, energy) and access to capital in a competitive global environment. While these market-economy factors were less broadly discussed by other sectors, references to economic factors across the governance and research sector groups were typically related to the government's provision of funding. The utilities sector mentioned economics both in terms of demand by industry and economic regulation by government, both of which affect their future growth and profitability, including the need to improve infrastructure.

The second major theme across all sectors was the **influence of government,** and the effect of policy uncertainty on activities such as adaptation planning. For the mining company and service sectors this typically related to regulation and taxation issues (e.g. a future carbon tax), for the governance sector this related to environmental regulation and local government reform, while for the research sector the concern was around future levels of government funding.

Societal perceptions, expectations and pressures were another series of drivers and issues commonly discussed across the groups. Heightened societal sensitivity and expectations of resource use by the mining industry (e.g. water, energy) and environmental and social impacts on communities were seen as a challenge. In many cases they were linked to comments about government regulation of mining, as they manifested through the political process or the media to pressure government to make changes to the way mining is regulated.

Workforce and staffing issues were mentioned principally by the mining company, governance and research sectors. The types of issues raised related particularly to high turnover and skills shortages. Infrastructure was discussed in terms of being able to adequately meet future demands, and changing requirements to access more sustainable resources. A variety of climate adaptation challenges, including the pace of climate change and legacy issues were raised, as was the need for rapid technological advancement to meet these challenges.

<u>Question 2: What are the implications of the climate projections presented for your operation/sector group?</u>
Moving from thinking about the broad range of issues affecting their sector, to those more specifically related to climate change, a broad range of 'major' themes were evident. The theme areas identified within each sector group are displayed in Figure 8. The major themes identified by the groups included:

- use of scarce resources (principally water and energy),
- impacts on environment and community,
- hazards and workforce issues,
- infrastructure impacts, and
- mine planning and design.

The main issues raised by the **mining sector** related to the effects of extreme weather events, such as: damage to infrastructure; the need for greater onsite storage of supplies such as diesel, reagents and water in the case of loss of access flooding; and hazards and safety issues such as flooding, slope instability, and wind-blown debris. Improved mine planning, design and technologies to deal with extreme events were also mentioned.

The **industry services group** focussed on issues to do with: business analysis and reporting; complying with regulations; dealing with the increased need for, or community expectations of, improved management of scarce or costly resources such as water and energy; and, attracting workers to mining communities.

Utilities representatives mainly focussed on implications for infrastructure, in terms of its location, damage from extreme weather events and design requirements. They also mentioned that additional infrastructure and/or different types will be required to provide resource security (e.g. energy, water).

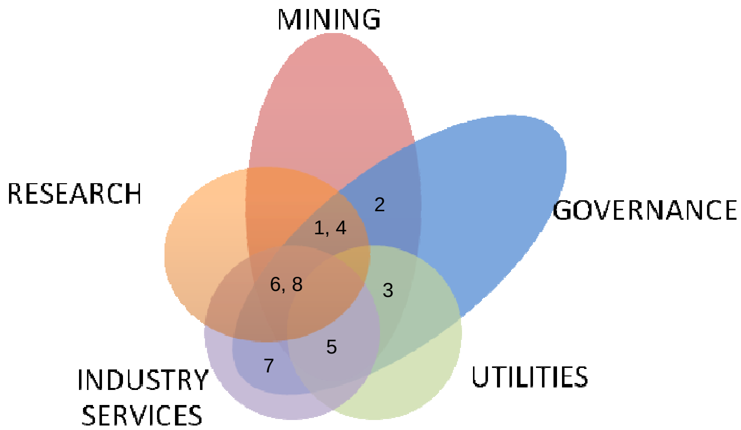

Figure 8. Implications of climate projections by sector group: 1=Economic factors; 2=Hazards; 3=Infrastructure; 4=Mine planning and design; 5=Resource use; 6=Workforce issues; 7=Policy; 8=Impacts on environment and communities. (See also Appendix D)

The **governance A group** considered impacts on the mining industry, the community and the environment. They included increased water costs due to access and scarcity issues, broader national economic and population health impacts of climate change, and the combined effect on the environment of land clearing and climate change.

The **governance B group** focussed on how governments typically interested in city and coastal issues may neglect regional areas, and that this could have major implications for mining community adaptation to climate change. Key limitations were seen as inappropriate policies and lack of funding. A potential (partial) solution was seen in industry being willing to assist local government in terms of provision or funding of infrastructure. Other issues raised by this group included: the difficulty of attracting and retaining the mining workforce in regional areas with increasing temperatures and preferences for coastal climates; understanding the impact of changing mining practices, such as increased automation; and, the affect of more extreme heat waves on infrastructure maintenance.

The **research sector group** mentioned the need for mining education, training and research organisations to incorporate consideration of climate change impacts in their programs. This included knowledge about risk assessment, and technical design and costings of current and future mines to improve their resilience.

Looking across these different sector groups, a prominent **'meta-theme'** emerging was the need for development of infrastructure and technologies that could more efficiently utilise resources, such as water and energy, as they become increasingly scarce or costly under a warmer and drier climate. An interesting aspect of this issue, mentioned by a number of groups, was that water scarcity may lead to increased energy costs. This is because accessing new sources and/or desalinating water may be energy intensive and require additions to the current energy infrastructure. In relation to this, other groups stated that adaptive capacity is strongly related to the costs of adaptation measures, or conversely, funding limitations.

The impact of climate change on the mining workforce was mentioned in terms of both safety issues and the potential difficulty in finding suitably skilled staff. Safety concerns were mainly related to the hazards posed by extreme weather events, such as cyclones, storms and flooding. An issue that was raised principally in relation to the impacts of climate change on the community, but equally relevant to the mine workforce, was health risks from shifting geographic occurrence of disease. Difficulty finding suitably skilled staff was partly seen as an impact of less amenable working conditions and partly related to a lack of relevant education and training.

Impacts on the environment and community were discussed in relation to protecting the environment from fire under hotter and drier conditions (mining sector), heightened community expectations for responsible mine management of scarce resources (industry services), national economy and population health impacts from climate change (governance A), perceptions that hotter/drier conditions will exacerbate coastal/regional tensions (governance B) and expectations that mining education provision should incorporate climate change aspects (research sector).

Interestingly, economic factors and government regulation, two major themes in the preceding discussions, were mentioned far less. In relation to government regulation, this is possibly because it was emphasised in the introduction to the workshop, and in the explanation of this specific question, that the focus should be on direct climate change impacts, rather than those brought about by government policy responses to climate change (e.g. emissions mitigation). Further, in regard to economic factors, although many items related to issues that could arguably ultimately have a financial cost, such as infrastructure 'damage' and 'changes', 'new technologies', 'increased renewable energy use' and 'attraction & retention of workforce', this cost was often not explicitly mentioned.

Overall, it is evident that participants felt that climate change would require adaptation within both the mining industry and its communities to more efficiently use scarce resources, upgrade and/or modify the infrastructure serving them, as well as mine designs and operations, and to safeguard employees and the surrounding communities and the environment.

Question 3: What types of factors will influence the vulnerability of your operation/sector group to a changing climate?

While the previous question identified those areas where each group were vulnerable to climate change, question three sought to identify the types of factors that would *affect* each sector group's vulnerability. The main issues or factors affecting vulnerability that recurred across the sector groups were (see Figure 9):

- access to the essential resources (e.g. water, energy, funds) and infrastructure needed to adapt to climate change;
- access to necessary information and knowledge (which can be seen as another form of resource); and,
- the degree of behaviour change required across all sectors of society (businesses, government and community) to address the challenges of climate change and increase adaptive capacity.

Although access to key resources, infrastructure and knowledge, and acceptance of behaviour change were the dominant themes across sector groups, a broad range of additional factors were seen as influencing vulnerability to climate change. These included: government policy leadership (linked to the issue of behaviour change); the costs, risks and returns associated with adaptation measures (emphasised under Q.2 above); society-wide impacts, pressures and expectations that tend to influence government policy and regulation; availability of appropriately skilled workers (who, again, can be seen as another form of resource); and the connections between issues and inter-dependencies between sectors that lead to cumulative and/or compounding knock-on effects across them.

The main factors identified by the **mining sector** were:

- the availability of detailed and credible information and knowledge (e.g. vulnerability thresholds, location specific climate projections, the availability of scarce resources, and adaptation methods);
- acceptance of the need to adapt within the business community; and
- understanding the interacting effects of climate events across the supply chain.

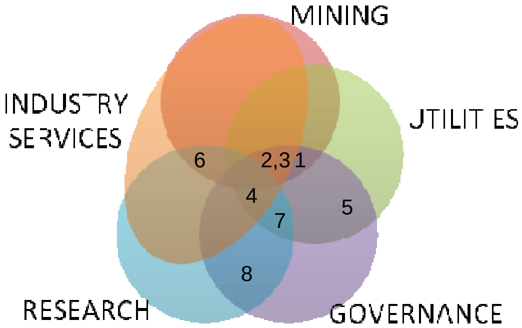

Figure 9. Factors that will influence vulnerability to climate change by sector group: 1=Access to resources; 2=Behaviour change; 3=Knowledge; 4=Costs and risk/return; 5=Policy and leadership; 6=Cumulative impacts; 7=Society; 8=Workforce. (See also Appendix D)

Factors mentioned by the **industry services group** included:

- unwillingness to change within the government and business community;
- maladaptive responses such as poorly thought out solutions (for example selecting insufficient emergency power sources);
- risks related to investing in new technology under conditions of uncertainty; and,
- global climate change impacts that have a knock-on effect to local industry (for example damage or disruption to the supply chain or change in demand for commodities)

The **utilities sector** nominated their main influencing factors as:

- a lack of agreement at the federal or state government level regarding climate change policy, which made it difficult for utilities companies to justify the cost of adaptation measure to their regulators; and,
- change of culture in society regarding the way utilities are used and valued, affecting capacity requirements and the ability to source alternative supplies, and therefore the ability of companies to provide a service.

The types of factors the **governance A group** identified included:

- government leadership or political will on the issue, which affects funding levels to address it;
- the speed with which the climate changes, which affects time available to adapt and the costs of doing so;
- the scarcity of resources such as funds, human capital, essential services and infrastructure to apply to the problem (which is again linked to government leadership and priorities); and,
- societal issues such as increased population pressures, consumerism, unemployment and increasing health needs of an ageing population.

The **governance B group** focussed on the ability of state and federal government to provide practical policy solutions to adapt to climate change as a key factor contributing to the overall mining community vulnerability. They mentioned issues such as:

- the need for improved assessment processes;
- alternative funding systems for public infrastructure;

- policy, methods and technologies to better manage scarce resources such as water; and,
- the need to meet increased demands for information, including baseline environmental monitoring.

Factors seen as affecting the capacity of governments (and communities) to respond to climate change included declining resources, lower volunteerism and the increased power consumption required to manage infrastructure. The point was made that infrastructure was designed for optimum performance under current climatic conditions and any change in conditions would inevitability reduce the performance and increase the cost or maintaining this infrastructure.

The **research group** focussed on the factors they saw as influencing the vulnerability of the mining sector and identified that hotter working conditions in the mines, together with the problems of work-life balance brought about by fly-in fly-out work schedules, may reduce the capacity of the mining sector to attract the human resources they needed. They also discussed greater risks and costs involved in mining under new climatic conditions that could reduce returns; and knock-on effects between mines and other stakeholders, as well as the cumulative impacts of multiple mines, which could create community tensions.

<u>Question 4: What are the measurable indicators for each area of climate vulnerability in your operation/sector group?</u>

This question sought to identify the types of specific, measurable indicators that could be used to identify vulnerability for each sector group represented. The most commonly identified indicators across all the sector groups fell into three major categories (see Figure 10):

- <u>economic indicators:</u> for example, input costs for mining such as overheads and materials costs, commodity prices, insurance premiums, a potential carbon price being implemented, and the consumer price index (CPI) in relation to prices generally being driven higher as a result of climate change effects;
- <u>infrastructure capacity measures</u>: such as load demands, supply disruptions or faults, and maintenance schedules; and,
- <u>social indicators</u>: particularly those related to behavioural change and political support for addressing climate change problems.

Other indicators mentioned included: mine production measures; natural resource availability, particularly water; weather and climatic conditions; and workforce or human capital related indicators (e.g. health and safety, skills gaps).

The **mining sector** focussed on natural resource indicators such as water availability and production measures such as the number of days lost to wet weather. The **mining industry services** group nominated policy and behavioural change measures and economic indicators such as commodity prices and technology costs. The **utilities** group focussed on infrastructure related indicators such as load demands and faults related to weather events, as well and natural resource (water) measures.

The two **governance** groups nominated social indicators relating to behavioural change and support for new policy measures, and indicators that measured the demand for, and ability to provide, public infrastructure. The **research sector** first sought to define vulnerability, viewing it as the risk of adverse events, including the costs once these had occurred. In terms of measures of vulnerability relevant to their sector, they nominated the number of people that would be needed to be trained to plan for and develop the solutions to adapt to climate change, which had implications for funding requirements for their sector.

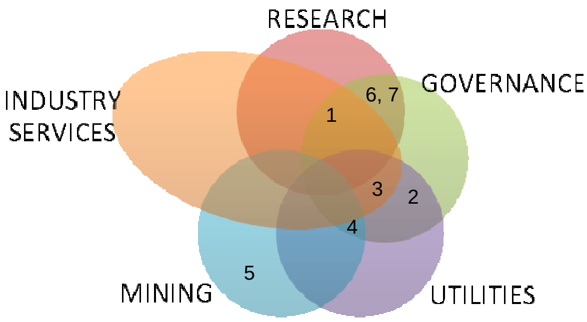

Figure 10. Measurable indicators for each area of climate vulnerability by sector: 1=Economic indicators; 2=Infrastructure change; 3=Social/behaviour; 4=Natural resources; 5=Production indicators; 6=Weather/climatic indicators; 7=Workforce/HR indicators. (See also Appendix D)

Climate change implications: mixed-group discussion

One of the key aims of the workshop was to explore climate change implications and adaptation strategies across a range of stakeholders in the mining industry. Following the sector group discussions, each sector group presented a summary of their findings across the four questions to the entire group. Workshop attendees were then asked to move to different tables and form cross-sectoral groups to discuss the common issues and interactions that were emerging, as well as any differences. Attendees were asked to consider three questions:

- Was your group thinking about vulnerability differently to other groups?
- Do you have different definitions or indicators of vulnerability?
- Which issues are common to multiple groups and which are unique to specific sectors of the mining industry?

A diverse range of themes emerged from the cross-sectoral table discussions. These have been divided into major, medium and minor themes, based on the frequency of occurrence across the discussions, and summarised in Figure 11.

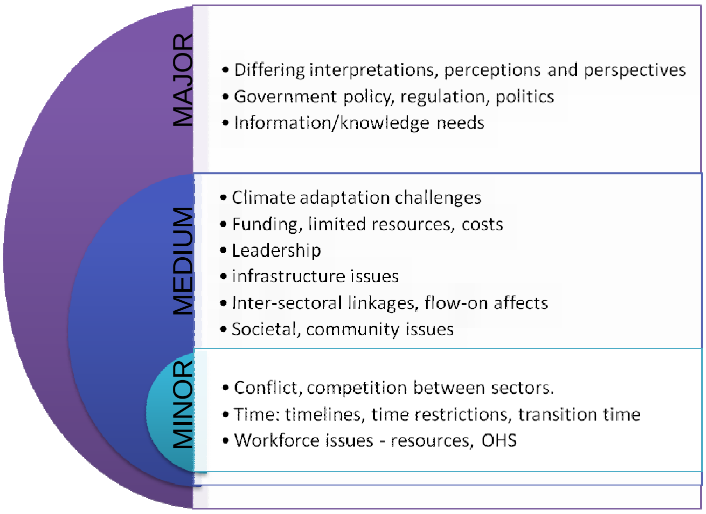

Figure 11. Relative incidence of discussion points for each topic raised

Many comments by the mixed sectoral groups referred to the **diversity of interpretations, perspectives and focus** across the various sectors. As could be expected, participants noted that each sector group emphasised different aspects or had a 'different slant' on the same issue or question. These differences in perspective were sometimes related to comments about potential conflict and complexity in dealing with issues. However, some groups noted that similar themes ('governance' and 'societal') arose across the different groups and that there were 'no violent disagreements' between sectors.

A second major theme related to the importance of **government policy and regulation**. This was tied to the issue of leadership; namely, the need for a political resolution and policy direction that would provide impetus for action on climate change adaptation by business, community and government entities across Australia. It was also linked to the issues of the need for better information and of funding or resource allocation to support climate change adaptation. Comments such as "waiting for government (and) credible data" and "need to influence government to obtain funding to respond" exemplify some of these sentiments. Without a definitive policy direction, as represented in legislation and regulation for a collective national response, and credible, situation-specific information, it was considered difficult for some organisations to justify allocating resources to take action. For mining companies, while they were less dependent upon government leadership to take action, they also wanted better climate projection information and certainty around a range of policy issues related to climate change action, although the driver for decisions (cost-benefit analysis for taking specific actions) was different. However, on issues such as water efficiency the mining industry representatives felt that immediate benefits may be realised through action independent of other decisions.

While the diversity of sectoral perspectives was emphasised, another prominent theme was the **inter-dependencies between sectors**. Many issues, such as water, energy and infrastructure, were considered to be critical inputs to a range of sectors. Additionally, the flow-on effects of impacts and vulnerabilities in one sector leading to consequences for other sectors was often mentioned. Similar to the differences in sectoral perspectives, these inter-sectoral linkages and interdependencies were likewise seen as contributing to the complexity of the climate vulnerability issue and were another reason cited for the need for governance leadership. One group mentioned the need for "taking leadership to bring together different stakeholders to seek common purpose" while other groups noted "everything is dependent on everything" and "vulnerability is more complex than we tend to think".

Issues related to the **workforce and human resources** ("inability to attract and retain people"), **infrastructure** ("previous design/specs versus future conditions") and social and **community perceptions and impacts** ("socially – everyone's affected"), were similar to those mentioned within the sectoral group discussions summarised above. These were often related to a broader range of adaptation challenges or barriers, such as the need to "figure out what climate change actually means practically to operations", which is also related to the need for specific and relevant information, and to be "innovative and creative" in dealing with the potential challenges under conditions of uncertainty and limited funds.

Another issue occasionally cited, typically in terms of a challenge to adaptation, was that of **time**. This included the view that "different (sectoral) perspectives (of) timelines" could exacerbate vulnerability. The time potentially wasted "waiting for government" to show leadership was contrasted with the capacity for early organisational leadership which could reduce the transition time to a more resilient condition.

Summary of the likely vulnerability of the mining industry and community to climate change
Reviewing responses to all the vulnerability questions, including the inter-sectoral session, a number of key themes are apparent. These are:

- economic factors – supply and demand, costs, risks and returns;
- government – policy, leadership, funding;
- societal, community and environmental issues – expectations, pressures, behaviours and impacts;
- workforce and human resources – labour supply, skills gaps and health and safety;
- infrastructure, technology and technical concerns;
- managing scarce resources (mainly water and energy); and
- information and knowledge needs.

As is the case across society, the place of economic factors, government policy and community expectations are fundamental to climate change vulnerability and adaptive capacity within the mining industry and its associated stakeholder groups. In addition, it is evident that the availability of a range of 'resources', broadly defined, that support mining businesses and communities, such as water, energy, labour, infrastructure, technology and knowledge, will be critical considerations. Considering the important role that mining plays for the GE region, the impacts of future climate variability and change on these 'resources' have implications beyond the mining value chain. Specifically, the relationship between local populations and workforce availability, implications of climate change for mining and public infrastructure, and the need for quality information to inform decision making regarding adaptation options, illustrate the deeper connection between mining and communities in the GE region.

Industries, services and communities dependent upon mining are vulnerable should mining suffer from climate change and similarly, mining may suffer if these groups were not there to support them due to non-adaptation. Sufficiently adapted and maintained infrastructure such as roads, railways, water and power would reduce both mining and its communities' vulnerability to climate change just as technical and technological solutions would assist with adaptation and reduce vulnerability.

Importantly for future strategic and collaborative adaptation planning, the major issues were mentioned by all of the sectoral groups, although their prominence differed depending on perspective. For example, the themes that tended to recur across the various questions for the **mining sector** were issues around economics, managing scarce resources, technical and production concerns, and the workforce. These themes can be seen as having direct relevance to the business of mining. In contrast, the **governance** groups continually emphasised government leadership, policy and funding priorities and the societal, community and environmental issues that government bodies are tasked with managing, as could be expected. However, the governance group also consistently raised economic factors (although this typically related to government funding) and mining workforce issues, while the mining sector group often referred to societal, community and environmental issues. This emphasises that all of the dominant themes had implications for each sector, although the specific way in which they were manifested differed in each sector. Importantly, the recurrence of themes across sectors is also a reflection of the inter-dependencies between sectors, with issues in one sector having implications for others, as was emphasised in the mixed group discussions.

The findings suggest that climate adaptation in mining regions will not only require a focus on these major themes, but also that substantial interaction between sectors will be required to effectively deal with the challenges. While a fully integrated response may not be possible, due to both practical and institutional constraints, it may be beneficial for the various sectors, and for the region as a whole, to pursue multi-sector engagement, interaction and joint-planning as much as possible.

Defining the resource availability for successful adaptation

The next task for workshop attendees was to assess the availability of resources to support adaptation to the implications identified for their specific sector groups. Participants moved back to their original sectoral tables and were provided with information regarding a framework for categorising and assessing resource availability.

The framework used to assess resource availability for adaptation was derived from the sustainable livelihoods framework applied in other recent CSIRO research on community climate adaptation (Nelson et al. 2010; Park et al. 2009) and originally developed by Ellis (2000) to construct an adaptive capacity index. This framework conceptualises adaptation resources as five primary organisational assets: human, social, natural, physical and financial capital (see Table 2 for examples within a mining context).

Table 2. Description and examples of five capitals for adaptation

Resource type	Description	Indicators	Mining industry examples
Human capital	Education, skills, health	Qualified, experienced staff; labour availability	No. of qualified engineers
Social capital	Social networks & associations (claims & obligations)	Connections to other human and organisational resources; institutions; governance entities and processes; culture and heritage	Membership of mining industry associations; community organisations; connections to political figures
Physical capital	Means of production and goods derived from economic production	Infrastructure, machines, technology;	Roads, ports, energy supply lines, earth-moving equipment, mine housing
Financial capital	Financial assets, income streams, access to credit	cash, shares; profit/loss statements; lines of credit	Cash reserves; share price/ equity position; mine income
Natural capital	Land, water, vegetation	Geographic features; land area; access to water; biodiversity	Exploration leases; groundwater availability; revegetation seedstock

First, each individual was asked to think about how to define each type of capital for their sector and to individually assess the availability of each resource type in order to adapt successfully to future climate variability and change. Attendees were also asked to generate two to three indicators for each type of capital that they could use to evaluate the availability of these resources on a scale from 0 (unavailable) to 5 (full availability) on a ‘spider diagram’ template provided to participants. Sector resources were then mapped onto the ‘spider diagram’ displaying relative resource availability across the five capitals. The group then discussed their individual assessments and developed a consensus group position on the indicators and an average score for each type of capital through discussion. This consensus position was recorded by the groups on a larger version of the 'spider diagram' template (see Figure 12 for an example). Four groups were formed for this exercise: governance (combining both tables), mining industry and services, utilities, and researchers.

Governance sector

The governance group rated their resource capacity as moderate across the different types of capital, with slightly stronger ratings for social capital (Figure 12). They suggested this reflected a strong drive in government agencies to be geared towards the development of social skills and capabilities internally. They stated that human capital availability varied between agencies, with some having much more capacity than others.

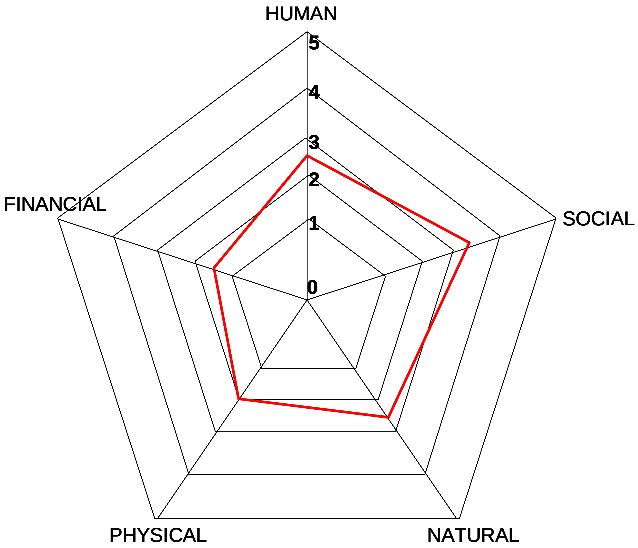

Figure 12. Spider diagram produced by the Governance sector group where '0' represents unavailability of a resource type and '5' represents full availability.

With regards to natural capital, the group again selected a moderate value because while most agencies are not overly reliant upon natural capital to fulfil their roles, some do work with this form of capital in the daily execution of their tasks, such as environmental and agricultural agencies. Physical capital (e.g. machinery) was rated quite low as many activities are now outsourced or outside of the domain of local agency control and therefore must be contracted back in. Financial capital received the lowest rating by this group, because although it was mentioned that "governments have all the money", they noted the difficulty in gaining funding for specific local projects. This group did not identify key indicators for each type of capital.

Industry sector

The key finding from this sector's discussion was that even within companies individuals with different roles had different opinions, as did other industry and mining services members. Those in management positions identified that they have to think about adaptation from two points of view: existing businesses and new businesses. It was suggested the latter of these would be easier to adapt than existing businesses because of the sunk cost of deployed infrastructure and technology. In contrast, those consultants present felt they were able to view adaptation from one view point on behalf of a client. Figure 13 thus displays a range of resource positions for the sector.

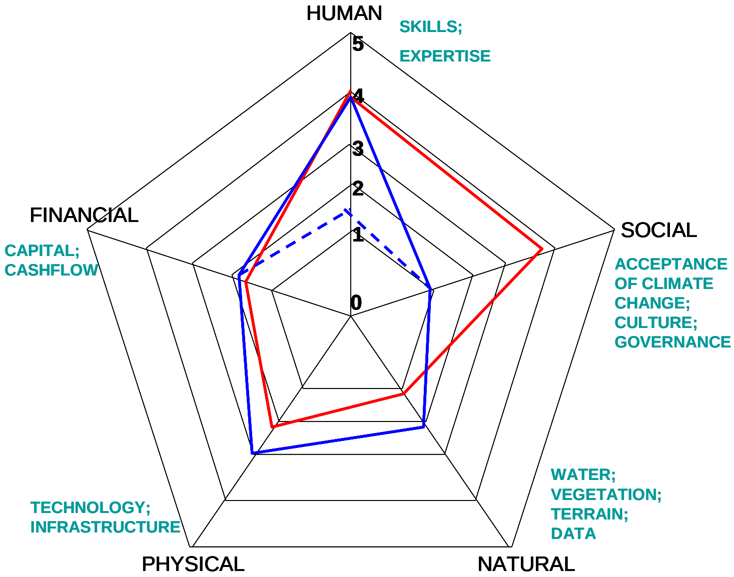

Figure 13. Spider diagram produced by the Industry sector group (blue line: industry [general expertise]; blue dotted line: industry [specific climate adaptation expertise]; red line: consultants to industry).

It was agreed that there is sufficient human capital in both industry and consulting although some parts of industry may lack the sufficient skill sets to follow through with adaptation. In regards to social capital, they reported that consultants are suited to the work of climate change adaptation as their skill set is geared towards social interaction and engagement: a key route to action on adaptation. However, it was felt that industry presently lacks the requisite business structure and culture to drive the concept of adaptation forward, as reflected by the lack of acceptance of the issue in many parts of industry. Natural and physical capitals for both groups were identified as moderate to low and focussed on water, vegetation, terrain and data, as well technology and infrastructure. Financially, it was reported there is a general lack of cash-flow and capital to drive climate change adaptation, particularly for existing mining operations.

<u>Research sector</u>

The research group could not reach consensus on four of the five capitals as each institution represented had a different set of needs and perspective on adaptation in the mining industry (Figure 14). They also suggested that by "…influencing one of the aspects (capitals) you can then change one of the others" and that there is a strong connection between the capitals. Human capital was rated relatively strong and they suggested that people's skills and numbers of people available would be key drivers/indicators.

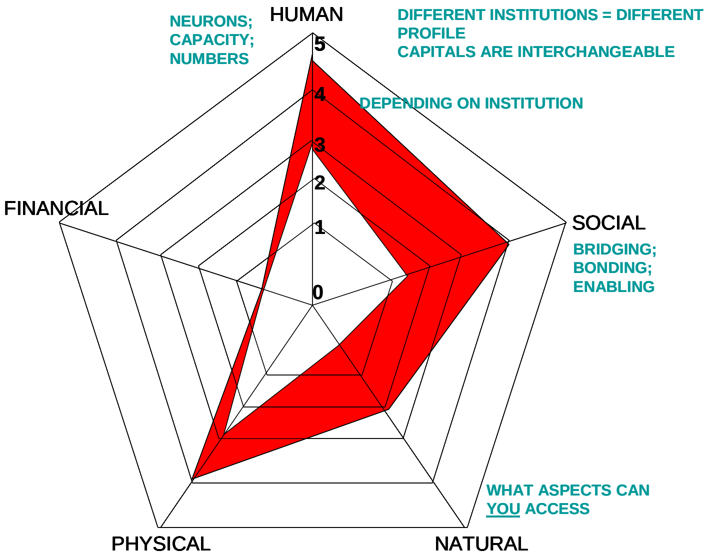

Figure 14. Spider diagram produced by the Research sector group (coloured area represents variation in group members' scores for each capital).

Financial capital was identified as a particularly weak area for all research institutions, while physical capital was identified as being relatively strong. The research group felt social capital was mainly related to bridging, bonding and enabling of people in order to meet the requirements for climate change adaptation. Finally, from a natural capital perspective, the group felt this depended on physical access to different forms of this capital to deploy for adaptation and that this was a contextual question.

Utilities sector

The utilities sector group included power and water providers for the region. Their responses suggested they do not see a particular capital as either lacking or leading, although social and natural capital were the least available relative to the other capitals discussed (Figure 15). Human resources or skills were seen as being somewhat available with skills and being able to work together considered the main drivers for adaptation. Social capital was seen as fairly weak and community engagement was suggested to be the way forward in this area. From a natural capital perspective, also seen as somewhat weak, the utilities companies identified that distance from water source and connection to renewable energy may be of significance.

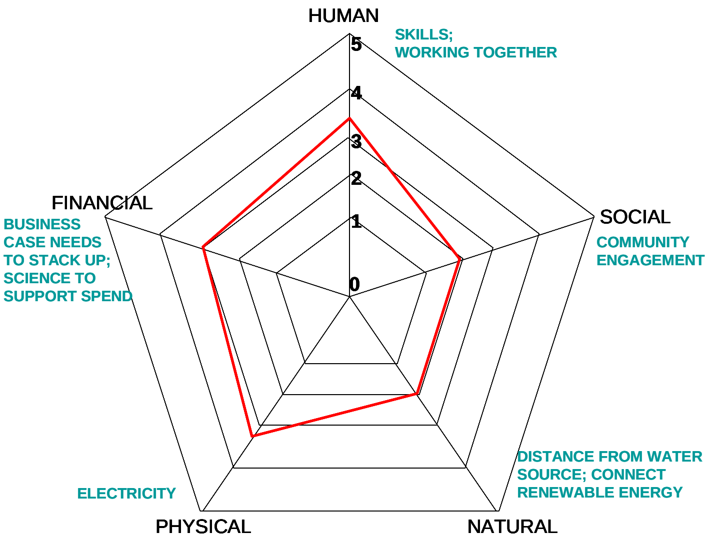

Figure 15. Spider diagram produced by the Utilities sector group

Physical capital was identified as being stronger but electricity was identified as a primary concern considering the climate change implications discussed by this group (e.g. lower transmission efficiency under hotter and drier conditions, capacity increases due to population growth). Finally, financial capital was moderately strong although it was noted that for a business case to be accepted by regulators and investors (e.g. expansion or increases in costs) it must be supported by science, as without credible data the money wouldn't be made available for adaptation to take place.

Summary of findings

Overall, vulnerability to climate change and adaptive capacity were viewed within a **broader context** dominated by economic, regulatory and societal pressures that affected each sector's prosperity or functional capacity. Alongside these pressures were a range of resource constraints, such as water, energy, labour, technology and infrastructure that impinged on the capacity of the various sectors to achieve their goals.

Looking at the **impacts of projected regional climate change** more specifically, the main areas of concern were: use of scarce resources (principally water and energy), impacts on environment and community, hazards and workforce issues, infrastructure impacts, and mine planning and design. It is apparent here that a major concern about climate change is its impact on the various resource constraints that currently impinge on sectoral capacity. For example, as heavy rain and intense heat can cause both down time and long-lasting effects on mine equipment and staff, participants identified that processes and affected equipment would require adaptation. Additionally, effects on recharge to water resources would be of concern to those in the region who use dams and groundwater so real time data on rainfall, recharge and evapotranspiration would be of benefit. The increasing need for cooling people and equipment would impact on energy use and costs, both within and external to mines and its operations. Also, external and critical infrastructure such as power lines, water pipelines and roads have been known in the past to suffer from extreme weather events which may become more prevalent in the future.

With regards to **factors that influence vulnerability to climate change**, most groups again identified access to key resources such as water, energy infrastructure, funds, labour and knowledge as being critical. In addition to these, the issue of leadership was viewed as an important factor in enabling future action. Specifically, the need for a political resolution and government policy direction to provide impetus for action across society was emphasised. It was apparent that participants felt that, without a definitive policy direction, as represented in legislation and regulation for a collective national response, and lacking credible information, some organisations will find it difficult to justify allocating resources to take action. Although mining companies may be considered less dependent upon government leadership to take action than other sector organisations, they are similarly dependent on good information.

Other important factors influencing vulnerability to climate change included: the costs, risks and returns associated with adaptation measures; societal expectations that tend to influence government policy and regulation; and the connections between issues and dependencies between sectors that lead to cumulative and/or compounding knock-on effects.

Despite many apparent constraints to action, it was recognised that organisations can be proactive on some issues that would currently provide benefits, such as improving water and energy use efficiency. For mining companies, although it may be easier and less costly to bring 'adapted' methods and processes to new mines than to existing mines, adaptation of the latter may still be effective for health and safety, community and environmental aspects.

Turning to **specific measurable indicators of climate vulnerability**, the dominant measures suggested by participants were economic indicators, infrastructure capacity measures and social indicators. Other measures included mine production figures, natural resource levels, climatic conditions and workforce metrics. The types of indicators suggested differed significantly by sector however, which suggests that at this level of vulnerability assessment quite specific measures are required according to the type of operation or organisational function.

In **the cross-sectoral discussions of vulnerabilities**, both the divergence of perspectives and similarities of concerns between sectors became more apparent. The orientation of each sector or stakeholder group to their particular business or function was recognised, such as the production and business focus of mining companies, and broader community or 'public good' focus of the governance groups. However, also apparent was the similar dependency of different sectors on common resources (e.g. water) and influencing factors (e.g. government policy), and of the inter-dependency between sectors. The flow-on effects of impacts and vulnerabilities in one sector leading to consequences for other sectors was recognised as having far reaching consequences. Both the differences and interdependencies between sectors contribute to the complexity of the climate vulnerability issue.

In relation to the issue of **resources available for adaptation,** it was apparent from the 'spider diagram' assessments that although there may be sufficient human capital capabilities generally across the sectors, lack of balance in the other capitals may need management and collaboration. Requirement for the different capitals within each sector will depend upon the specific nature and scope of adaptation activities required by the particular sector. This highlights the importance of assessing both vulnerability and adaptation strategies, as it is really the latter – "what needs to be done" – that determines the resources or capitals that need to be applied.

It was apparent that the different capitals are interrelated, for example social capital can enable access to, or influence behaviour that may reduce the need for other capitals; while financial capital may be able to purchase some of the others outright, such as skilled labour (human), water and land (natural) and machinery and technology (physical capital). This flexibility of capital use means that some organisations have considerable capacity to change the balance of capitals they hold in order to address different types of tasks, which is important for adaptation. However, while different capitals may be transferred or rebalanced internally within an organisation, the key to regional adaptation may be to enable this to occur between different organisations or sectors. For example, it was mentioned that in some places there are already agreements in place between mining companies and local government authorities to share resources or undertake specific tasks for one another. Proactive planning to determine the types of capitals available in a given region and agreements on how they could be shared to adapt to a changing climate would therefore appear beneficial.

Discussion and Conclusion

Through the appraisals of both the broader context that influenced sectoral prosperity as well as the various factors that influence their vulnerability to climate change, it was apparent that policy leadership (government and/or corporate) regarding climate change; 'credible', situation-specific information; and, access to key resources were considered the main ingredients required to instigate preparations for climate change by organisations within the region. Current uncertainties around future government climate policy as well as what climatic conditions will actually eventuate in the region, and therefore what this will mean to individual organisations, were viewed as undermining decisive adaptation responses. While it was mentioned that addressing some issues, such as improving efficiency and security of future water and energy supplies would be beneficial to the region regardless of climate change, it was apparent that other areas such as preparing for more extreme weather events are reliant on convincing high level decision-makers that these measures are necessary.

Regardless of high-level leadership and perceptions of information credibility, a further major constraint affecting vulnerability and adaptive capacity was identified in access to key resources such as water, energy, funds, skilled labour, infrastructure and technology. The review of the resources available to enable adaptation in the latter part of the workshop organised these according to the five different types of *capital*. Apart from funds, which may only require authorisation by an organisation's high-level decision-makers to supply, many of these resources may not be readily accessible. Security of essential water and energy supplies, including the infrastructure that underpins them, typically relies upon cooperative action between multiple sectors (different levels of government, utility providers and mining organisation) to develop agreements around supply, demand and price. The availability of appropriately skilled labour, expertise and technology may be constrained by competitive factors (multiple mining developments at the same time) or a lack of specific training and knowledge in the existing labour market and institutional arena (e.g. mining companies, education and research organisations and consultancies may simply lack the experience and knowledge to deal with, and train people for, the new conditions and situations arising). Additionally, it was noted that as climatic conditions changed, people may be less inclined to work in remote inland areas, or due to extreme events, may be unable to access these areas due to disruptions to transportation. For both the security of essential resources and access to skills and technology, supply lags may be considerable. This issue was identified by a number of participants who mentioned the importance of time as an issue in relation to adaptive capacity, particularly with regards to the 'time to transition' compared to the speed at which climate change is taking place.

The issue of access to scarce resources points to the dependencies between sectors, although there were many other examples of common reliance on resources and of 'knock-on effects', as vulnerabilities and adaptation responses in one sector impacted on other sectors. In particular, the discussion about the five capitals underpinning adaptive capacity highlighted commonalities in resource reliance; as well as the possibilities and constraints to sharing capitals between sectors and organisations, and the capacity for behaviour change in one sector to influence vulnerability in others. Another example of interdependency was that of utilities companies regulated by government. Utilities may find it difficult to justify costs for adaptation measures to their regulators and it was suggested that higher government leadership on climate change would greatly assist them in making their case. Further, if communities that surround mining operations are slow to prepare for climatic change (or vice-versa) it may be difficult for the forward thinking mining companies (or communities) to get the other to buy-in to their own plans, increasing the vulnerability of both. These interdependencies also suggest a mix of bottom-up and top-down leadership would appear important to create effective change.

A final issue that merits discussion is the evidence here that climate change, in affecting fundamental aspects of operations (energy, water, infrastructure, labour etc), may usefully be constructed partly as a matter of interconnected business risk assessment and management. In this framework, first, climate adaptation is not simply a 'green' environmental or sustainability issue but, as suggested by Rogers (2010:14), encompasses, and may be best communicated as, an issue of "risks, costs, service continuity, duty of care, liability, insurance and… reputation". Second, interdependent organisations are best served by broadening their individual risk assessment processes to encompass a collaborative approach to adaptation as part of their normal management plans.

However, an orientation to risk management should not blind organisations to opportunities to capture any benefits or strategic advantages that arise from climate change. Adaptation and resilience is more than just risk management as it derives from capitalising on opportunities as well as dealing with threats. Overall then, climate adaptation planning may be most effectively implemented through being embedded in the normal risk and broader management planning of the organisation, rather than being a separate 'add-on' to these core activities. Finally, acknowledgement needs to be given to the many uncertainties that still exist around our knowledge of what the exact climate, and therefore, risk (and opportunity) parameters will apply in the future and the likelihood that these will shift over time as our knowledge develops (White and Etkin 1997).

Conclusion

The Goldfields-Esperance region is currently a prosperous mining community. Nevertheless, the mining industry upon which it depends faces a range of future challenges including climate change. In the Goldfields-Esperance region, the climate is expected to become warmer and drier with increased incidence and severity of extreme weather events. These changes are expected to pose a range of challenges to the region in terms of water, energy, infrastructure, human resources and mining-community relations. Dealing with these issues will require careful assessment of vulnerabilities, opportunities and adaptation options by individual organisations. The greatest value for the region will be achieved through engagement processes that integrate climate adaption planning across a broad range of regional stakeholders.

The workshop reported here is an important step along the adaptation journey and has provided valuable information on perceptions in the mining sector of this region. Additionally, the workshop brought together multiple stakeholders in this mining region, including up- and down-stream providers, users and governance bodies, to build knowledge of expected local climate change, share ideas and concerns, and develop relationships.

This report is the first of a series of regional CSIRO reports in addition to being the first report for Australia that specifically focuses on perception, attitudes and adaptation requirements for and within the whole of the mining value chain. The workshop has identified some major aspects of climate vulnerability in the Goldfields mining region, from a range of sectoral perspectives. The results have provided an insight into the broader contextual drivers of future sectoral development, specific climate change impacts expected or perceived, factors that are likely to influence sectoral vulnerability, and specific, measurable indicators of vulnerability for each sector. Importantly, it has illuminated many of the cross-sectoral vulnerabilities and interdependencies that exist. In addition, the examination of the capacities of each sector in terms of the five capitals, together with the adaptation challenges and options identified in the course of this vulnerability analysis, has increased our knowledge of the adaptive capacity of the region.

A key finding that is common across both the vulnerability and adaptive capacity sessions was that while there were differences in sectoral vulnerabilities, needs and capacities, the sectors were bound by inter-dependencies. Not only were different sectors largely influenced by similar issues, with economic conditions, government policy, and societal pressures chief amongst these, but climatic impacts in one sector appeared likely to have significant implications across most other sectors. This would suggest that it will be beneficial for different sectors to pursue communication, interaction and joint-planning as much as possible. While a fully integrated response may not be possible, or desirable, due to both practical and institutional constraints, a central and engaged regional organisation would seem well placed to facilitate an optimally integrated approach into the future.

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