



# Climate adaptation in regional mining value chains

A case-study of the Goldfields-Esperance Region, Western Australia

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Goldfields Environmental Management Group (GEMG)



## Climate Adaptation Flagship

CSIRO Earth Science and Resource Engineering

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Source: Photo: Barton Loechel

# Executive summary

Climate change poses a potential range of threats and opportunities for mining regions around Australia. Recent studies have suggested that mine operations as well as the related infrastructure, businesses and communities associated with mining, may be affected by flooding, drought, bushfires, storms and sea level rise.

Western Australia's Goldfields-Esperance (GE) region is an important mineral province for Australia, contributing an estimated \$12 billion of Gross Regional Product in 2010-11. The regional mining value chain, which also supports mining activities in the adjoining Mid-west and Wheatbelt regions, supplies a range of mineral products, notably gold, nickel, base metals such as copper and zinc, and iron ore to both domestic and overseas markets.

This case-study, supported by the Chamber of Minerals and Energy and the Goldfields Environmental Management Group, sought to identify the implications of climate change for the Goldfields-Esperance regional mining value chain.

A mining value chain approach focuses on the linkages between sectors and how impacts flow from one area to another, providing a holistic and integrated understanding of the regional mining system.

Our analysis used a moderate-emissions scenario for future climates. Under this scenario, climate change projections for the Goldfields region suggest that from a 1990 base level, temperatures will continue rising to be between 0.6 to 1°C warmer by 2030, but that annual rainfall will decline by between 5-7%, particularly over the April-October period.

The project methodology involved desktop research and data gathering, development of regional mining system maps to aid discussion, interviews with a broad range of regional mining value chain stakeholders, and a workshop to test preliminary findings and extend understanding of inter-sectoral impacts and pathways to adaptation.

The results identify key vulnerabilities and opportunities for critical mining value chain components or sectors, the 'spill-over' effects or 'cascading impacts' between them, and potential adaptation options.

All sectors involved in this study will potentially be affected by climate change, with a clear seasonal effect associated with the declining incidence and severity of winter storms but an increase of summer storms.

Likely impacts include:

- Restraints on potable water supply from south-west Western Australia (SWWA) due to the winter drying effect but greater local opportunities for fresh water capture in summer
- Improved stability of electricity supply in winter but greater instability in summer associated with the shifting seasonal incidence of storms
- Similar shifting seasonality of disruptions to road transport and mine production from rainfall events and to port operations from storms
- Generally detrimental changes to the natural ecology of the region (from drier winters, hotter and wetter summers, and consequent bushfires), and
- Changes to the liveability of the region with milder winters but hotter and wetter summers.

The most common spill-over or cascading impacts that were identified were the effect of damage or disruption to 'upstream' components of the supply chain, such as water, energy and transport, on mining productivity and viability. These impacts then affected other components of the chain, notably human resources (employment), the environment, and community liveability. It was also apparent that impacts on sectors lower down the supply chain, such as ports, can have ramifications for upstream sectors. Spill-over effects between sectors at the same level of the supply chain, notably between water and energy supply, cascaded on to affect other sectors such as the community.

The research identified a range of factors affecting effective adaptation as well as key elements of desirable ('win-win', 'no-regrets') and dysfunctional ('win-lose', 'high-regrets') adaptation options.

Difficulties or barriers to effective adaptation included:

- Problems justifying, sharing and full accounting of the costs associated with adaptation
- Uncertainty about the nature of climate change impacts, especially with regard to the investment horizon of mines
- Organisational cultural attitudes to learning and change, and
- Inflexible company policies and/or government regulation.

One of the most difficult questions to answer is how costs can be shared equitably by the various stakeholders who stand to gain or lose from the implementation of adaptation measures. For example, improving water and energy supply security in the region, or improving the resilience of the transport system, has benefits for multiple groups; however the primary organisation responsible for the sector or subsector may not wish to bear the full costs because they have little way of ensuring others who benefit will share those costs. This suggests that careful attention needs to be placed on achieving institutional arrangements that align incentive structures to make it worthwhile for sectoral players to undertake adaptation measures.

**Key recommendations** for facilitating viable pathways to climate change adaptation in a regional context were identified as:

- Develop institutional arrangements that create appropriate incentives and cost sharing for adaptation
- Improve or import the expertise to identify and assess available adaptation options
- Continue education and awareness raising in organisations and communities
- Strategies that improve work culture attitudes to learning, change and regulatory compliance
- Strategies that promote organisational leadership on adaptation and sustainability issues
- Prioritise engagement and consultation at all levels to achieve responsive and flexible management strategies and government regulation around climate adaptation, and
- Ensure continual improvement of adaptation strategies through ongoing monitoring, evaluation and review.



# 1 Introduction and background

Climate change can be an important driver of social, economic and environmental change in regional areas of Australia and poses a range of threats and opportunities to the mining industry (Hodgkinson et al 2010; Loechel et al 2013). Western Australia's Goldfields-Esperance (GE) region is an important mineral province for Australia, contributing an estimated \$12 billion of Gross Regional Product (GRP) in 2010-11 (GEDC 2013). Minerals production accounted for about 70% of this, equating to 9% of Western Australia's minerals and petroleum value (DMP 2013).

Previous work by CSIRO investigating the likely impacts of climate change on the Goldfields-Esperance mining region (Loechel et al 2010) identified a range of potential impacts. Impacts were identified in the energy, water, transport, human resources, environment and community sectors. Further, one of the key messages from this work was that many impacts were likely to cross sectoral boundaries, flowing from one sector to another.

This mining value chain study arose out of a desire to gain a greater understanding of the cross-sectoral impacts identified in the 2010 workshop and to explore potential adaptation options. Exploration of the climate change impacts across the regional mining value chain, and tracing the linkages and cascading impacts between different components of the mining industry, will be valuable in identifying viable pathways for future climate change adaptation.

The mining value chain is conceptualised broadly and includes a range of organisations and sectors important to the conduct of the resource industry in the region including: mining companies, mining service providers, utility and infrastructure providers (e.g. water, power, ports), local and/or state government agencies and community groups, and the surrounding natural environment.

The project area generally encompasses the geographic region covered by the Goldfields Esperance Development Commission (GEDC) (see Figure 1). However, sites outside this boundary, such as those parts of the Northern Goldfields located in the Mid West Region and iron ore projects near Southern Cross in the Wheatbelt region, have been included for consideration as warranted by their practical relevance to the regional mining value chain.

It is envisaged that the outputs of the study will provide a sound basis for more detailed and comprehensive assessment by individual organisations of their own specific climate-related vulnerabilities and adaptive capacities, within a broader regional context. Likewise these outputs will provide the basis upon which coordinated climate adaptation planning for the region can occur. In addition, a better understanding of the regional mining value chain adaptive capacity can be expected to contribute significantly to the G-E region's broader objective of sustainable development.





Figure 1 Goldfields-Esperance region area of study

Source: [www.gedc.gov.au](http://www.gedc.gov.au)

## 1.1 Project aims

The project aims included:

- Development of a framework to assess the specific vulnerabilities and adaptation options for key sectors within the regional mining value chain
- Tracing the linkages or ‘cascading effects’ between sectors under different scenarios
- Engaging mining value chain stakeholders in order to strengthen this assessment of climate related risks and implications further, using local knowledge and experience
- Development of a regional mining value chain map scoping vulnerabilities and adaptive capacities within and between sectors across the region
- Identifying key elements of ‘no-regrets’ and win-win’ adaptation options, as well as those elements more likely to lead to ‘high regrets’ or ‘win-lose’ outcomes in a regional context
- Identification of key elements of viable pathways to adaptation, including barriers and synergies to achieving meaningful adaptation in a regional context

## 1.2 Building on previous work

A range of recent studies have investigated potential impacts of climate change on the region and have therefore provided useful background information to inform this project. These include the CSIRO workshop conducted in 2010 mentioned above, the Indian Ocean Climate Initiative project Stage 3 (IOCI3), a number of studies examining impacts of climate change on regional ecosystems, and a community water supply study.

### **1.2.1 THE CSIRO-GEDC GOLDFIELDS-ESPERANCE REGIONAL MINING CLIMATE VULNERABILITY WORKSHOP**

In 2010, CSIRO held a regional Mining Climate Vulnerability workshop in association with the Goldfields Esperance Development Commission (GEDC) (Loechel et al. 2010). This workshop presented climate change projections to mining stakeholders and value chain representatives in the region and enabled discussion of potential impacts.

Some of the major areas of vulnerability for the region identified in the workshop included: availability of scarce resources (principally water and energy); impacts on environment and community; hazards and workforce issues; infrastructure impacts; and mine planning and design. 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 inter-dependencies between sectors that lead to cumulative and/or compounding knock-on effects across them.

Key adaptation needs identified by participants in the 2010 workshop included:

- Access to relevant, specific and credible information, particularly that related to:
  - future availability of critical resources (e.g. water and energy)
  - future operating conditions for infrastructure, equipment and personnel
- Knowledge and expertise relating to adaptation methods and technologies
- Funds to support adaptation; and
- Commitment and policy direction by government to provide impetus for action across the mining value chain, regional communities and society more broadly.

While there were differences in sectoral vulnerabilities, needs and capacities, the various sectors were bound by similar issues. The main issues common across sectors were dependence upon critical infrastructure and resources, economic conditions, government policy direction, and societal expectations. With climatic impacts in any one sector likely to have significant implications across most other sectors, it was apparent that it would be beneficial for the different sectors to pursue open communication, interaction and joint-planning as much as possible.

### **1.2.2 THE INDIAN OCEAN CLIMATE INITIATIVE STAGE 3 PROJECT - (IOCI3)**

The Indian Ocean Climate Initiative (IOCI) is a partnership between the Western Australian Government, the CSIRO and the Bureau of Meteorology, to support informed decision-making on climate variability and change in Western Australia (IOCI 2012). It aims to provide state-of-the-art, regionally specific knowledge of both past and projected climate trends in WA to policy makers and other stakeholders to support climate adaptation in the state. Stage 3 of the Initiative (IOCI3), completed in 2012, performed analyses that partly encompass the Goldfields-Esperance region. The key study areas for IOCI3 focussed on south-west Western Australia (SWWA), basically the area south-west of a line approximately from Esperance to Northampton, and north-west Western Australia (NWWA) (the Pilbara and Kimberley regions). While most of the Goldfields-Esperance region lies to the north-east of SWWA and south-east of NWWA (Figure 2), the IOCI has nevertheless provided a fundamental level of understanding of the climate systems influencing the whole of the state. In addition, references in the study to 'Inland' regions and weather station data in the Kalgoorlie area are specifically relevant to the Goldfields region.



Figure 2 The key study areas for IOCI3 as indicated by red lines

Source: IOCI 2012

### 1.2.3 THE IMPACT OF CLIMATE CHANGE ON REGIONAL ECOSYSTEMS

Recent ecological analyses have evaluated potential outcomes of climate change for ecosystems of the Great Western Woodlands (Prober et al. 2012) and Hummock grasslands (Smyth et al. 2013), both of which overlap substantially with the Goldfields-Esperance region. Various modelling approaches suggest biota in both areas will be subject to high levels of environmental stress under moderate to high emissions climate scenarios.

One of the greatest risks relevant to mining activities identified by these studies was a high likelihood of increasing bushfire under scenarios of increasing summer rain. Summer rains are likely to increase the growth of summer grasses (including invasive exotics such as buffel grass, *Cenchrus ciliaris*), resulting in more continuous ground fuels and potentially hotter and more frequent fires. This could result in catastrophic fires that could transform eucalypt or Mulga woodlands to grassland or shrubland. The potential persistence of woodlands was also expected to decrease under more extreme scenarios of rainfall decline (potentially influencing liveability in the region). At the same time, mining-related activity was recognised as potentially reducing the resilience of native ecosystems to climate change. Potential impacts include exacerbation of fire risk through increased ignitions and facilitation of exotic grass invasions, and exacerbation of moisture stress through altered hydrology (e.g. associated with roading or water management).

## 1.2.4 STUDY OF RESILIENCE AND WATER SECURITY IN OUTBACK CITIES

Another relevant community water supply study (Albrecht et al 2010) investigated the views of the residents of Kalgoorlie regarding the future (year 2070) of the town and region under different scenarios. The scenarios incorporated a number of variables, notably climate change, mining industry prospects, government interventions and technological development. The study found that residents had a generally optimistic view of the future of the region, believing that while water supply may become more restricted, advances in technology would solve many of the problems a changing climate may bring. The study contrasted the situation of Kalgoorlie with that of Broken Hill and suggested that the culture of optimism that tends to pervade the mining sector can result in resistance to serious consideration of climate adaptation issues.

## 1.3 The Goldfields-Esperance region

The Goldfields-Esperance (GE) region is vast in area (771,276 km<sup>2</sup>) covering just under one third of Western Australia's land mass and has a diverse ecology, encompassing desert, temperate eucalypt woodlands and coastal national parks.

It is the largest of Western Australia's nine regions and over three times the size of the state of Victoria. The GE region is bounded by the Pilbara Region and Gibson Desert to the north, the Wheatbelt and Mid-West regions to the west and north respectively, the Great Southern Region to the south-west, the Southern Ocean and the Great Victoria Desert, the Nullarbor Plain and the South Australian border to the east (Figure 3).

The region's population is approximately 57,500 according to the 2011 Census (ABS 2013) and is projected to rise to 62,200 by 2026 (GEDC 2012). The regional population is predominantly located in the major towns of Kalgoorlie-Boulder and Esperance, with the remaining population being situated in many smaller, rural and remote towns and settlements in the region. In 2011, 5,328 people identified themselves as Aboriginal, representing 9.3% of the total regional population (ABS 2013). The dispersed and remote population centres can create challenges for provision of services and coordination of planning to attract investment for infrastructure (GEDC 2012).

In 2011, the largest employer was the mining industry, which employed 27% of the region's workforce followed by retail trade (7.5%) and manufacturing (7.1%). Construction, health care and education were the next most significant employment areas (6.8%, 6.5% and 6.4% respectively). Minerals account for 71% of gross regional product. In 2011-12 this equated to \$9.2 billion in value and represented 9% of Western Australia's minerals and petroleum value (DMP 2013).

The region is characterised by a wide range of vegetation types, varying as rainfall declines from the south-west to north-east, and with more localised soil patterns (Beard 1990). Diverse, fire-prone scrub-heath and mallee-heath predominate in the more coastal, south-western parts. These are adjoined to the north by mosaics of eucalypt woodland, shrubland and mallee of the globally significant 'Great Western Woodlands'. These include some of the largest tracts of the world's remaining temperate woodlands, and over 25% of Australia's eucalypt species (Watson et al. 2008). The Great Western Woodlands are bound to the north by the 'Menzies line', where eucalypt woodlands give way to the *Casuarina* and *Acacia* (particularly Mulga, *A. aneura* sens. lat.) woodlands and hummock grasslands (*Triodia* spp. or spinifex) that characterise the northern parts of the region. The hummock grasslands may also support scattered eucalypts, particularly *Eucalyptus gongylocarpa*. The region also includes chenopod shrublands of the Nullarbor Plain (Beard 1990).

Only the south-western parts of the region have been cleared for intensive agriculture, with resultant fragmentation and degradation of native vegetation. Extensive pastoralism is the more predominant agricultural landuse, influencing the condition of many of the chenopod shrublands, *Acacia* woodlands and eucalypt woodlands. While in the early years of the mining industry significant areas of the Great Western Woodlands were cut for timber (3 million of the total 16 million hectares (19%) of the GWW is estimated to have been cleared) much of this area has since recovered to varying degrees (DEC, undated). However,

significant areas of woodland, mallee and shrubland have remained largely unexploited for livestock grazing, agriculture or timber, and are globally significant from a biodiversity conservation perspective (Watson et al. 2008).

The region's landscape includes long, shallow salt-lakes, gentle hills and low ranges with gum woodlands on the Kalgoorlie Plain through to treeless plains and flat, arid topography in the Nullarbor, and low-heath remnant vegetation with salmon gum and Wheatbelt plateau (cropping and livestock) on the Esperance Plain. Additionally, the Meekatharra Plateau, characterised by gently undulating plains, and low, rugged ranges and hills has a diverse vegetation mix, whilst the deserts north of Nullarbor and east of the Meekatharra plateaux have linear sand ridges, hummocky grass and Spinifex (Western Australian Planning Commission 2000). The greatest proportion of land in the region is described as being for 'other minimal use', with other uses including grazing, cropping, nature conservation, water bodies, some forestry, mining and urban use.

Geologically, there are five main geological and structural units: the Yilgarn Craton is the oldest and consists of Archaean age granite, gneiss and volcanic and sedimentary rocks; the Musgrave Block and the Fraser orogen are of both metamorphosed and unmetamorphosed sedimentary and volcanic rocks of early to mid Proterozoic age; the Officer Basin of relatively undeformed and unmetamorphosed sedimentary rocks of Proterozoic to Mesozoic age; and the Eucla basin comprising of limestones of tertiary age. During the humid Cretaceous period, deep, chemical weathering of soils to depths of 50 metres occurred resulting in infertile soil later, during the drier Oligocene turning to a hard, laterite crust. Sand over the laterite is believed to have formed during the Ice Age 15-18,000 years ago when the climate was cool, dry and windy. In all areas, soils are typically highly weathered and lacking in nutrients, vulnerable to wind and water erosion and calcrete and laterite is common (Western Australian Planning Commission, 2000).





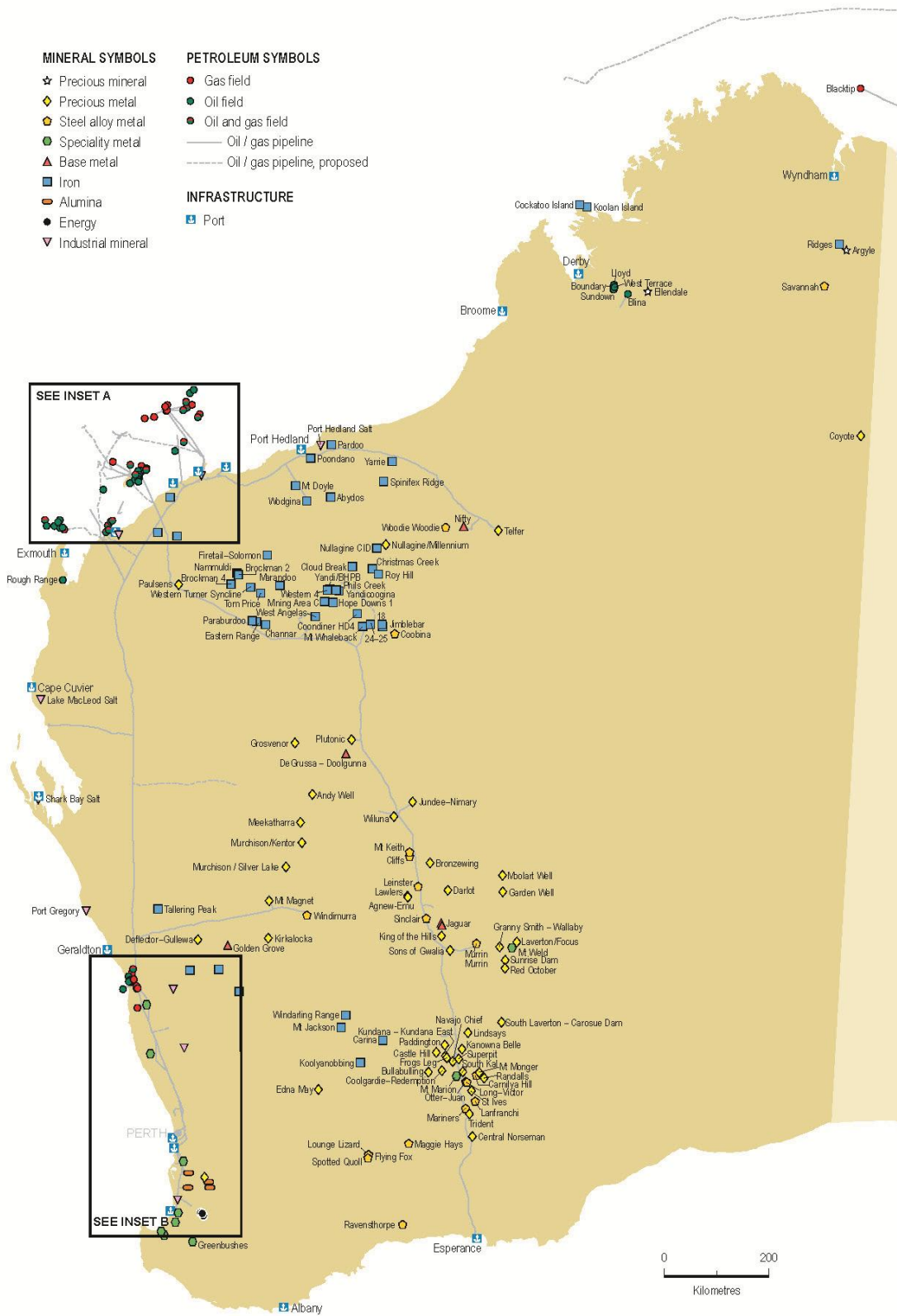
## 1.4 The regional mining value chain

The regional mining value chain includes a range of organisations and sectors that are important to the resource industry in the region. These include mining companies, mining service providers, utility and infrastructure providers (e.g. water, power, transport), local and/or state government agencies and community groups, the surrounding environment and the mineral resources it contains.

There is considerable mining infrastructure across the region, from actual mines, through to mineral processing plants, utilities and transport infrastructure.

Figure 4 displays the major mining projects in the region. The main minerals produced are gold, nickel and base metals. The adjoining Wheatbelt and Mid-west regions also produce considerable quantities of iron ore, gold and base metals (see Appendix A for location of major mining projects in these regions; Appendix B for the value of mineral commodities by region). Mineral production in these adjoining regions has relevance to the Goldfields-Esperance mining value chain because some iron ore and nickel products in particular are transported via the Goldfields-Esperance region's transport infrastructure and are also reliant on mining services located within the region.





StatisticsDigest\_2012\_11

**Figure 4 Location of major WA mining operations**

Source: WA Dept Mines & Petroleum 2011

## 1.5 The WA Goldfields' climate: past and future

The Goldfields-Esperance region's climate classification ranges from 'desert', to the north and east of Kalgoorlie-Boulder, through 'grassland', south of the city, to 'temperate' in the coastal areas around Esperance (based on the Köppen classification system; see Figure 5). As such, the northern and western areas of the region experience much hotter and drier conditions than the southern and particularly coastal areas (see Table 1).

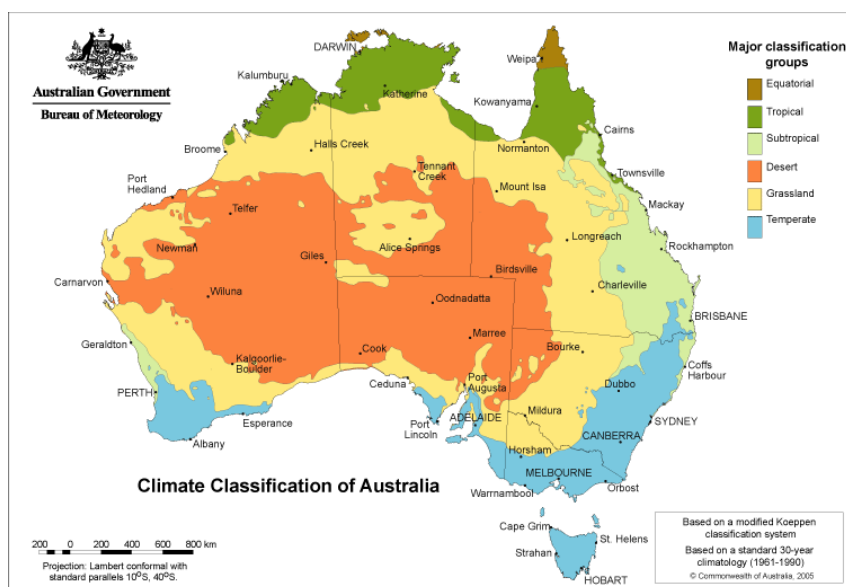


Figure 5 Climate classification of Australia

Source: BOM 2013a

Table 1 Climate statistics for different locations in the Goldfields-Esperance region

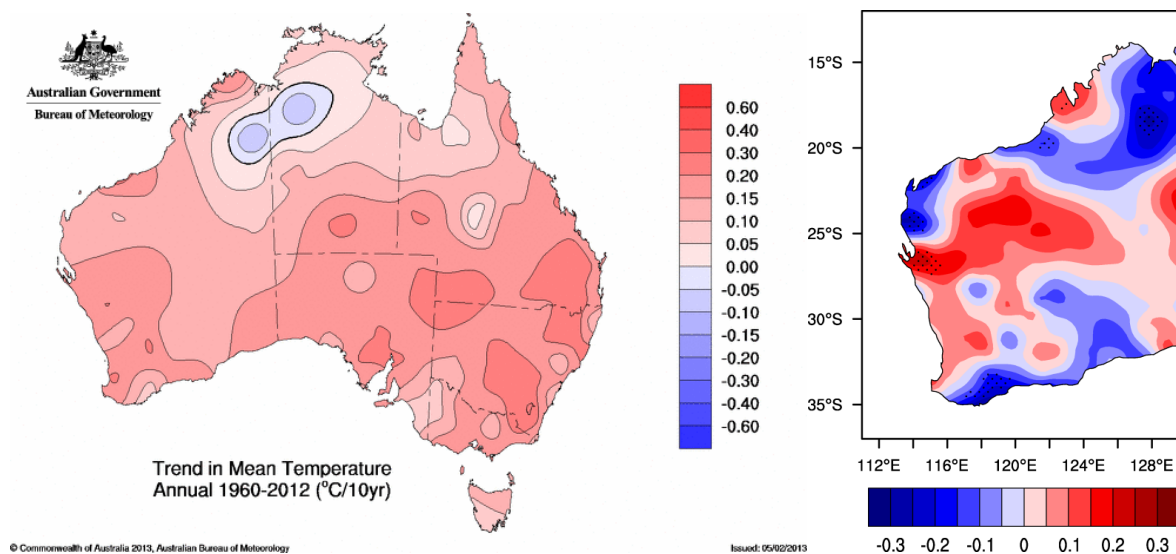
| CLIMATIC VARIABLE  | ESPERANCE       | KALGOORLIE-BOULDER                    | LEINSTER        | WARBURTON       |
|--|-----------------|---------------------------------------|-----------------|-----------------|
| Mean Maximum Temperature   | 21.9°C          | 25.2°C                                | 28°C            | 29.7°C          |
| Mean number of extreme hot days per year ( $\geq 40^\circ\text{C}$ ) | 2.5             | 9                                     | 22.6            | 34.6            |
| Mean number of frost days ( $\leq 0^\circ\text{C}$ )                 | 0               | 3.9                                   | 1.1             | 4.2             |
| Mean annual rainfall (mm)  | 618.3           | 266.7                                 | 263.3           | 249.3           |
| Seasonal rainfall pattern  | Winter dominant | Fairly evenly spread, least in Spring | Summer dominant | Summer dominant |
| Mean wind speed (km/h)   | 24.5            | 15.9                                  | 17.8            | 16.4            |

Source: Table compiled from monthly climate statistics, BOM 2013b

### 1.5.1 HISTORICAL TRENDS

#### Temperature

Similar to the annual mean temperature trend for Western Australia overall, mean temperatures in the Goldfields-Esperance region have increased around  $0.9^\circ\text{C}$  over the last 50 years (Figure 6a). However, mean maximum *summer* temperature trends have been more variable across the region over this period. While central parts of the region (roughly corresponding to the Goldfields) have warmed slightly, southern areas on or close to the coast, as well as eastern areas extending over and to the north of the Nullarbor Plain, have cooled (Figure 6b; IOCI 2012).



**Figure 6 Temperature trends in Western Australia. (a) Mean temperature trend over the period 1960 to 2012 in degrees Celsius per decade. (b) Mean maximum temperature trend December to February over the period 1961 to 2011 in degrees Celsius per decade**

Source: a) BOM 2013c; b) IOCI 2012

### Rainfall

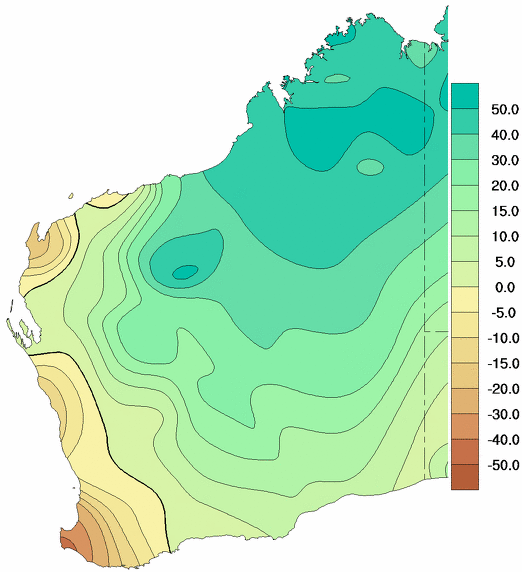
The south-west of Western Australia (SWWA), including the G-E region, has experienced a large reduction in winter and autumn rainfall over the last sixty years (IOCI 2012). This is largely attributed to increased stability of the atmosphere during this period over this area, due to changes in atmospheric circulation and thermal structure, producing a decline in frequency and intensity of winter storms (IOCI 2012). At the same time, there has been an observed southward expansion of tropical weather systems, resulting in increased summer storm activity and rainfall. The net effect for the G-E region has been a slight increase in mean annual rainfall over this period, with the greatest increases experienced in the north-eastern parts of the region (Figure 7).

### Other observations

Since the early 1990s, the southern coast of WA has experienced sea level rise in the order of 5.3 millimetres per year, somewhat higher than eastern Australia (2-3mm/yr) but lower than Fremantle (8.6 mm/yr) and north-west WA (8.1mm/yr) (McEvoy et al 2013). This represents acceleration from the historical trend, where sea level around Australia is observed to have risen about 17 centimetres between 1842 and 2002, equivalent to a rate of 1.2 millimetres per year (Church et al 2008).

As yet there have been no clear or consistent trends observed in coastal or inland wind speeds for this region (Troccoli et al 2011).

Trend in Annual Total Rainfall 1950-2012 (mm/10yr)



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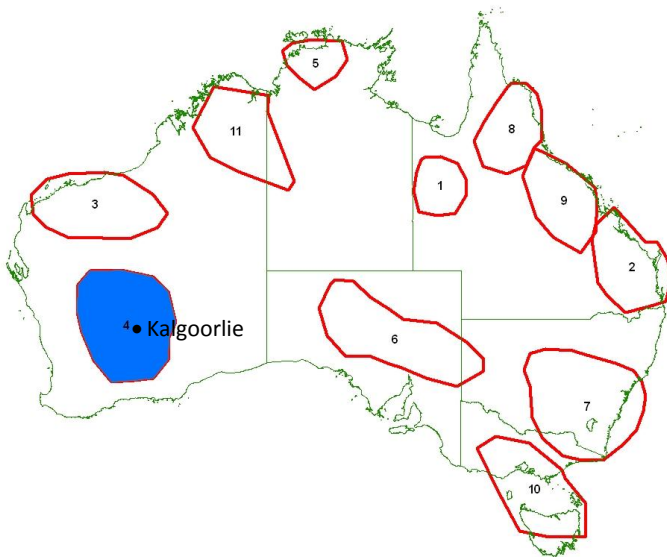
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**Figure 7 Trend in annual total rainfall of WA 1950-2012**

Source: BOM 2013c

### 1.5.2 FUTURE CLIMATE PROJECTIONS

Climate projections (changes in monthly temperatures and rainfall from a 1990 baseline) have been developed by CSIRO for 2030 and 2070 for key Australian mineral provinces displayed in Figure 8. Region 4 on this map corresponds with the main mining areas of the WA Goldfields. The regional level projections were developed using novel statistical downscaling methods (Kokic et al. 2011) utilising four of the best performing climate models for the Australian region, based on model ability to predict observed historical change. The projections are based on a single emission scenario 'A1B' representing a "middle-of-the-road" view of future greenhouse gas emissions growth (Crimp 2010).



**Figure 8 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.**

Source: Loechel et al. 2010

The specific temperature and rainfall projections for the region are displayed in Table 2. They suggest that by 2030 future climate conditions for Region 4 are predicted to be between 0.6 to 1°C warmer and 5 to 7% drier, particularly in the May-October period, compared to the 1990 baseline. While it is apparent that the projected temperature increase is a continuation of observed historical trends, the projected rainfall decline by 2030, particularly in the November to April period, is in contrast to the overall (mainly summer) trend towards wetter conditions observed in the region over the past 60 years. It is unclear whether this difference between observed and projected rainfall trends is due to the climate models underestimating the expansion of rain bearing tropical influences on the region due to anthropogenic warming, or to shorter term fluctuations in the normal climatic cycles that influence regional rainfall.

**Table 2 Projected change scenarios for temperature and rainfall in Region 4 [NCAR = National Centre for Atmospheric Research; ECHAM = Max Planck Institute for Meteorology; GFDL = Geophysical Fluid Dynamics Laboratory; HADGEM = Hadley Centre Global Environmental Model]**

| Projected changes in temperature and rainfall REGION 4 |         |          |         |          |         |          |         |          |
|--|---------|----------|---------|----------|---------|----------|---------|----------|
| SOURCE:  | NCAR    | NCAR     | ECHAM   | ECHAM    | GFDL    | GFDL     | HADGEM  | HADGEM   |
|  | Temp °C | Rain (%) | Temp °C | Rain (%) | Temp °C | Rain (%) | Temp °C | Rain (%) |
| November to April 2030                                 | 1.09    | 4        | 1.09    | -1       | 1.16    | -5       | 0.93    | -4       |
| May to October 2030                                    | 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      |

Source: <http://www.csiro.au/ozclim/home.do>

### Sea level rise

Detailed sea level rise projections have not been performed for the different coastal zones around Australia for the 2030 and 2070 timeframes. The Intergovernmental Panel on Climate Change (IPCC) has estimated global sea-level rise of between 18-59 centimetres and potentially as high as 79 centimetres by 2100 (CSIRO and BoM, 2007), while others have suggested that a rise of more than 1.0 metre and as high as 1.5 metres cannot be ruled out, depending on different emissions and ice sheet melting scenarios (Steffen 2009, cited in DCC 2009).

## 2 Project Methodology

### 2.1 Key elements

This study sought to develop a greater understanding of the likely impacts of climate change on the regional mining value chain, particularly in terms of linkages and cascading impacts between sectors, and in light of this, to identify potential measures and pathways to adaptation. The key elements of the project methodology were as follows (see Appendix C for list of research team members):

1. Provision of relevant background information
2. Collating and developing a preliminary set of maps of mining projects and key infrastructure in the Goldfields-Esperance region to build knowledge of the regional mining value chain and assist interview and workshop discussions
3. Conducting interviews with organisations across a broad range of regional mining value chain sectors to identify current linkages across and between sectors and key vulnerabilities and adaptation measures
4. Conducting a workshop with these stakeholders in the region to test and validate preliminary findings, discuss the regional mining value chain climate adaptation issues collectively, and build new knowledge
5. Qualitative analysis and synthesis of data for reporting.

#### 2.1.1 BACKGROUND INFORMATION

The CSIRO-GEDC Regional Mining Climate Vulnerability Workshop report (Loechel et al 2010) was initially provided as background information to the project sponsors. This report together with the preliminary infrastructure mapping report (Loechel 2013; also see below), which provided a range of maps and background information on this research project, were provided to confirmed interview participants prior to interview. Confirmed workshop participants were also sent the preliminary infrastructure mapping report (Loechel 2013) prior to the workshop.

#### 2.1.2 MAPS

The preliminary infrastructure mapping report “GE region mining value chain infrastructure maps” (Loechel 2013) collated a range of publicly available maps displaying mining projects and related infrastructure in the Goldfields-Esperance and adjoining regions in Western Australia (Appendix A). This report also included two regional mining value chain maps/diagrams developed as part of this research:

- A succinct overview of the location of key infrastructure important to the regional mining value chain (see Figure 9 for final version)
- A schematic depiction of a typical mining value chain adapted to the particular institutional arrangements of the GE region (see Figure 10 for final version)

The preliminary mapping report was circulated for discussion and validation to the project sponsors and interview and workshop participants as described above.

### **2.1.3 INTERVIEWS**

Key organisations relevant to the regional mining value chain were identified as potential participants for interviews. Potentially relevant organisations and individuals (organisation representatives) were identified using both information gleaned from the regional mining value chain mapping exercise and information supplied by the project sponsors. These organisations and/or individuals were then sent an email inviting participation in interviews, together with an Interview Participant Information Sheet and Consent Form (see Appendix D).

Twenty semi-structured interviews were conducted in February-March 2013, representing 20 different organisations and involving a total of 23 consenting participants. Organisation representatives interviewed were from the following sectors: mining companies/industry, energy (electricity, gas, renewables), water, transport (roads, rail, port), environment, local government, state government, community, and regional development.

Most interviews were conducted face-to-face in Kalgoorlie-Boulder; four interviews were conducted by telephone. Prior to interviews, participants were provided with both the preliminary infrastructure mapping report (to further test and/or validate these maps) and the 2010 CSIRO-GEDC workshop report to inform the discussion. The interviews sought organisation level information on:

- mining value chain vulnerabilities and adaptive capacity
- key relationships, including dependencies and effects on other supply chain participants
- perceived barriers to, and enablers of, climate change adaptation

The interview schedule is provided in Appendix E.

### **2.1.4 WORKSHOP**

A workshop was conducted in Kalgoorlie-Boulder on 23<sup>rd</sup> April 2013 to test and discuss preliminary findings. Workshop participants were recruited both from the list of identified organisations and organisation representatives invited for interview, as well as from a broader list of potentially relevant organisations, mainly developed from information provided in these interviews. A total of 22 regional mining stakeholders participated in the workshop, of which eight had participated in an interview and a further seven were from organisations that had participated. The participants therefore comprised a very similar range of organisations and sectors as the interviews.

The principal aims of the workshop were to test and validate preliminary findings and to build new knowledge, particularly with regards to identifying:

- Cascading climate impacts between sectors
- Key elements of viable regional pathways to adaptation, notably win-win and win-lose adaptation options, and barriers and enablers to synergistic adaptation.

Workshop information was recorded via written notes of whole group discussions and presentations and diagrams and notes recorded by small group discussion on large sheets of 'butchers paper'. Specifically designed information recording documents were also used for particular sessions.

### **2.1.5 DATA ANALYSIS & REPORTING**

All data was analysed using qualitative techniques, such as narrative analysis and coding for themes, to identify key issues. As described above, early project findings were reported and tested both at interviews (in the case of the preliminary mapping report) and the workshop (in the case of interview findings). This report represents the synthesis of the workshop results with these earlier findings.

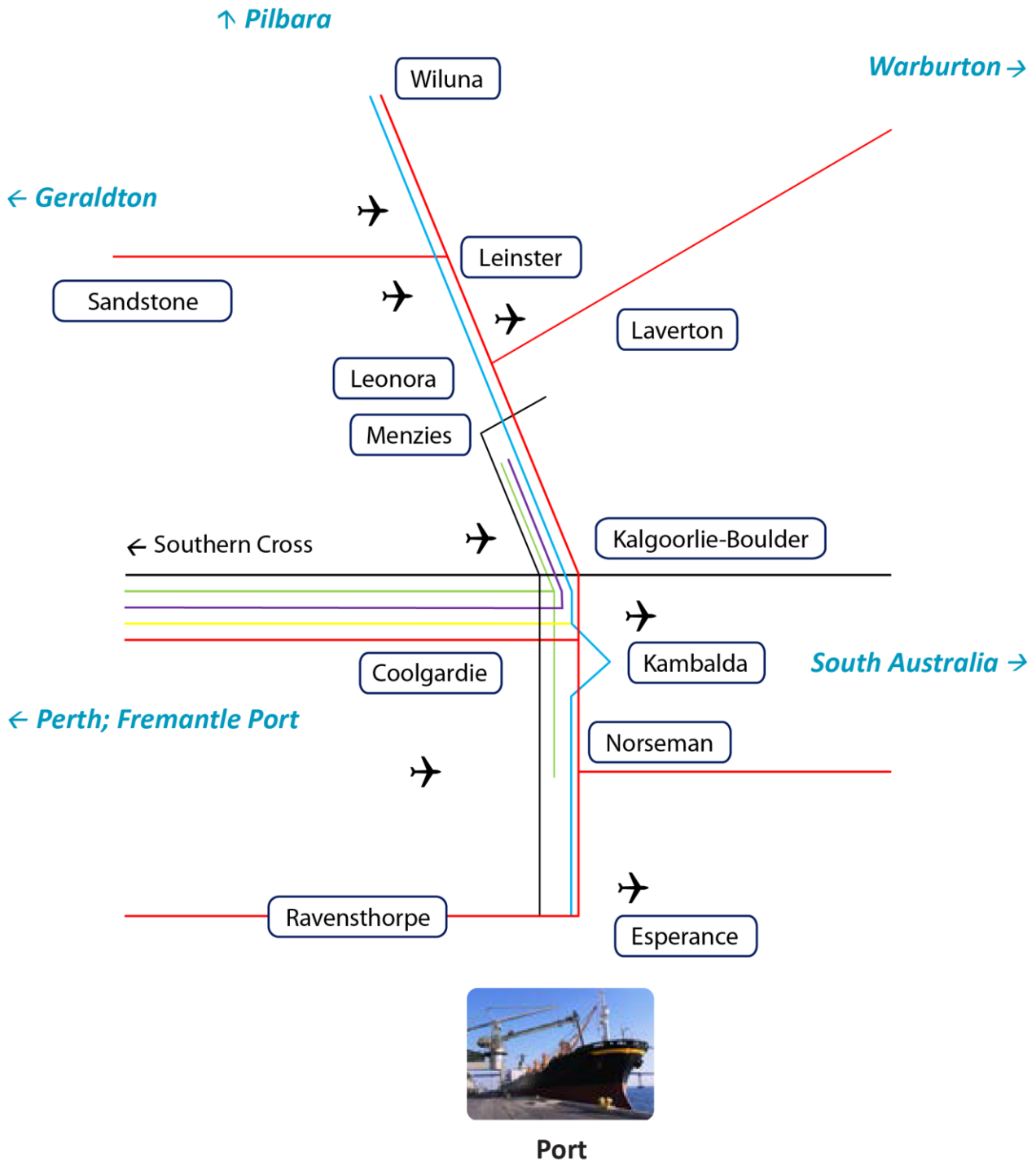


## 3 Results

### 3.1 Mapping of the regional mining value chain

The regional mining value chain is supported by a range of critical infrastructure, of which the most basic are depicted in schematic form in Figure 9. Detailed geographic maps of the mining infrastructure supporting the Goldfields- Esperance and adjoining regions are provided in Appendix A. Key infrastructure components are described in more detail in Appendix F, of which the key sectors can be categorised as:

- Energy: primarily an electricity grid, the South West Integrated System (SWIS) utilising coal and wind resources; a gas pipeline from the north-west gas production area; diesel fuelled generators; and small solar systems
- Water: pipeline of potable water from Mundaring Dam near Perth; treated groundwater; saline and hyper-saline water sourced on mine sites
- Transport: road, rail, seaports and airports
- Telecommunications: telephone and internet services
- Social and community infrastructure: health, education, recreation, law and order, waste management and other facilities
- Environment: landforms, water courses, soil, native flora & fauna.



| Map Key: |                               |
|----------|-------------------------------|
|          | Road                          |
|          | Rail                          |
|          | Water pipeline                |
|          | Gas pipeline                  |
|          | Electricity power line        |
|          | Telecommunications line/cable |

Figure 9 Schematic map of major infrastructure arterials transecting the Goldfields-Esperance region

The structure of the regional mining value chain is depicted in Figure 10. This figure depicts three main components: inputs and outputs, support systems, and governance/ regulatory institutions. The support systems roughly equate to the infrastructure assets supporting the mining value chain. The resulting map shows a flow of inputs (e.g. energy, water, materials, labour, etc) through their corresponding support/infrastructure systems (e.g. electricity grid, water pipeline, transport systems), as influenced or regulated by a range of government and non-government institutions. The outputs of the chain are primarily of two types: mineral products for sale to customers and waste products to be treated before release to the surrounding environment.

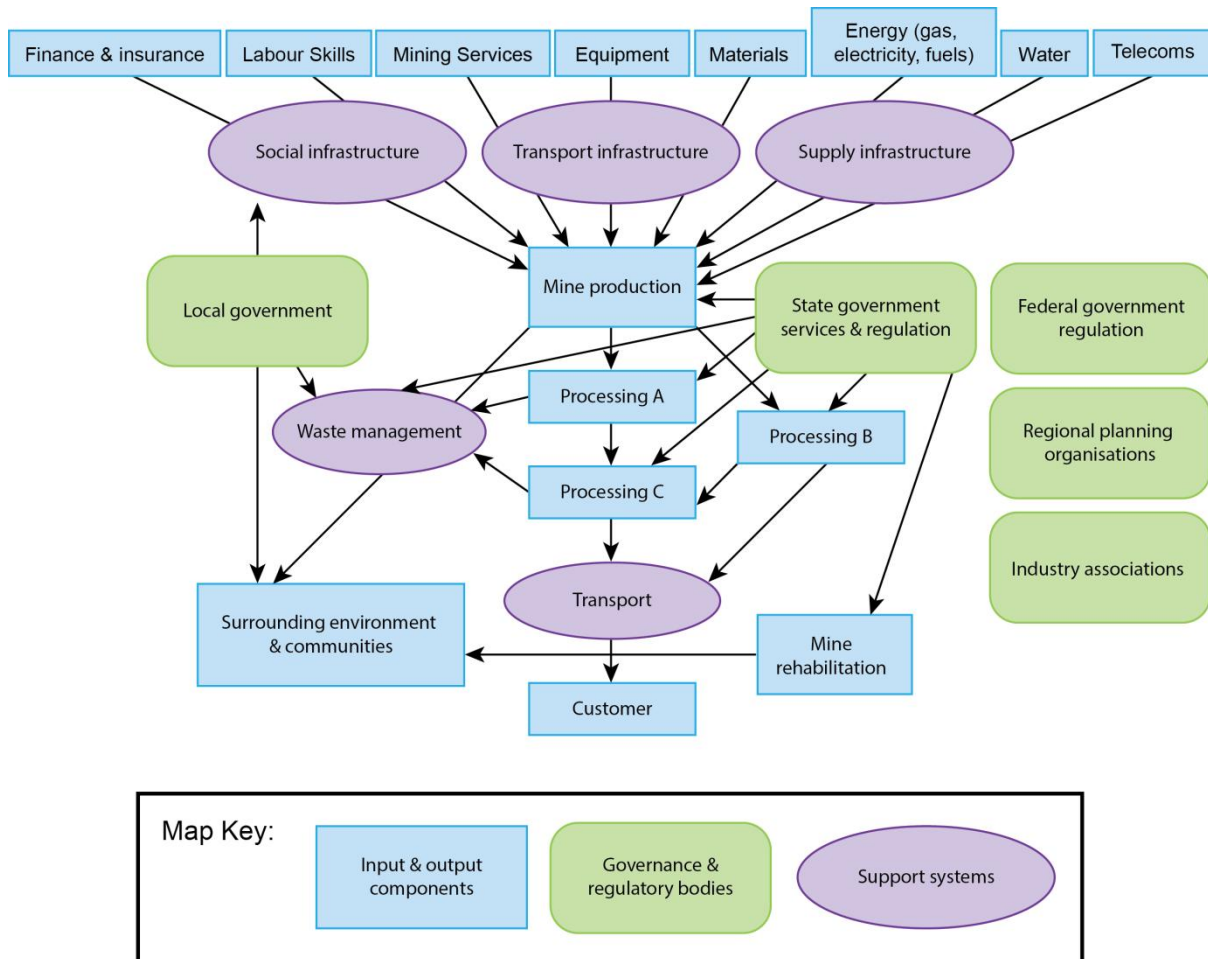


Figure 10 Schematic outline of a typical regional mining value chain

### 3.2 Key climate change issues identified for the regional mining value chain from synthesis of interview and workshop results

Analysis of interview and workshop data identified a number of key issues arising from climate change for the regional mining value chain. These are summarised below in terms of the impacts that the most important climatic change effects (e.g. heat, rainfall, wind, etc) may have on the main infrastructure systems supporting the regional mining value chain (energy, water, transport, mine production and processing, environment and community).

Diagrammatic representations of the climate change vulnerabilities, impacts and adaptation options produced by workshop participants for the various sectors are displayed in Appendix G.



Source: Norton Gold Fields; Photo: Greg Tossel

### 3.2.1 ENERGY

For energy supply there is a clear seasonal differentiation in risk arising from climate change. Projected future summer storms, rainfall events, and hotter temperatures will likely increase energy demand and potentially damage energy infrastructure as well as infrastructure that support energy generation (e.g. roads for diesel transport). By contrast in winter, it is likely that as temperatures will be warmer and storms less frequent and intense, risk to energy related infrastructure and services will be lower. This could potentially see a gradual but asymmetrical seasonal shift in system risk weighting, declining somewhat in winter and increasing in summer.

Key adaptation options identified included upgrading the electricity grid (SWIS) infrastructure to prevent faults, improving capacity to isolate fault location to prevent impacts on the rest of the grid, and improving the capacity of redundant and backup systems in case of faults (e.g. solar/diesel hybrid generators). A greater reliance on gas was also suggested as the supply pipelines are less vulnerable to extreme weather events.

| ENERGY             | IMPACTS   |
|--------------------|---|
| <b>Temperature</b> | <ul style="list-style-type: none"> <li>• Hotter summer conditions are expected to potentially:               <ul style="list-style-type: none"> <li>– increase demand for energy: cooling requirements and water pumping (e.g. for mine dust suppression, and town parks and gardens)</li> <li>– reduce electricity transmission/supply efficiency (SWIS)</li> <li>– overheat transformers leading to thermal overload, faults and blackouts</li> <li>– increase power line sag</li> </ul> </li> <li>• Increased incidence of summer storms increases wind gusts and lightning strikes and both increase the likelihood of electrical faults and bushfires</li> <li>• The combination of increased electricity demand and increased incidence of electrical faults in summer may reduce security of summer electricity supply through the SWIS</li> <li>• Winter demand and faults expected to decrease due to warmer temperatures and fewer projected winter storms</li> </ul> |
| <b>Rainfall</b>    | <ul style="list-style-type: none"> <li>• Limited impact on power lines, and SWIS grid infrastructure, from intense rainfall</li> <li>• Gas pipeline is also well protected from intense rainfall events because it is buried               <ul style="list-style-type: none"> <li>– erosion from extreme flooding from increased cyclone intensity projected for the north-west region of WA could expose the gas pipeline to damage</li> </ul> </li> <li>• Supply of diesel to remote mines may be disrupted by increasing summer rain, although the opposite is expected in winter due to the winter drying trend</li> <li>• Drying of south-west WA (SWWA) may increase sea-water desalination and groundwater pumping energy demands there, indirectly increasing pressure on electricity supply to the G-E region through the SWIS</li> </ul>  |
| <b>Other</b>       | <ul style="list-style-type: none"> <li>• Solar energy seen as a ‘complementary’ resource as its productivity increases in summer when energy demand increases</li> <li>• SWIS systemic vulnerability affects all energy sources (coal, gas, diesel, wind, solar)</li> </ul>   |
| <b>Spill-over</b>  | <ul style="list-style-type: none"> <li>• Faults/disruption to energy supply affects mines, mining services (e.g. town based engineering firms), telecommunication, and community: they can cascade through the system to affect business profitability, employment and community liveability</li> <li>• Many mines have back-up diesel generators in the case of disruption to electricity supply, as do many towns; may need upgrading for future increased summer storms</li> <li>• Fighting bushfires sparked from electricity faults can be complicated by the fact the electricity supply to water pumps can be affected</li> </ul>  |

### 3.2.2 WATER

In general, apart from mines located within reach of the Goldfields Water Supply Scheme (GWSS), most mines rely heavily on groundwater, which varies widely in quality from hyper-saline in central parts of the Goldfields region around Kalgoorlie-Boulder to relatively fresh (low salinity) in areas accessing the Officer Basin in the north of the region. Those mines whose groundwater supply is hyper-saline rely on capturing runoff, importing water or desalination (where feasible) to meet their fresh water needs.

Key adaptation options identified included increasing water use efficiency, notably: the use of ‘fit-for-purpose’ water to avoid unnecessary use of high quality water; reuse of water from one process and/or sector to another (e.g. the community sells treated waste water to the mines for their fresh – but non-potable – water needs); and, recycling water (e.g. mines recycle their process water a number of times). Other opportunities identified included: greater storm water capture; strategic storage of water of different types (potable, fresh, saline, recycled); identifying and exploiting additional sources of water where cost effective and environmentally acceptable (e.g. piping low saline groundwater from Eucla and/or Officer Basins); and desalination.

| WATER                       | IMPACTS   |
|-----------------------------|---|
| <b>Winter drying trend</b>  | <ul style="list-style-type: none"> <li>• A large proportion (around 45%) of GWSS potable water supply is used for mining</li> <li>• Potential for severe pressure on potable water supply to the Goldfields region. Mundaring Dam decline would mean less available water, affecting GWSS supply security/price</li> <li>• Winter drying is likely to affect fresh water supply to those mines and communities that rely on winter rainfall capture (summer wetting trend may offset this considerably)</li> <li>• Region’s natural ecology affected: systems traditionally reliant on higher winter rainfall such as the Great Western Woodlands, pastoral industry, and mine site rehabilitation</li> </ul>   |
| <b>Summer wetting trend</b> | <ul style="list-style-type: none"> <li>• Provides greater runoff and fresh water capture opportunities for communities and mines – water supply increased at time of greatest need for dust suppression and community parks and gardens: potential offset of future warmer summers</li> <li>• Wetter summers may be detrimental to the natural ecology               <ul style="list-style-type: none"> <li>– pest species (e.g. Buffel Grass) invade southward, increasing summer fuel load and fire risk to areas such as the GW Woodlands that are poorly adapted to frequent bushfires</li> <li>– intense rainfall events also increases erosion of exposed landscapes</li> </ul> </li> </ul>   |
| <b>Spill-over</b>           | <ul style="list-style-type: none"> <li>• Similar to the energy system, reduced water supply can affect a broad range of sectors, including mines, mining services, and community. These effects can cascade through the system to affect business profitability, employment and community liveability</li> <li>• Increased requirement to pump or desalinate water as supply becomes restricted can increase energy demand, impacting the energy system</li> <li>• Increased incidence of summer storms can spark bushfires, increasing demand for water pumping, however in addition to the complications from electrical faults noted above, intense rainfall from these storms can also cause erosion that compromises water supply pipelines, also hampering bushfire fighting</li> <li>• Use of more saline water and/or desalination of saline water increases risks from release of saline waste to the environment</li> </ul> |



### 3.2.3 TRANSPORT

For transport, there were strong connections and linkages between elements of the broader transportation system. Road and rail in particular were closely linked with respect to impacts and opportunities for adaptation. Where reducing load on the road system was a key need for the future, rail's heavier construction and lower susceptibility to climate effects make it well positioned to take this additional load. Port impacts on the whole were relatively isolated from these other elements of the transport system.

Adaptation options for road, rail and port infrastructure included upgrading planning, construction and maintenance processes to incorporate, for example, specifications from areas where projected weather is more common. Deploying improved technology was also proposed for road (e.g. heat resistant road sealant) and rail (e.g. replace timber sleepers with steel and/or cement). Moving freight traffic from road to rail was also described as a win-win adaptation option, with incentives, disincentives (e.g. user-pays system for roads) and regulation discussed as levers for creating change. Provision or upgrading of alternative routes in and out of the region was also proposed for improving the adaptive capacity of this and other regions (e.g. the 'PortLink' and 'Outback Way' proposals). Port options included upgrading operational systems, techniques and/or equipment to those used by ports in windier environments. A key question across these proposals was 'who pays?' i.e. incentive structures and equitable cost sharing arrangements.

| TRANSPORT         | IMPACTS   |
|-------------------|---|
| <b>Roads</b>      | <ul style="list-style-type: none"> <li>• Intense summer rainfall causes erosion, cut outs/scouring of sealed and unsealed roads               <ul style="list-style-type: none"> <li>– increases road repair and maintenance costs</li> <li>– transport delay, disruptions from road closure/ repairs</li> <li>– public safety issue, particularly on roads shared by large trucks and tourists</li> </ul> </li> <li>• Higher summer rainfall may increase the growth of roadside vegetation which is dangerous for motorists – restricts vision of wildlife hazards and costly to maintain</li> <li>• Drier winter conditions are beneficial to unsealed roads – less easily damaged by traffic, so repair and maintenance costs should reduce</li> <li>• Warmer temperatures dry out unsealed roads more quickly and have a protective effect</li> <li>• Extremely hot conditions can soften bitumen so degrades more quickly under traffic</li> <li>• Bushfires potentially dangerous for motorists and trucks on remote/isolated stretches</li> </ul> |
| <b>Spill-over</b> | <ul style="list-style-type: none"> <li>• Broad sectoral effects, including mines, mining services, road freight haulage, tourism and community. Affect profitability, employment and community liveability</li> <li>• Poorer roads lead to increased: costs for repair/maintenance (governments and mines); damage to vehicles; disruptions and/or reduce productivity for multiple sectors (trucking, mining, tourism, community), and safety risks for all roads users</li> </ul>   |
| <b>Rail</b>       | <ul style="list-style-type: none"> <li>• Rail lines buckle in heatwaves</li> <li>• Intense summer rainfall leads to trackside erosion (scouring). While rail is more difficult to damage, ex-cyclone rainfall has potential to be more disruptive in the future</li> <li>• Bushfires may cause damage to trackside infrastructure</li> </ul>  |
| <b>Spill-over</b> | <ul style="list-style-type: none"> <li>• Rail freight delays (from the above) have potential to reduce productivity of a wide spectrum of mine-related businesses, as well as communities</li> </ul>  |
| <b>Port</b>       | <ul style="list-style-type: none"> <li>• Sea-level rise plus increased wind speeds may lead to greater wave height/energy, leading to increases in:               <ul style="list-style-type: none"> <li>– Movement of ships at berth, damaging berths/wharves</li> <li>– Reduced productivity in ship loading/unloading</li> <li>– Erosion of shoreline structures</li> </ul> </li> <li>• Ocean chemistry changes (carbonation, chlorination) together with greater wave heights and 'splash energy' increases corrosion of port infrastructure (wood, cement, steel structures)</li> </ul>  |
| <b>Spill-over</b> | <ul style="list-style-type: none"> <li>• Reduced port productivity affects many other businesses including transport companies, mines, mine process operations (e.g. smelters) and mine services</li> <li>• Dust from drying, warmer and windier conditions may affect the surrounding community</li> </ul>   |



### 3.2.4 MINING OPERATIONS

As with the other industry sectors, impacts of climate change for mining operations were seen to be mixed. Where drier and hotter weather was potentially detrimental for the health and safety of workers, efficiency of machinery and increasing the need for dust suppression, this climate outcome was also likely to lead to increased efficiencies in tailings dams and reducing damage to dirt roads. This same mixed pattern was observed for summer storms and winter drying.

Adaptation options for mining included strengthening and improving infrastructure to cope with projected future climate conditions through better planning, design, construction and maintenance to improve resilience and safety of operations. Operational systems, techniques and equipment that assist in creating more resilient and efficient operations were also suggested, as was greater capture and storage of summer rainfall runoff.

| MINING               | IMPACTS   |
|----------------------|---|
| <b>Heat</b>          | <ul style="list-style-type: none"> <li>• Occupational health and safety risk to workers, especially those working at the bottom of mine pits and in the open – drillers, surveyors, maintenance, exploration, etc.</li> <li>• Reduced machinery efficiency/productivity</li> <li>• Dries out roads more quickly, minimising road damage and haulage disruption from rainfall but more watering required for dust suppression</li> <li>• Dries out tailing dams more quickly, improving their productivity</li> </ul>  |
| <b>Summer storms</b> | <ul style="list-style-type: none"> <li>• More (intense) summer rain:               <ul style="list-style-type: none"> <li>– increases opportunity for capture of water runoff from intense falls</li> <li>– may improve success of vegetation rehabilitation for some species</li> <li>– may reduce mine pit wall stability, increase erosion/reduce stability of earthwork structures such as tailing dam walls, roads, ore stockpiles and rehabilitation areas</li> <li>– can lead to disruptive flooding of mine pits, tunnels and tailings dams</li> <li>– could present a range of health and safety risks such as flooding, road damage, pit wall instability, bushfires, and greater incidence of mosquito borne diseases</li> </ul> </li> <li>• More summer rain creates greater disruption on unsealed roads:               <ul style="list-style-type: none"> <li>– mine production and/or ore haulage from pits to stockpiles/processing facilities must cease if haul roads become too slippery</li> <li>– intense falls can damage roads, creating longer delays</li> <li>– remote operations particularly vulnerable to rain disruptions to unsealed roads</li> </ul> </li> <li>• Lightning strikes               <ul style="list-style-type: none"> <li>– direct danger to workers and may damage facilities, mines have to shut down</li> <li>– indirect danger through bushfires</li> </ul> </li> <li>• Wind gusts               <ul style="list-style-type: none"> <li>– create dust, affects workers and nearby communities</li> <li>– strong winds risk damage to infrastructure</li> </ul> </li> </ul> |
| <b>Winter drying</b> | <ul style="list-style-type: none"> <li>• Less winter rain may mean               <ul style="list-style-type: none"> <li>– less disruption to mine production from slippery unsealed roads at this time of year</li> <li>– less successful rehabilitation of winter rain dependent species</li> <li>– reduced water supply security (mainly for mines dependent on the GWSS)</li> </ul> </li> <li>• Fewer winter storms reduce incidence of lightning strikes and wind gusts</li> </ul>  |
| <b>Spill-over</b>    | <ul style="list-style-type: none"> <li>• Hotter conditions may increase dust problems for nearby communities from mines</li> <li>• Hotter conditions may reduce attraction of industry/region (workers and families)</li> <li>• Intense rainfall events may lead to tailings and other mine waste discharge problems into the surrounding environment and communities</li> <li>• Increased mine costs/reduction in mine productivity reduces mine profitability, potentially impacts demand for range inputs (i.e. labour and mine services), and broader employment, business and social conditions in dependent communities and industries</li> </ul>   |

### 3.2.5 COMMUNITY AND HUMAN RESOURCES

In terms of community, participants again identified both positive and negative impacts from climate change. Extra summer rain may improve water security in some communities and tourism may be enhanced through greater greening and wildflower abundance of the landscape in summer. However, impacts on liveability and potential for exposure related health consequences weighed as negatives. Adaptation options for community included pragmatic steps like shorter shifts on mine sites and more night sporting activities to prevent heat stress. There was also an idea that higher workforce turnover will need to be accepted, which may actually make it easier to promote more sustainable organisational cultures. Finally, longer term planning regarding infrastructure that takes climate change into account was suggested, along with education campaigns to increase awareness and capacity to respond to emergent risks, especially in remote communities, such as increased flooding, bushfires and mosquito borne diseases.

| COMMUNITY AND HUMAN RESOURCES | IMPACTS  |
|-------------------------------|--|
| <b>Temperature</b>            | <ul style="list-style-type: none"> <li>• Hotter weather (increased incidence, severity, duration of hot spells) may:               <ul style="list-style-type: none"> <li>– reduce perceptions of liveability/attractiveness of the region to workers and families</li> <li>– increase incidence of heat stress/skin cancer in workers and vulnerable groups</li> </ul> </li> <li>• Warmer overall conditions may reduce winter heating demand</li> </ul>  |
| <b>Summer storms</b>          | <ul style="list-style-type: none"> <li>• Higher summer rainfall may:               <ul style="list-style-type: none"> <li>– reduce severity of water shortage problems in some communities</li> <li>– increase summer ‘greening’ effect (i.e. profusion of vegetation and wildflowers)</li> <li>– increase summer wetting effect (i.e. lakes fill with water, recreational opportunity)</li> <li>– improve perceptions of natural beauty and therefore community liveability and attractiveness to workers’ families and tourists</li> <li>– present a range of health and safety risks such as flooding, poorer road conditions, isolation in remote areas, and greater incidence of mosquito borne diseases</li> </ul> </li> <li>• Increased lightning strikes may cause:               <ul style="list-style-type: none"> <li>– danger to workers in exposed locations (e.g. elevated areas on mines)</li> <li>– faults in electricity grid: inconvenient (air conditioning) but also dangerous if affects mine equipment, community medical equipment, bushfire fighting, etc</li> <li>– risk of bushfire to some communities, workers, motorists, tourists</li> <li>– bushfires may affect perceptions of the area’s natural beauty</li> </ul> </li> <li>• Increased wind gusts create more dust and, if severe, risk of damage to life and property</li> </ul> |
| <b>Winter drying</b>          | <ul style="list-style-type: none"> <li>• May lead to increased water restrictions and/or costs in winter               <ul style="list-style-type: none"> <li>– highly dependent on effects of winter drying in SWWA and Mundaring Dam as the region’s main potable water source</li> <li>– water for parks and gardens are more dependent on runoff, which may be offset by increased summer rains, unless these prove to be unreliable</li> </ul> </li> <li>• Improve condition of unsealed roads in winter</li> <li>• A drier natural landscape in winter may alter perceptions of the area’s natural beauty</li> </ul>   |
| <b>Other issues</b>           | <ul style="list-style-type: none"> <li>• Esperance sub-region coastal zone: sea level rise + increased wind speeds + increased corrosiveness of sea water chemistry could lead to greater coastal zone erosion, inundation from storm surge, and degradation of coastal infrastructure</li> <li>• Difficulty of measuring climate change impacts compared to other factors, e.g. economic, social, family factors may impact more than climate in worker decisions</li> </ul>  |
| <b>Spill-over</b>             | <ul style="list-style-type: none"> <li>• Hotter conditions:               <ul style="list-style-type: none"> <li>– increase air conditioning and water demand, leading to greater power and water use, stressing a system already at capacity, leading to further restrictions/shortages</li> <li>– affect timing of community sporting activities: move to cooler but later period in the evening, which can impinge on family life</li> </ul> </li> </ul>  |

### 3.2.6 ENVIRONMENT

The overall warming, winter drying and summer wetting of the terrestrial landscape is likely to result in northern environmental conditions and ecological systems moving south. *Acacia* species of the mulga areas may progressively replace the *Eucalyptus* species that dominate the Great Western Woodlands, which may recede.

Adaptation options included minimising disturbance to ecosystems as disturbance favours invasive species, and implementing early detection and control programs (e.g. for feral pests) to prevent outbreaks and promote containment. Engineering solutions were suggested to: reduce landscape and coastal erosion; improve waste dump design for improved performance and reduction of risks of discharge to the environment, and; create new habitats and microclimates (e.g. swales for development of wetlands, manage water runoff, filter pollutants, and increase rainwater infiltration). Other improvements mentioned included: upgrading bushfire prevention strategies and response capability; improving mine rehabilitation efforts by focusing on areas where success is more likely; and, considering climate resilience of planting mixtures.

| ENVIRONMENT                    | IMPACTS  |
|--------------------------------|--|
| <b>Increased summer storms</b> | <ul style="list-style-type: none"> <li>Increased summer rainfall will:               <ul style="list-style-type: none"> <li>increase summer vegetation growth, including rehabilitation areas</li> <li>lead to the invasion of northern weed species (e.g. Buffel Grass) and other pest/feral species (flora and fauna)</li> <li>affect native wildlife population distribution and survival (specifics unclear)</li> </ul> </li> <li>More intense summer rain will:               <ul style="list-style-type: none"> <li>increased surface flows/erosion of the landscape, including rehabilitation areas</li> <li>greater runoff may mean less moisture is captured by deeper rooted vegetation</li> </ul> </li> </ul> |
| <b>Warming</b>                 | <ul style="list-style-type: none"> <li>Warmer overall conditions and increased frequency, severity and duration of hot spells are expected</li> <li>Resulting increased evapotranspiration will exacerbate the projected winter drying effect</li> <li>Warming and drying will affect native wildlife population distribution and survival</li> <li>There is the potential for major ecosystem shifts</li> </ul>   |
| <b>Increased fire risk</b>     | <ul style="list-style-type: none"> <li>Summer vegetation growth increases fuel load</li> <li>Summer storms increase lightning strikes</li> <li>Warmer conditions, heat waves increase fire risk</li> <li>These factors greatly increase the risk of extensive summer fires in the Great Western Woodland (already apparent in recent years) whose ecology is usually not fire prone</li> </ul>   |
| <b>Sea-level rise</b>          | <ul style="list-style-type: none"> <li>Esperance sub-region coastal zone: sea level rise together + increased wind speeds, is likely to lead to greater erosion of coastal features and inundation of low lying coastal ecosystems from storm surge</li> </ul>   |
| <b>Spill-over</b>              | <ul style="list-style-type: none"> <li>Changes to the natural environment may affect the liveability and attractiveness of the region to workers and their families</li> <li>Greater impacts on the environment from mining due to climatic change (e.g. intense summer rainfall leading to mine waste discharge failures) may increase pressure for further government regulation</li> </ul>  |

## 3.3 Cascading impacts between sectors

### 3.3.1 SUMMARY OF CASCADING IMPACTS BETWEEN SECTORS

The sectoral analysis above identifies key issues by sector for the supply chain as well as those ‘spill-over’ impacts that have implications for other sectors. This section provides a summary of these spill-over effects and cascading impacts between sectors.

#### Cascading impacts down the supply chain

The most common spill-over or cascading impacts identified were the effect of damage or disruption to ‘upstream’ components of the mining value chain (e.g. water, energy and transport) on mining productivity and viability. These impacts then had effects on other components of the supply chain, notably human resources (employment), the environment, and community liveability. A number of examples are displayed below (separate sectors are underlined).

#### Energy → mining → human resources → community

More summer storms, particularly lightning strikes, are likely to lead to more electricity grid faults which results in more mine downtime and therefore, reduced mine production, productivity and profitability. This may ultimately lead to less demand for mine labour with consequent social impacts on the community.

#### Water → mining → human resources → community

The drying of SWWA may result in reduced fresh water supply and/or higher fresh water costs for mining. This could potentially have negative impacts on production, productivity and profitability, as well affecting water-use intensive mining services and other businesses in the community. Apart from the direct effect of reduced water supply on the community, these business impacts could again affect demand for labour and hence community social wellbeing.

Conversely, wetter summers may increase fresh water capture on mines at this time of year, which could potentially offset the above impacts to some degree.

#### Mining → human resources → community → mining services

Hotter conditions will lead to increased evaporation, resulting in increased mine and road dust (which, together with the heat) may lead to poorer working conditions for workers and members of surrounding communities. This may result in perceptions of poorer regional liveability and thus reduced desire for workers and/or their families to live and work in the region, resulting in reduced supply of skills to mining, mining services other businesses in the community

#### Transport → mining → human resources → community

Greater incidence of intense rainfall events (in summer) may lead to more road transport disruptions, thereby reduced mining productivity at this time of year, with consequent employment and community impacts (similar to above).

#### Cascading impacts up the supply chain

Impacts on sectors lower down the supply chain can have ramifications for upstream sectors:

#### Port → road/ rail → mining

Sea level rise and increased wind speeds may lead to greater disruption to port operations as well as damage to port infrastructure, thus reducing port productivity and increasing costs. The flow on effect is likely to be reduced productivity of upstream sectors (road, rail, mines and related businesses) as it takes longer and/or costs more to import and export goods

## Cascading impacts across sectors

A number of the spill-over effects identified were those between sectors at the same 'level' of the supply chain, notably between water and energy supply, that then went on to affect other sectors such as the community and environment:

### **Water → mining → energy → community**

Increased on-site water pumping by mines in order to increase water use efficiency (e.g. reuse and recycling of water) may lead to increased energy demand by mines and therefore increased demand on the electricity grid. Increased demand on an already supply constrained system may lead to more electricity grid faults which not only disrupts mine operations but also other businesses and the community.

### **Energy → telecommunications → other inputs & support systems**

Summer storms produce lightning strikes and wind gusts that can cause electricity grid faults and thereby telecommunications failure. This may result in reduced ability to organise other mine inputs & support systems (labour, mine services, transport etc)

## 3.4 Elements of viable pathways to regional adaptation

The results summarised in Section 3.2 outline the main adaptation options identified for each sector from both interviews and the workshop. However, the workshop participants were asked to not only nominate adaptation options but to identify their advantages and disadvantages. They were then asked to nominate those groups whom they thought the wins/advantages and losses/disadvantages (if any) would accrue, and thereby to classify the options as win-win or win-lose. These results are displayed in Appendix H. Some general points can be made from analysis of these results:

- Some of the proposed adaptation options have benefits for all involved and/or have a clear benefit even without considering the need to adapt to climate change. That is, they are 'win-win' and/or 'no regrets' options because the organisation (and others) will benefit from them anyway. Notable examples are measures to improve energy and water use efficiency, worker health and safety, and mine rehabilitation outcomes. Indeed one mining company participant commented (in workshop discussion) that there was nothing among the adaptation options that had been proposed that the industry was not already trying to implement, because they were already viewed as valuable.
- Nevertheless, in many cases a number of barriers to implementing these 'win-win' and/or 'no regrets' options were apparent, such as upfront costs (capital outlays), knowledge and/or cultural barriers, and institutional and/or political complications. Specific examples included:
  - Resistance to providing capital outlay for cost-effective medium-long term water or energy efficiency measures because there is a lack of certainty around the production/investment horizon of the mine
  - Cultural attitudes, such as low value placed on education and training and/or regulatory compliance, resistance to change, and organisational inertia or lack of leadership, that can all hamper staff education and awareness raising campaigns to change practices
  - Innovation to improve outcomes may be hampered by inflexible or inappropriate regulation.
- Adaptation measures generally involve not only financial costs but also uncertainty about the precise nature of likely impacts (that is, the potential impact from climate change and therefore the potential value of adaptation). This makes it difficult to calculate cost/benefits of adaptation and therefore to justify expensive measure such as upgrading infrastructure to a higher standard.
- One of the most difficult questions to answer is how costs can be shared equitably by the various stakeholders who stand to gain or lose from implementation of the adaptation measure:
  - For example, improving water and energy supply security in the region, or improving the resilience of the transport system, have benefits for multiple groups; however the primary organisation

responsible for the sector or subsector may not wish to bear the cost because they have little way of ensuring others who benefit will contribute to those costs

- This suggests that careful attention needs to be placed on facilitating institutional arrangements that align incentive structures that make it worthwhile for sectoral players to undertake adaptation measures (i.e. cost sharing to achieve mutual benefit)
  - It also suggests that in some cases government intervention may be required because it is impractical or inordinately difficult (at least politically) to achieve such institutional arrangements. For example, the costs of maintaining roads are in many cases met by government (local, state or federal) whereas the benefits are primarily accrued by transport operators, mining companies and mine service providers. It is difficult (practically and politically) for governments to install differential tolling systems on roads that distinguish between users, or alternatively, to sell high cost public roads to those organisations that have an incentive to maintain them.
  - Another related issue is that of externalities, where the disadvantages or costs of an adaptation measure are borne by other parties. These were often identified for the environment, where efforts to deal with increased heat, reduced water supplies, or increased transport infrastructure, for example, are likely to lead to environmental damage.
- Another form of cost identified, which was less clear-cut, was trade-offs with desirable actions or outcomes in other domains or at a later time. This points to the opportunity-costs associated with some adaptation options and the need for a full or holistic accounting of costs and benefits. An example was continued or increased use of hyper-saline water which reduces the need for fresh water (which is in short supply in the region) while acting as a potent dust suppression agent. However hyper-saline water increases corrosion of equipment and kills roadside vegetation. Adapting by using this potential (fresh) water saving measure therefore involves trade-offs because it produces problems elsewhere, and therefore was identified as a ‘win-lose’ and/or (potentially) ‘high regrets’ option.

### 3.4.1 TOWARDS VIABLE PATHWAYS TO REGIONAL ADAPTATION

Given that many of the ‘adaptation options’ are actions from which multiple organisations are likely to benefit, but do not undertake due to a range of barriers, attention clearly needs to focus on overcoming these barriers. Workshop participants were asked about the factors that make it difficult to achieve ‘desirable’ (‘win-win’, ‘no- or low-regrets’) adaptation options (i.e. what are the barriers), how they thought these difficulties could be overcome (i.e. what are the ‘enablers’ to adaptation), and what might be the unintended outcomes of attempting to overcome these barriers (i.e. what externalities may result). Additionally, and conversely, participants were asked about what makes it hard to avoid ‘dysfunctional’ (‘win-lose’, ‘high regrets’) adaptation options (i.e. another way of asking what are the barriers to desirable adaptation), what could make it easier to avoid them, and any unintended outcomes. The summarised results are displayed in Appendix I. While the main barriers have been identified above (upfront costs and/or lack of mechanisms that create or align incentives to overcome them, knowledge and/or cultural barriers, and institutional and/or political complications), some general points can be made with regard to the ‘enablers’ that point to potential pathways to more viable adaptation in a regional context.

- Common responses to the question of helpful ‘enablers’ of action included:
  - additional funds, financial incentives or other resources
  - education and awareness raising
  - engagement and consultation
  - expertise, research and/or technological progress
  - methods of including the true costs of actions/non-action in organisational decision-making
  - corporate or government support (resources, leadership) and/or mandates (policy, regulation)
  - flexibility/responsiveness of company management and/or government regulation
  - planning, monitoring and evaluation.

## 4 Discussion and conclusion

This study has identified a wide range of specific vulnerabilities and adaptation options in critical components or sectors of the Goldfields-Esperance regional mining value chain. It has also identified a number of spill-over effects and ‘cascading impacts’ between sectors. However, perhaps more importantly, the study has sought to identify a range of factors that influence the effective, efficient and equitable implementation of adaptation measures at a regional level.

All sectors involved in this study will potentially be affected by climate change, with a clear seasonal affect associated with the declining incidence and severity of winter storms but an increase of these events in summer. Likely impacts include restraints on potable water supply from SWWA due to the winter drying effect there but greater local opportunities for fresh water capture in summer; improved stability of electricity supply in winter but greater instability in summer associated with the shifting seasonal incidence of storms; similar shifting seasonality of disruptions to road transport and mine production from rainfall events and to port operations from storms; generally detrimental changes to the natural ecology of the region (from drier winters, hotter and wetter summers, and consequent bushfires); and changes to the liveability of the region with milder winters but hotter and wetter summers.

A range of difficulties or barriers to adaptation are evident, notably around the justification, sharing, externalisation and otherwise full accounting of costs; uncertainty about the nature of impacts and/or the investment horizon of mines; cultural attitudes to learning and change; and inflexible company management and government regulation. It is also evident from the results above that the key elements of ‘no-regrets’ and win-win’ adaptation options include: certainty of beneficial outcomes regardless of the extent of climate change; mutual benefit for multiple stakeholders; and the equitable sharing and full accounting of costs, including opportunity costs, trade-offs and externalities. Conversely, ‘high regrets’ or ‘win-lose’ outcomes in a regional context, are likely to be characterised by: high uncertainty around investment pay off in the event of changes in the nature or rate of projected climate change, or changes in the parameters of the mining investment profile; inequitable sharing or externalising of costs; and, narrow or inadequate accounting of costs.

In addition to approaches that seek to maximise the use of ‘no-regrets’ and ‘win-win’ adaptation options and minimise ‘high regrets’ or ‘win-lose’ ones, a number of other key elements enabling or facilitating viable pathways to adaptation in a regional context can be identified. These include:

- The development of institutional arrangements that create appropriate incentive structures for adaptation
- Improving or importing the knowledge/expertise to identify and assess available options as well as the costs of non-action
- Ongoing education and awareness raising in organisations and communities
- Strategies that improve work culture attitudes to learning, change and regulatory compliance, and promote organisational leadership on adaptation or sustainability issues
- Engagement and consultation both within organisations and, at the regional level, between organisations and/or institutions (such as government, industry and community) to ensure responsive and flexible development and implementation of management strategies and government regulation
- Ongoing monitoring, evaluation, review and improvement of adaptation planning and implementation.

This project has provided an opportunity for focussed cross-sectoral discussion on future development of the region under changing climatic conditions. These discussions, together with the findings presented in this report, provide a basis for continued, collaborative dialogue amongst stakeholders to build pathways to more viable mining adaptation in the region. Here we have presented some of the insights, ideas and views of the stakeholders, on impacts they foresee and ways in which vulnerability could be reduced, including barriers and facilitators of effective adaptation. Importantly, this report provides planners with evidence of current, local knowledge of the system as a whole that can be drawn upon in the journey to adaptation.





Source: Norton Gold Fields; Photo: Greg Tossel

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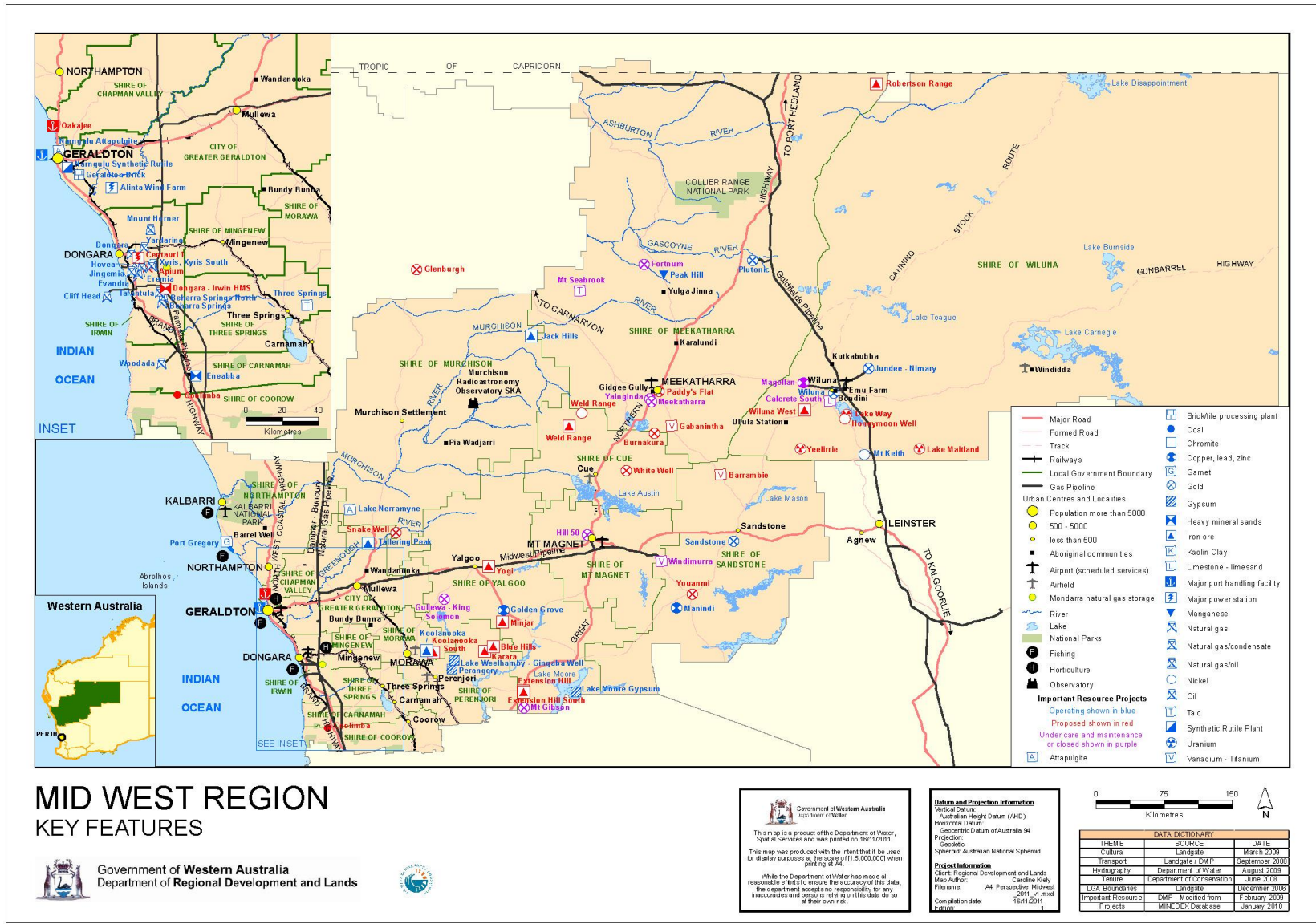


Figure 12 Mining related infrastructure within the Mid West region of WA





# WHEATBELT REGION KEY FEATURES



Government of Western Australia  
Department of Regional Development and Lands



Government of Western Australia  
Department of Water

This map is a product of the Department of Water, Spatial Services and was printed on 19/06/2009.  
This map was produced with the intent that it be used for display purposes at the scale of 1:250,000 when printing at A4.

While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

**Datum and Projection Information**  
Vertical Datum: Australian Height Datum (AHD)  
Horizontal Datum: Geocentric Datum of Australia 94  
Projection: MGA 94 Zone 50  
Spheroid: Australian National Spheroid

**Project Information**  
Client: Regional Development and Lands  
Map Author: Tina Abdel  
Filename: Perspective\_Wheatbelt\_2009\_v1.mxd  
Compilation date: 05/03/2010  
Edition: 1

0 40 80  
Kilometres

DATA DICTIONARY

| THEME                       | SOURCE                                | DATE           |
|-----------------------------|---------------------------------------|----------------|
| Cultural                    | Landgate / DOW                        | March 2009     |
| Transport                   | Landgate / DMIP                       | September 2008 |
| Hydrography                 | Department of Water                   | August 2009    |
| Tenure                      | Department of Conservation            | June 2008      |
| LGA Boundaries              | Landgate                              | December 2006  |
| Important Resource Projects | DMIP - Modified from MINEDEX Database | February 2009  |

Figure 13 Mining related infrastructure within the Wheatbelt region of WA

## Appendix B Value of minerals by region

Table 3 Value of minerals in the Goldfields-Esperance and adjoining regions in 2011-12

| <b>GOLDFIELDS-ESPERANCE REGION</b> | <b>2011-12 VALUE (\$)</b> |
|------------------------------------|---------------------------|
| Gold                               | 6,048,668,468             |
| Nickel, Platinum and Palladium     | 2,798,337,354             |
| Cobalt                             | 131,324,019               |
| Copper & Zinc                      | 95,342,629                |
| Silver                             | 31,703,640                |
| Gypsum & Limesand                  | 14,304,822                |
| Construction materials             | 6,124,216                 |
| Other                              | 19,482,784                |
| <b>TOTAL</b>                       | <b>9,145,287,932</b>      |

| <b>MID WEST REGION</b>        | <b>2011-12 VALUE (\$)</b> |
|-------------------------------|---------------------------|
| Gold                          | 832,197,728               |
| Iron Ore                      | 577,412,679               |
| Copper, Lead and Zinc         | 351,203,644               |
| Cobalt, Nickel & Talc         | 297,784,641               |
| Heavy Mineral Sands, Chromite | 241,512,910               |
| Silver                        | 53,854,603                |
| Natural Gas                   | 33,318,766                |
| Crude Oil and Condensate      | 14,201,953                |
| Other                         | 3,985,386                 |
| <b>TOTAL</b>                  | <b>2,405,472,310</b>      |

| <b>WHEATBELT REGION</b>        | <b>2011-12 VALUE (\$)</b> |
|--------------------------------|---------------------------|
| Iron Ore                       | 1,342,483,170             |
| Nickel, Copper and Salt        | 506,515,898               |
| Gypsum and Heavy Mineral Sands | 505,367,557               |
| Gold and Silver                | 299,535,057               |
| Other                          | 16,965,352                |
| <b>TOTAL</b>                   | <b>2,670,867,034</b>      |

Source: WA Dept Mines & Petroleum 2013



## Appendix C The research team

### **Barton Loechel, Social Scientist, CSIRO**

[Project conceptualisation, development and management, client liaison, map development, data collection fieldwork (interviews & workshop), data analysis and report writing]

Dr Barton Loechel is a social researcher in the Science into Society Group within the CSIRO Earth Sciences and Resource Engineering Division. He primarily works within the 'Adaptive primary industries, enterprises and communities' research theme in the CSIRO Climate Adaptation Flagship. Barton is currently investigating how the mining industry and its related communities can best prepare for climate change. He has expertise and qualifications in regional planning, rural sociology, agribusiness and agricultural science. Barton's understanding of rural industries, communities and governance systems brings a valuable set of skills and insights to achieving a sustainable future for rural Australia.

### **Jane Hodgkinson, Geologist, Data Analyst, CSIRO**

[Project conceptualisation, data analysis and report writing]

Jane is a geoscientist and has worked at CSIRO for nearly six years, where she began in both mine-modelling and non-traditional statistical analysis of exploration and geological data. For the last three years, Jane has been broadly involved with a number of projects that tackle both climate change mitigation and adaptation specifically in the mining industry. Jane has also been involved with coal-related projects including coal-seam modelling and analysis of high sulphur coal. She was awarded her PhD for completing a study of geological control of the southeast Queensland landscape, performed using GIS, drainage analysis and seismic data.

### **Suzanne Prober, Ecologist, CSIRO**

[Data collection fieldwork (interviews & workshop), data analysis, and report writing]

Suzanne Prober is a Principal Research Scientist in vegetation ecology at CSIRO Ecosystem Sciences in Perth. Her research interests include understanding and restoring ecological function, diversity and resilience in temperate eucalypt woodlands, and climate adaptation and fire management in intact and fragmented landscapes. She leads the Great Western Woodlands TERN Supersite in Western Australia and has published over 50 scientific articles and book chapters.

### **Kieren Moffat, Social Scientist, CSIRO**

[Project conceptualisation and report writing]

Dr Kieren Moffat is a senior social scientist in the Science into Society Group within CSIRO Earth Science and Resource Engineering Division and leads the Resources in Society stream of research in the Minerals Down Under Flagship. His research interests include investigating the minerals industry's social licence to operate, citizen participation in resource governance, the role of technology and innovation in sustainable development, and responsible agreement making for mineral development.

# Appendix D Research Participant Information Sheet and Consent Form

## Interview Participant Information Sheet

### CLIMATE ADAPTATION FLAGSHIP

Queensland Centre for Advanced Technologies Technology Ct, Pullenvale QLD 4070 PO Box 883, Kenmore QLD 4069, Australia T (07) 3327 4072 • ABN 41 687 119 230

### INTERVIEW PARTICIPANT INFORMATION SHEET

#### Goldfields-Esperance Region mining-value-chain climate adaptation case-study

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is conducting research to explore adaptation to climate change in the mining industry in Australia. Specifically, CSIRO is partnering with the Chamber of Minerals and Energy Eastern Region (CME) and the Goldfields Environmental Management Group (GEMG) to undertake a case-study examining the implications for the mining-value-chain within the Goldfields-Esperance region of WA in 2013. This case-study will build on previous CSIRO work in the region in 2010 scoping some of the main climate adaptation issues identified by a range of stakeholder groups.

#### Why is this research being conducted?

The purpose of this study is to provide greater understanding of the implications of climate change for the regional mining value chain and viable pathways to adaptation. The 2010 workshop identified cross-sectoral linkages and potential for cascading impacts between sectors as of key significance to future regional climate change adaptation. This research also forms part of a larger CSIRO initiative seeking to understand how mining industries and communities can better prepare for climate change.

#### Who has been invited to participate in this research?

Personnel involved in organisations forming part of the regional mining value chain have been invited to participate. The mining value chain is conceptualised broadly and includes the broad range of organisations and sectors important to the conduct of the resource industry in the region, including: mining companies, mining service providers, utility and infrastructure providers (e.g. water, energy, roads, rail, ports), local and/or state government agencies and community groups, and the surrounding environment.

#### What is involved?

As a member of the regional mining value chain you are invited to attend an interview for this study. If you choose to take part in this research, we will contact you to arrange an interview with one of our researchers which should take approximately 30 minutes to 1 hour to complete. While the aim is to undertake as many interviews face-to-face in Kalgoorlie-Boulder in February, due to location or scheduling issues the interview may need to be conducted by telephone. The interview will seek information on the following topics:

- ☐ Nature of your operations; key value chain components and connections; key constraints and opportunities
- ☐ Key issues facing your organisation and/or sector at the moment and into the future
- ☐ Experience with past weather events and climate variability and how it has affected your mining value chain
- ☐ Perceptions of future climate change and its expected impacts on your business/organisation, including perceived barriers, opportunities and options to adapt
- ☐ Current weather and climate-related risk amelioration measures and strategies

The research team will not require detailed operational or business financial information.

#### Participation and withdrawal

Participation in this study is voluntary and you are free to withdraw from this study at any time without providing a reason for your withdrawal and without prejudice or penalty. If you do withdraw from the

study, the information that you have provided in your interview can be deleted if requested (any time prior to the analysis) and will not be included in the study unless you give us permission to use that information.

**Are there any risks in participating in this study?**

Participation in this study should involve no physical or mental discomfort, and no risks beyond those of everyday living. During the interview you are free to decline to answer any questions.

**How will the information I provide be recorded, used and kept?**

Your responses in the interview will be recorded through audio-recording and/or written notes and transcribed or summarised. This information will be collated with that of other study participants and analysed to produce research reports, presentations and academic publications. Individual responses will be kept confidential and will only be seen by members of the CSIRO research team (listed below). Your responses will also be made anonymous through a process of de-identification where your personal information is detached from your responses. All information will be stored in a secure location that is not accessible to any individuals other than the research team. Unless otherwise agreed by you in writing, you and your organisation will not be identified in any reports, presentations or publications following from this research.

**CSIRO research team**

Barton Loechel, Social Scientist (Project Leader); Kieren Moffat, Social Scientist; Jane Hodgkinson, Geologist; Suzanne Prober, Ecologist.

**How can I find out more about the study?**

If you have any questions concerning your participation in the study feel free to contact the project leader Dr Barton Loechel by phone (07 3327 4072) or email ([barton.loechel@csiro.au](mailto:barton.loechel@csiro.au)).

**Has this project received ethical clearance?**

This study has been cleared in accordance with the ethical review process of CSIRO within the guidelines of the National Statement on Ethical Conduct in Human Research. Alternatively any concerns or complaints about the ethical conduct of the study can be raised with the CSIRO's Social Science Human Research Ethics Committee by email at [cshrec@csiro.au](mailto:cshrec@csiro.au) or by contacting the Manager of Social Responsibility and Ethics on (07) 3833 5693.

**If you are willing and available to be involved in an interview for this study please complete the consent form overleaf. We thank you for your agreement to participate in this research.**

## INTERVIEW PARTICIPANT CONSENT FORM

### CLIMATE ADAPTATION FLAGSHIP

Queensland Centre for Advanced Technologies Technology Ct, Pullenvale QLD 4070 PO Box 883, Kenmore QLD 4069, Australia T (07) 3327 4072 •  
ABN 41 687 119 230

## INTERVIEW PARTICIPANT CONSENT FORM

### Goldfields-Esperance Region mining-value-chain climate adaptation case-study

Your involvement in this research is highly valued. After reading the information sheet provided, please review the information below and if you agree to participate in an interview, read and sign the 'agreement to participate' section provided at the end of this form, and scan and return the signed copy to the project researchers by reply email.

I acknowledge that:

- I agree to participate in this study by participating in an interview.
- I understand that I will not be able to participate in an interview until I have signed and returned this consent form.
- I understand that the interview will be audio recorded and transcribed.
- I understand that the interviewer will ask me about my organisation as it relates to the issue of climate adaptation by the mining-value-chain in the Goldfields-Esperance region.
- I understand that the interview should take approximately 30 minutes to 1 hour to complete.
- I understand that my participation is entirely voluntary. I am free to not answer any question I choose and **I am free to withdraw my participation at any time without having to provide a reason for my withdrawal.**
- I have been provided with information about the project and had any questions regarding my participation and any associated risks and benefits answered to my satisfaction.
- I have been provided with contact details of the research officers and understand that I can contact them should I have any questions or concerns. I have also been provided with the contact details of an independent ethics officer at CSIRO should I wish to raise any concerns or complaints about the conduct of the research.
- I understand that the information provided for this research will be used to compile research reports, presentations and academic publications. I also understand that the information I offer will not be individually identifiable to anyone outside of the CSIRO project team. No individually identifying information will be made available at any stage of the writing process.

#### Agreement to participate

My signature below confirms that I have read and understood the information above, and agree to participate in the CSIRO research project "Goldfields-Esperance Region mining-value-chain climate adaptation case-study".

Name: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## **WORKSHOP PARTICIPANT INFORMATION SHEET**

### **CLIMATE ADAPTATION FLAGSHIP**

Queensland Centre for Advanced Technologies Technology Ct, Pullenvale QLD 4070 PO Box 883, Kenmore QLD 4069, Australia T (07) 3327 4072 • ABN 41 687 119 230

## **WORKSHOP PARTICIPANT INFORMATION SHEET**

### **Goldfields-Esperance Region mining-value-chain climate adaptation case-study**

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) is conducting research to explore adaptation to climate change in the mining industry in Australia. Specifically, CSIRO is partnering with the Chamber of Minerals and Energy Eastern Region (CME) and the Goldfields Environmental Management Group (GEMG) to undertake a case-study examining the implications for the mining-value-chain within the Goldfields-Esperance region of WA in 2013. This case-study will build on previous CSIRO work in the region in 2010 scoping some of the main climate adaptation issues identified by a range of stakeholder groups.

#### **Why is this research being conducted?**

The purpose of this study is to provide greater understanding of the implications of climate change for the regional mining value chain and viable pathways to adaptation. The 2010 workshop identified cross-sectoral linkages and potential for cascading impacts between sectors as of key significance to future regional climate change adaptation. This research also forms part of a larger CSIRO initiative seeking to understand how mining industries and communities can better prepare for climate change.

#### **Who has been invited to participate in this research?**

Personnel involved in organisations forming part of the regional mining value chain have been invited to participate. The mining value chain is conceptualised broadly and includes the broad range of organisations and sectors important to the conduct of the resource industry in the region, including: mining companies, mining service providers, utility and infrastructure providers (e.g. water, energy, roads, rail, ports), local and/or state government agencies and community groups, and the surrounding environment.

#### **What is involved?**

As a member of the regional mining value chain you are invited to attend a workshop for this study. The purpose of the workshop are to: 1) gain regional stakeholder feedback on preliminary project findings and 2) to promote discussion of cascading impacts between sectors and potential pathways for viable regional mining value chain adaptation. The workshop will involve a series of presentations, whole group discussions and small group (table) discussions that you will be invited to participate in.

#### **Participation and withdrawal**

Participation in this workshop is voluntary and you are free to withdraw at any time without providing a reason for your withdrawal and without prejudice or penalty. If you do withdraw from the workshop, any individually identifiable information that you have provided to group discussions will be excluded if you so request (any time prior to the analysis).

#### **Are there any risks in participating in this study?**

Participation in this study should involve no physical or mental discomfort, and no risks beyond those of everyday living. During the workshop you are free not to participate in discussions.

#### **How will the information I provide be recorded, used and kept?**

Workshop discussions will be recorded through audio-recording and/or written notes and subsequently transcribed or summarised. The information will be collated with that of other study participants and analysed to produce research reports, presentations and academic publications. Following the workshop, any individually identifiable responses provided during the course of the workshop will be made anonymous through a process of de-identification where personal information is detached from the responses prior to analysis. All research data will be kept confidential, will be viewed only by members of the CSIRO research team (listed below) and will be stored in a secure location that is not accessible to any individuals other than the research team. Unless otherwise agreed by you in writing, you and your organisation will not be identified in any reports, presentations or publications following from this research.

#### **CSIRO research team**

Barton Loechel, Social Scientist (Project Leader); Kieren Moffat, Social Scientist; Jane Hodgkinson, Geologist; Suzanne Prober, Ecologist.

#### **How can I find out more about the study?**

If you have any questions concerning your participation in the study feel free to contact the project leader Dr Barton Loechel by phone (07 3327 4072) or email ([barton.loechel@csiro.au](mailto:barton.loechel@csiro.au)).

**Has this project received ethical clearance?**

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**If you are willing and available to participate in this workshop please complete the consent form overleaf. We thank you for your agreement to participate in this research.**

## WORKSHOP PARTICIPANT CONSENT FORM

### CLIMATE ADAPTATION FLAGSHIP

Queensland Centre for Advanced Technologies Technology Ct, Pullenvale QLD 4070 PO Box 883, Kenmore QLD 4069, Australia T (07) 3327 4072 •  
ABN 41 687 119 230

## WORKSHOP PARTICIPANT CONSENT FORM

### Goldfields-Esperance Region mining-value-chain climate adaptation case-study

Your involvement in this research is highly valued. After reading the information sheet provided, please review the information below and if you agree to participate in the workshop, read and sign the 'agreement to participate' section provided at the end of this form, and scan and return the signed copy to the project researchers by reply email.

I acknowledge that:

- I agree to participate in this study by participating in a workshop.
- I understand that I will not be able to participate in the workshop until I have signed and returned this consent form.
- I understand that the workshop will be recorded by both written notes that will be collected by the researchers and summarised, and by audio-recorder for transcription.
- I understand that the workshop will invite me to comment on matters relating to climate adaptation in the mining-value-chain of the Goldfields-Esperance region.
- I understand that the workshop will take about 8 hours and that I am free to leave at any time.
- I understand that my participation is entirely voluntary. I am free to not answer any question I choose and **I am free to withdraw my participation at any time without having to provide a reason for my withdrawal.**
- I have been provided with information about the project and had any questions regarding my participation and any associated risks and benefits answered to my satisfaction.
- I have been provided with contact details of the research officers and understand that I can contact them should I have any questions or concerns. I have also been provided with the contact details of an independent ethics officer at CSIRO should I wish to raise any concerns or complaints about the conduct of the research.
- I understand that the information provided for this research will be used to compile research reports, presentations and academic publications. I also understand that the information I offer will not be individually identifiable to anyone outside of the CSIRO project team. No individually identifying information will be made publically available at any stage of the writing process.

#### Agreement to participate

My signature below confirms that I have read and understood the information above, and agree to participate in the CSIRO research project workshop "Goldfields-Esperance Region mining-value-chain climate adaptation case-study".

Name: \_\_\_\_\_ Signature: \_\_\_\_\_ Date: \_\_\_\_\_



## Appendix E Interview schedule

Interview topic schedule:

- Nature of your role in the organisation
- Nature of your operations; how the 'business/production system' works
- Key drivers of business growth/ profitability/ productivity
- Key value chain components and connections; key constraints and opportunities
- Key issues facing your organisation and/or sector at the moment and into the future
- Problems in other sectors or components of the supply chain that affect your org.
- Problems in your organisation/ components of the supply chain that could affect others
- Experience with past weather events and climate variability and how it has affected your (mining) value chain
- Perceptions of future climate change and its expected impacts on your business/ organisation, including perceived barriers, opportunities and options to adapt
- Current weather and climate-related risk amelioration measures and strategies
- How your sector contributes to regional climate change adaptability

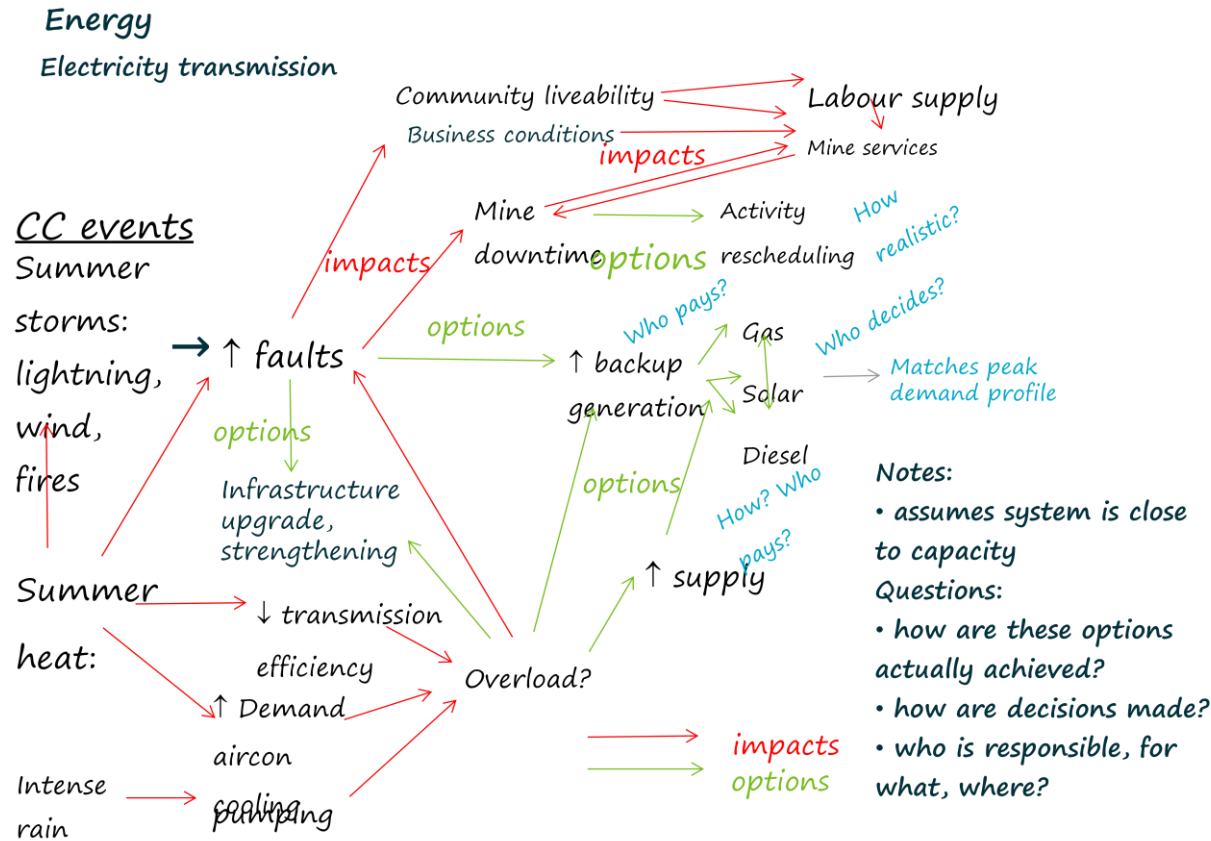
# Appendix F Mining value chain infrastructure

| INFRASTRUCTURE | COMPONENT  |
|----------------|--|
| Energy         | <ul style="list-style-type: none"> <li>• Coal powered electricity supplied through the South West Interconnected System (SWIS) (for more detail refer to Figure 14 in Appendix J);</li> <li>• Gas through the Goldfields Gas Pipeline (GGP) from the Carnarvon Basin and Northwest Shelf of Western Australia (for more detail refer to Figure 14 in Appendix J)</li> <li>• Diesel, powering generators in a number of towns and mines, particularly in locations remote from the SWIS and GGP</li> <li>• Wind turbines supply energy both from outside the region (Collgar Wind Farm, Merredin in the Wheatbelt region, into the SWIS) and within the region for Esperance which has a separate, mainly gas powered electricity grid</li> <li>• Solar to a small extent in some towns and mine sites</li> </ul>   |
| Water          | <ul style="list-style-type: none"> <li>• Potable water supplied through the Goldfields Water Supply Scheme (GWSS) from Mundaring Dam 40km east of Perth, by pipeline to Kalgoorlie and Norseman;</li> <li>• Treated groundwater systems supply a number of towns in the northern (Menzies, Leonora, Laverton) and southern (Esperance, Hopetoun) areas</li> <li>• Saline and hyper-saline groundwater is used by many mines in the region, some of which is desalinated onsite, however availability is not spatially consistent, often being determined by the local geomorphology of the site</li> </ul>   |
| Transport      | <ul style="list-style-type: none"> <li>• Roads – an extensive road network of (sealed and unsealed) Federal Highways, State Main Roads, Local Government local roads and streets, and private roads. Mining companies primarily maintain their private roads for access, ore haulage ('haul roads') and exploration purposes             <ul style="list-style-type: none"> <li>○ The Goldfields Highway runs north-south and is the main connector to:                 <ul style="list-style-type: none"> <li>▪ The Pilbara mining region in the north, via the Great Northern Highway</li> <li>▪ Esperance in the south, via the Coolgardie-Esperance Highway</li> <li>▪ The Great Eastern Highway runs east-west and is the main connector west to Perth.</li> </ul> </li> <li>○ The Eyre Highway, connecting to the Coolgardie-Esperance Highway at Norseman south of Kalgoorlie, also runs east-west and is the main road connection to the rest of Australia</li> <li>○ The Great Central Road is unsealed and is the main connector to Warburton in the far north-east of the region. It is part of the 'Outback Way', a mainly tourism route comprised of a number of highways running north-east across the Australian continent into Central Australia, the Northern Territory and eventually Queensland</li> </ul> </li> <li>• Rail             <ul style="list-style-type: none"> <li>○ The Eastern Goldfields Railway (EGR) from Perth to Kalgoorlie, which also links to:                 <ul style="list-style-type: none"> <li>▪ The Trans Australian Railway running east from Kalgoorlie to South Australia and connecting to all other States and Territories.</li> <li>▪ North-south lines from Leonora in the north through Menzies, Kalgoorlie, Kambalda, Norseman and finally Esperance in the south.</li> </ul> </li> </ul> </li> <li>• Port             <p>Esperance Port handles both bulk and containerised goods. The main mineral exports are bulk iron ore, bulk cereal grains and containerised nickel. The main imports are petroleum products, agricultural fertilisers, and sulphur (used in nickel smelting).</p> </li> <li>• Airports and airstrips             <ul style="list-style-type: none"> <li>○ Major airports are located at Kalgoorlie and Esperance, with scheduled flights, generally servicing the mining fly-in, fly-out workforce, also available at a number of smaller airports throughout the region (see Figure 9).</li> <li>○ Many mines have private airstrips</li> <li>○ Airports and airstrips provide a regular service not just for the transportation of labour but also of gold bullion to the Perth Mint</li> </ul> </li> </ul> |

|                               |  |
|-------------------------------|--|
| <b>Telecommunications</b>     | <ul style="list-style-type: none"> <li>• Fixed and mobile phone network</li> <li>• Internet services</li> </ul>  |
| <b>Mining services</b>        | <ul style="list-style-type: none"> <li>• A broad range of mining-related businesses are located in the region, including: drilling, engineering, construction, manufacturing, training, and consultancy services. A range of State agencies provide both services and regulate the industry. Most mining-related organisations are located in Kalgoorlie-Boulder with some in other smaller centres</li> </ul> |
| <b>Social &amp; community</b> | <ul style="list-style-type: none"> <li>• A range of Local and State government social services infrastructure – health, education, childcare, waste management, parks &amp; recreation facilities, police &amp; courts, emergency services, etc – supports the regional communities that the mining industry relies upon for mining services and labour supply</li> </ul>                                      |
| <b>Environment</b>            | <ul style="list-style-type: none"> <li>• The Great Western Woodlands is one of the largest and most intact remaining Mediterranean-climate woodlands in the world</li> <li>• A range of salt lakes (some used for mine saline waste water discharge)</li> </ul>  |

# Appendix G Workshop 'cascading impact' diagrams

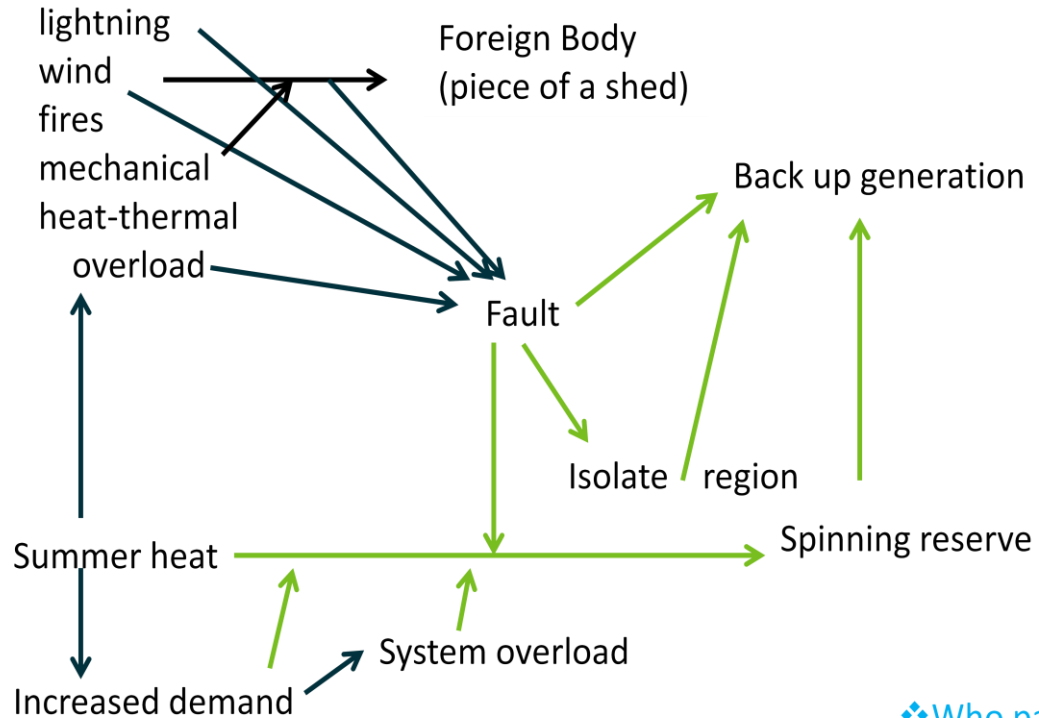
Example flow diagram provided to participants as guidance for the session task



## ENERGY

2

### Events



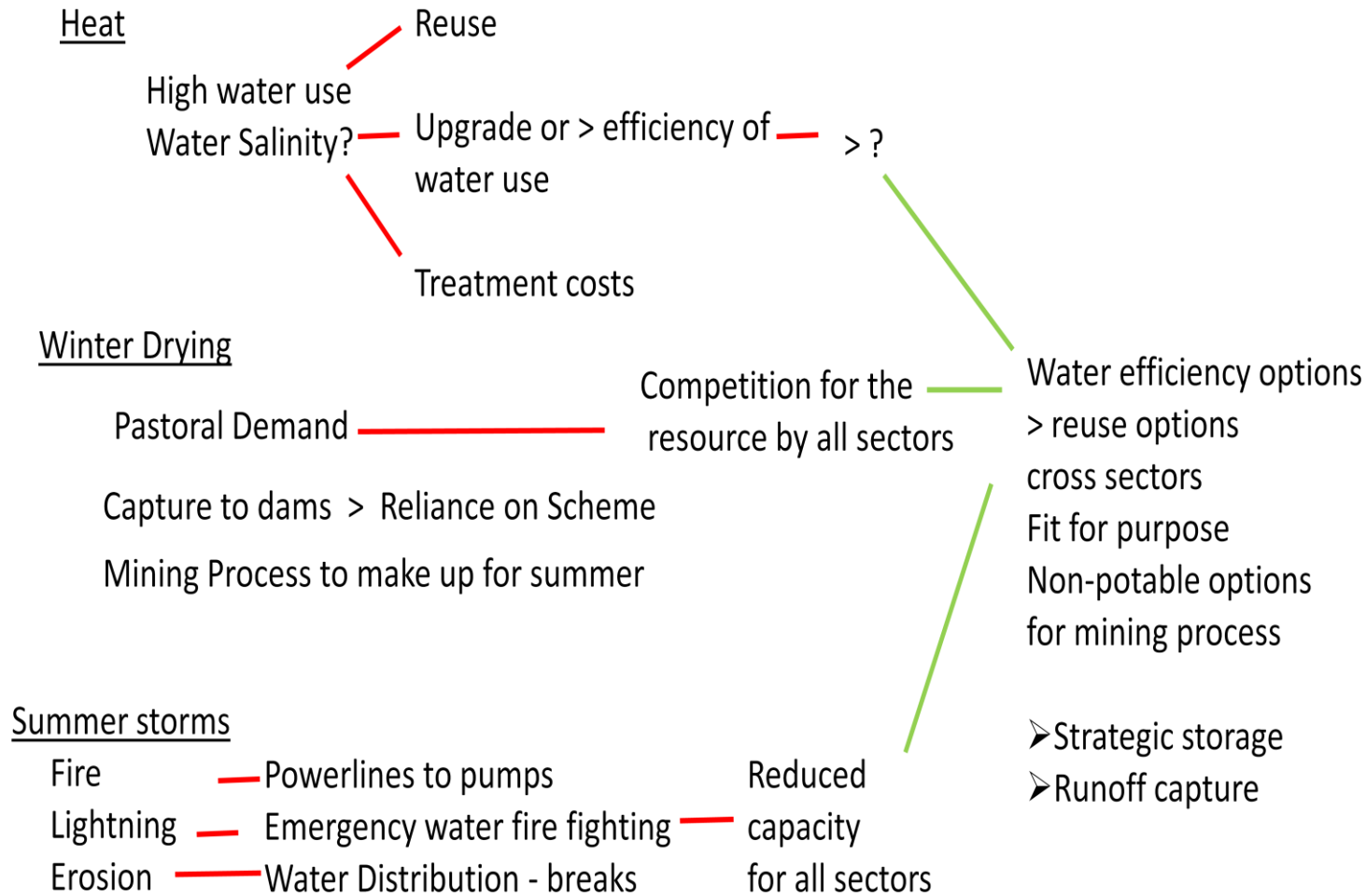
- ❖ Who pays
- ❖ Change the legacy of previous thinking
- ❖ Edge of grid generation
- ❖ Island Farm's and put them on hybrid systems

# WATER

1

Climate Change Events

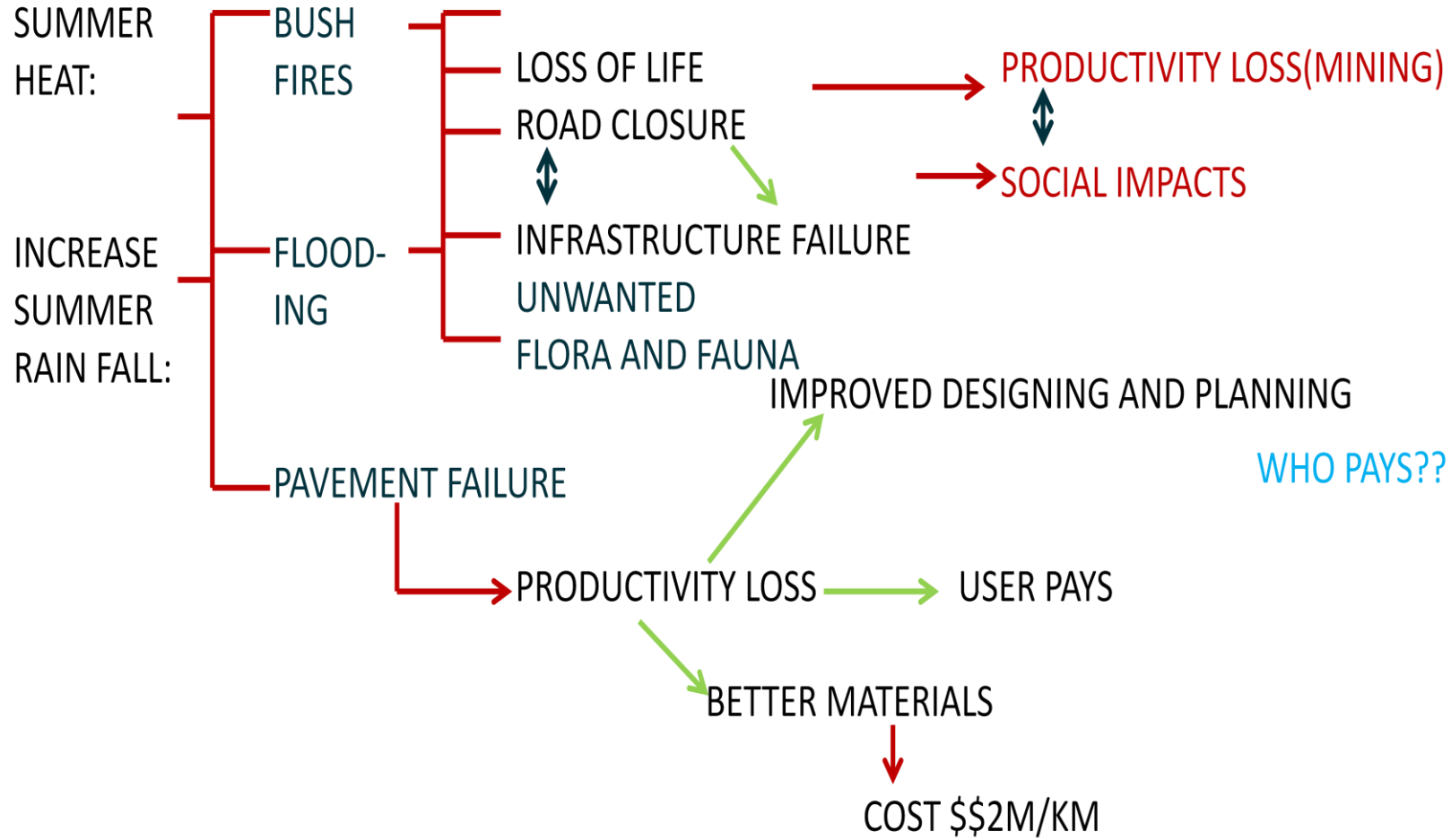
Water is a scarce and finite resource



# TRANSPORT

3a

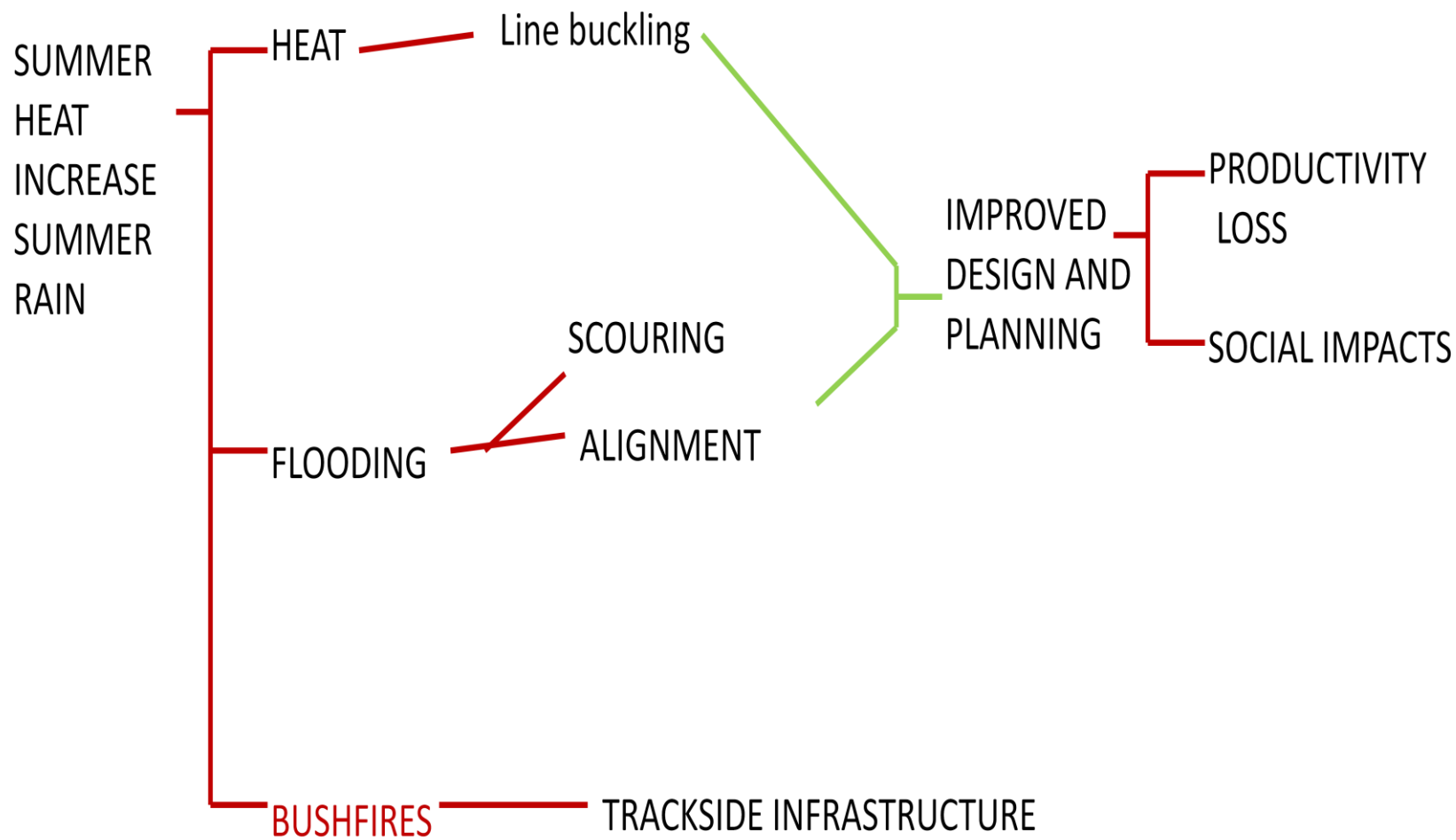
## ROADS



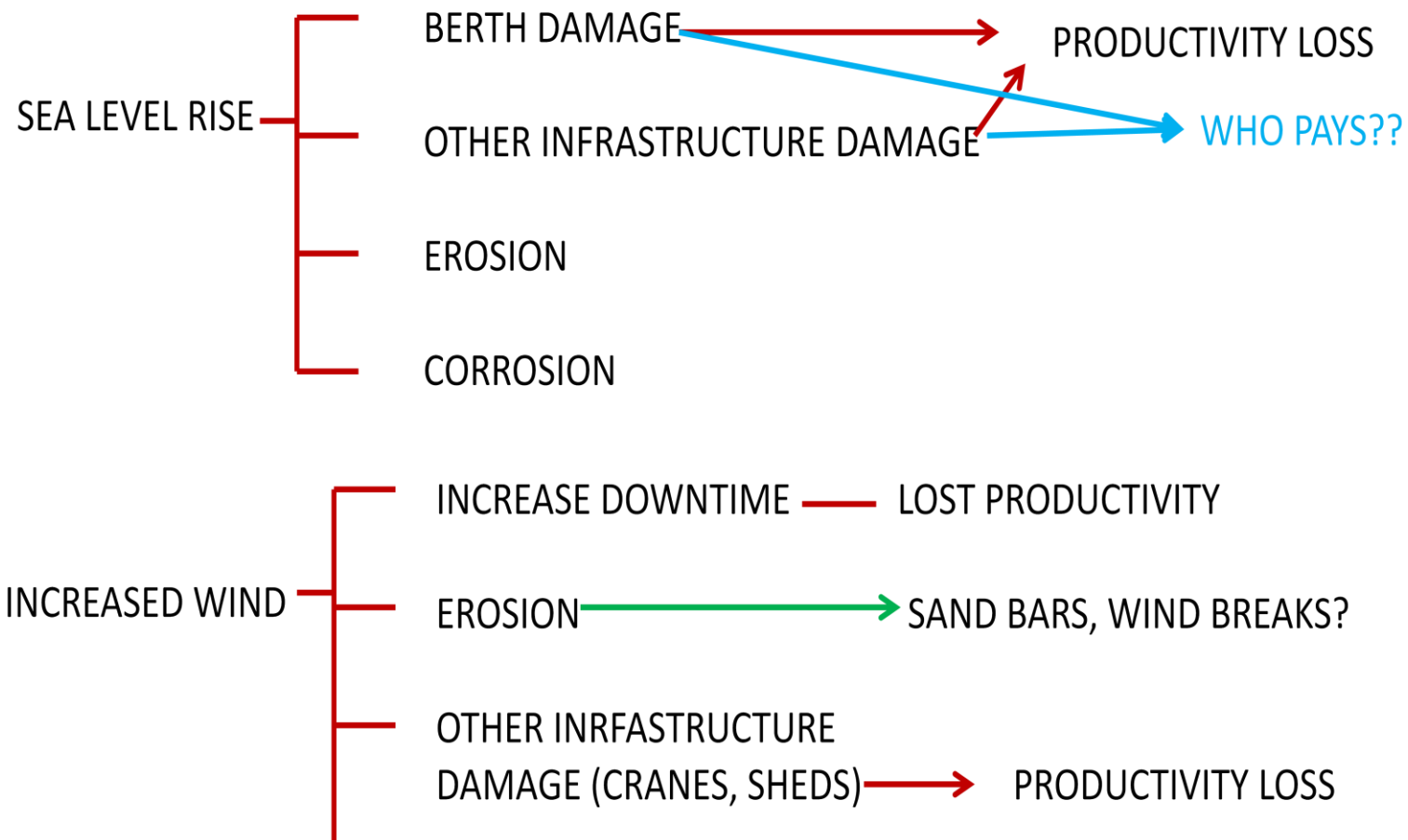


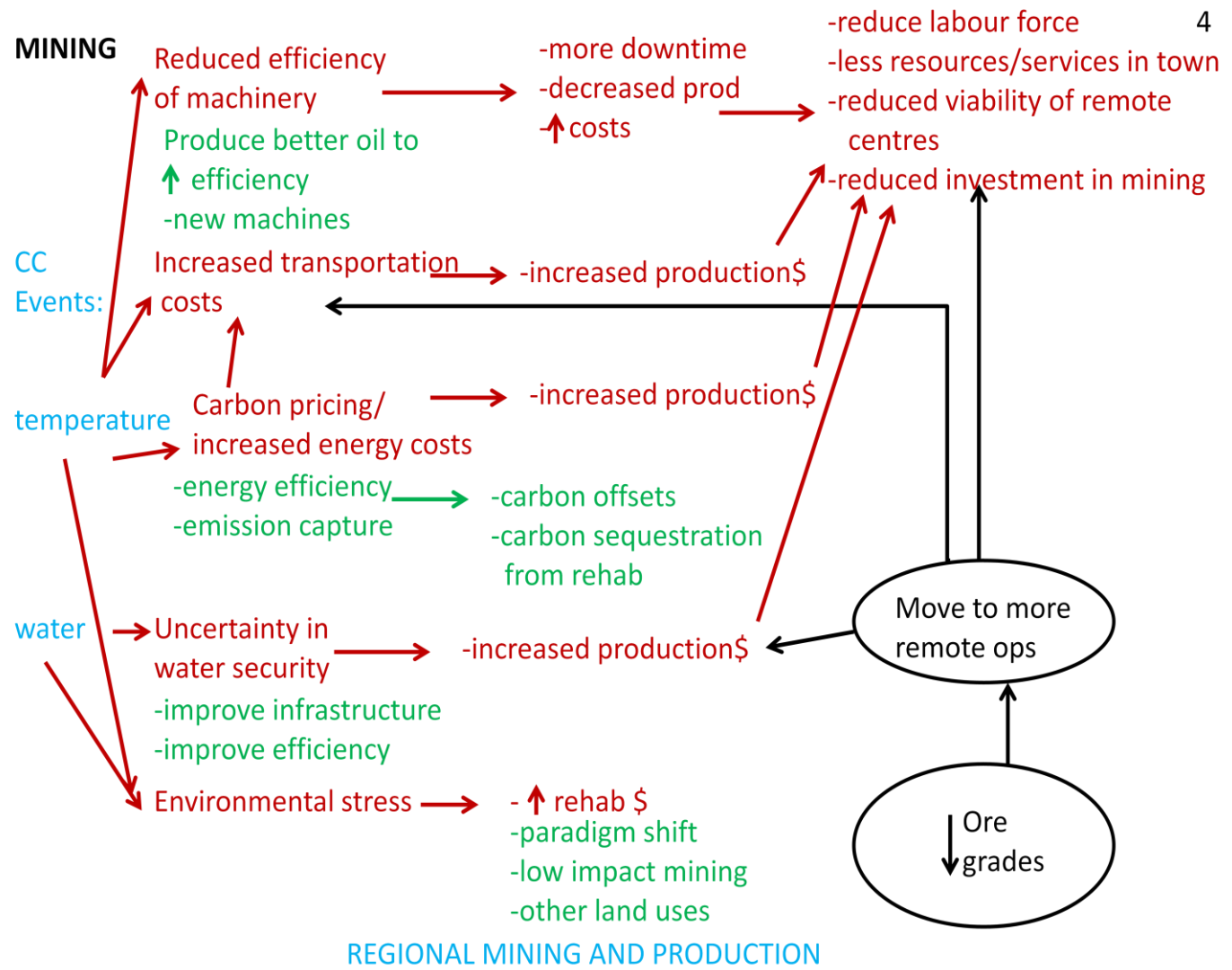
# RAIL

3b

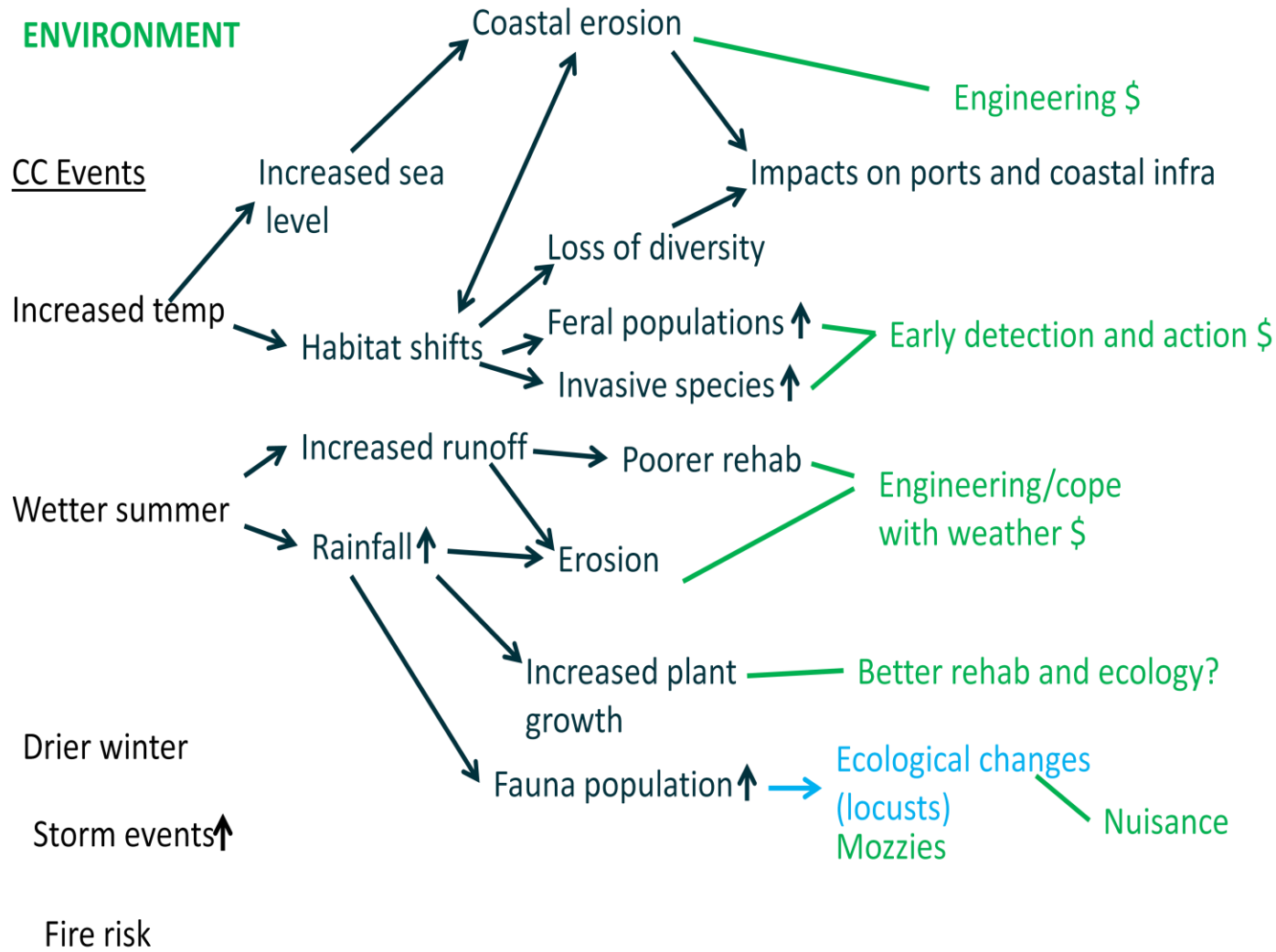


## PORT

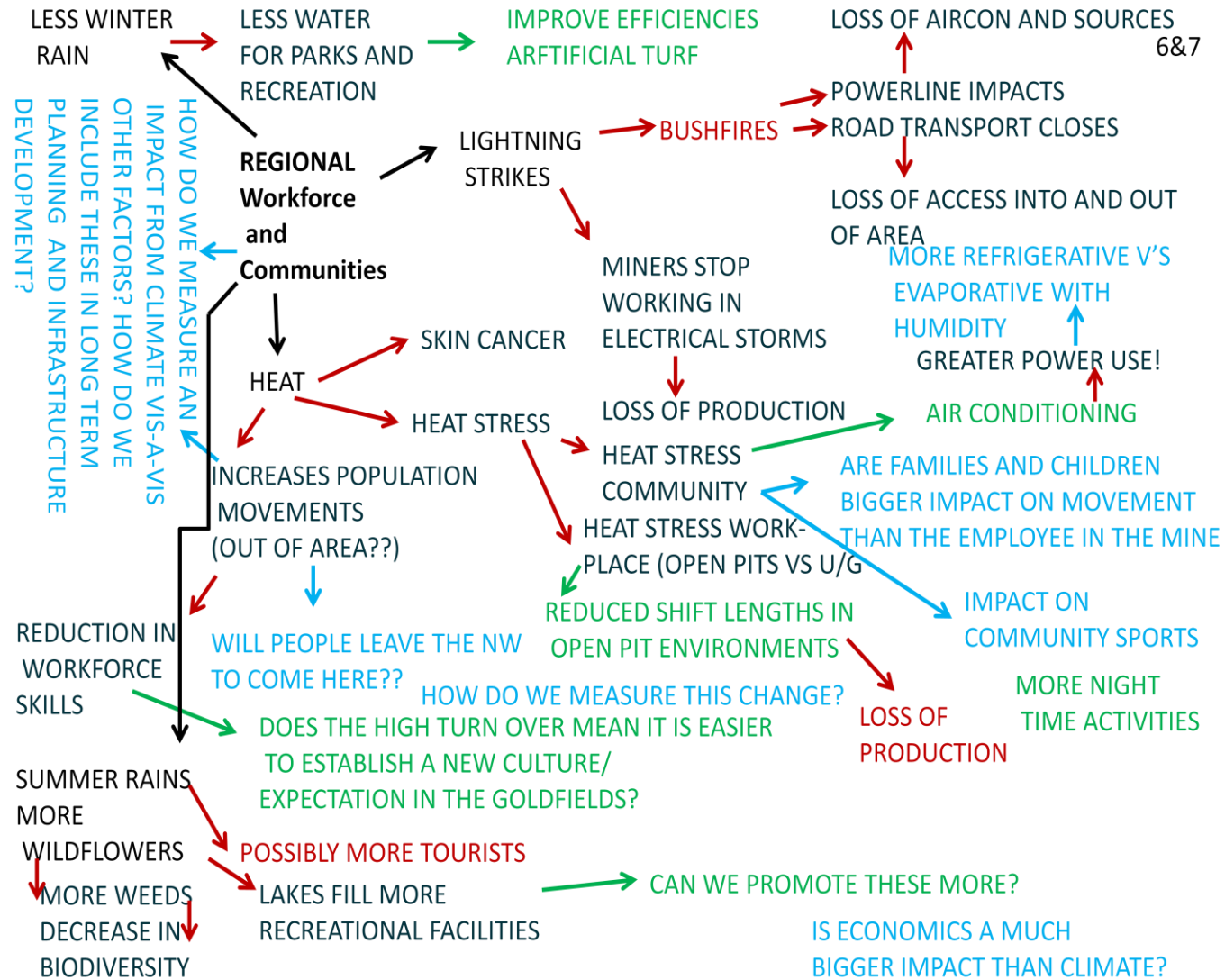




**ENVIRONMENT**



## Regional workforce and communities



## Appendix H Workshop Session 3b results: Adaptation Options

| Group    | Adaptation option description:              | Advantages  | Disadvantages   | Where, what and to whom are the 'wins' and 'losses' applied?   | Is it a 'win-win', 'no-regrets', 'win-lose' or 'high-regrets' option?  | Comments   |
|----------|---|---|---|--|--|--|
| WATER 1  | Water efficiency options                    | <ul style="list-style-type: none"> <li>↓ Peak &amp; overall demand</li> <li>↑ Life &amp; capacity of infrastructure</li> <li>↓ Cost</li> <li>Easy to adapt</li> <li>Available technology</li> </ul> | <ul style="list-style-type: none"> <li>False solutions</li> <li>Capital outlay</li> <li>Inertia/resistance to change/cultural change</li> </ul> | Nobody loses other than having to change   | Win-win  |  |
|          | Reuse options between sectors               | Fit for purpose and mutual benefit  | <ul style="list-style-type: none"> <li>Less water available to the environment</li> <li>Cost of water transport</li> </ul>                      | Mutual benefits provider and user  | <ul style="list-style-type: none"> <li>Win-win</li> <li>Missed opportunities</li> </ul>                                |  |
| WATER 2  | Water fit for purpose                       | Cost effective  | Cost  |  |  |  |
|          | Non-potable use for mining                  | Treat water and store water to standard required  |   |  |  |  |
|          | Non potable process schemes for mining      | <ul style="list-style-type: none"> <li>Cost effective</li> <li>Non potable</li> <li>Industry specific and negotiated within industry</li> </ul>   | Cost and distance – Eucla basin options or similar  | Participating companies water needs met  |  |  |
| ENERGY 1 | Solar hybrid generator (diesel/battery)     | <ul style="list-style-type: none"> <li>Reduced maintenance costs</li> <li>Reclaiming of network</li> <li>Less risk (safety – fire)</li> </ul>   | <ul style="list-style-type: none"> <li>Capital/outlay</li> <li>Set up cost</li> <li>Unit size meeting demand 'fit for purpose'</li> </ul>       | Losses to the supplier (of energy) <savings in maintenance   | <ul style="list-style-type: none"> <li>Buyer-no outage</li> <li>Supplier reduced costs (over time), win-win</li> </ul> | Trials suggest viable technological improvements in storage will facilitate            |
|          | Mini nuclear power station (self contained) | <ul style="list-style-type: none"> <li>Clean generation</li> <li>No refuelling</li> <li>1/3 cost of PV</li> </ul>   | <ul style="list-style-type: none"> <li>Waste disposal</li> <li>Safety</li> </ul>  | <ul style="list-style-type: none"> <li>End user</li> <li>State – uranium sales</li> <li>Losses – environment (waste)</li> <li>Win – environment (emissions)</li> </ul> |  | <ul style="list-style-type: none"> <li>Public perception</li> <li>Political</li> </ul> |

| Group                          | Adaptation option description:                        | Advantages  | Disadvantages   | Where, what and to whom are the 'wins' and 'losses' applied?                               | Is it a 'win-win', 'no-regrets', 'win-lose' or 'high-regrets' option? | Comments   |
|--------------------------------|---|---|---|--|---|--|
| <b>TRANSPORT 1</b>             | User pays   | Pay only for what you need<br>Reduced usage?<br>Influence individual behavior<br>Funds directed to roads  | Political will<br>Mining productivity impacted                  | Reduced carbon footprint<br>More funding available for network                             | Win – road service level<br>Lose - mining                             |  |
| <b>TRANSPORT 2</b>             | Roads – widen verge clearance                         | Reduce risks and results of incr. roadside veg and fauna after increased summer rain                      | Habitat loss<br>Increased barrier to fauna movement             | Wins – all road users. Safety<br>Losses – natural environment – tourism (roadside flowers) | Win-lose  |  |
|                                | Polymer binder to replace asphalt                     | Temp resistant<br>Increase traffic  | Cost (+30%)<br>C footprint                                      | Win - longer lasting; Temp resistant surface<br>Loss – cost, C footprint                   | Win-lose  |  |
| <b>MINING AND PRODUCTION 1</b> | Produce machinery efficiency and create new machinery | Increased production<br>More economical   | Research and development cost<br>Lag time                       | Companies<br>Community<br>Investors  | Win-win<br>Win-win<br>Win-win   | Increased production<br>Possibly increased capital cost but overall win-win<br>Keep job<br>Increased investment<br>Mining regional areas |
|                                | Energy efficiency and carbon offsets                  | Tax rebates<br>More rehab<br>Biodiversity<br>Offsets paid by mining companies<br>Reduce CO2<br>Atmosphere | Research and development cost<br>More expensive than carbon tax | Companies<br>Community<br>environment  | Win-win<br>Win-win<br>Win-win   |  |
| <b>MINING AND PRODUCTION 2</b> | High density tails                                    | ↓leaching<br>↓water use<br>↓landform footprint<br>↑life<br>↑stability                                     | ↑ Capital cost  | Company ↓cost<br>↑water availability community   | Win<br>Win  |  |



| Group                          | Adaptation option description:   | Advantages  | Disadvantages   | Where, what and to whom are the 'wins' and 'losses' applied?  | Is it a 'win-win', 'no-regrets', 'win-lose' or 'high-regrets' option? | Comments |
|--------------------------------|--|---|---|---|---|----------|
|                                | Leak detection   | ↓water use  | ↑Opportunity costs (Small)  | Company ↓costs  | Win   |          |
|                                |  | ↑\$savings  |   | Community ↑water availability   | Win   |          |
| <b>MINING AND PRODUCTION 3</b> | Alternative rehab models   | Research<br>Innovation<br>New techniques  | Cost  | Environment wins<br><br>Environment losses  | Win-win   |          |
| <b>ENVIRONMENTAL 1</b>         | Engineering of coastal erosion options e.g. Groyms, sea walls etc geofabrics | Stabilize foreshore<br>Protect infrastructure<br>Protect ESAs   | Imbedded carbon footprint if concrete used<br>High cost<br>Visual amenity<br>Scouring of sediment<br>Introducing 'non natural' engineering<br>Changes sediment movement | WIN<br>infra,<br>adjacent coastal habitat industry<br><br>LOSS: Financiers, beach further along                     | Win-lose  |          |
|                                | Early detection and control program  | Early detection<br>Preventing outbreak and spread<br>Containment<br>Having the collected knowledge<br>Compliance with govt. | Cost<br>Social impacts<br>Inadvertent spreading   | WIN: ecology, biodiversity, native flora and fauna, community, tourism<br><br>LOSS: company money, time, production | 'no regrets'  |          |
| <b>ENVIRONMENTAL 2</b>         | Waste dump design  | Performance<br>Relinquishment<br>Containment of contaminants<br>Habitat creation  | Cost<br>Could be a poor design – no guarantees<br>Areas are all different   | WIN: mining companies, environment, community and recreation<br><br>LOSS: mining companies, environment, community  | Could be all!<br><br>No perfect recipe                                |          |
|                                | Resilient  | Community<br>Compliance   | Poor weather can have a severe effect   |   |   |          |

| Group                                  | Adaptation option description:                              | Advantages   | Disadvantages   | Where, what and to whom are the 'wins' and 'losses' applied?  | Is it a 'win-win', 'no-regrets', 'win-lose' or 'high-regrets' option?               | Comments |
|--|---|--|---|---|---|----------|
| <b>COMMUNITY AND HUMAN RESOURCES 1</b> | Shorter shifts on mine sites                                | Reduces impact of heat stress  | Will cost companies more  | Companies (win & lose)  | Win-win for safety  |          |
|  |   | Improved OHS   | Workers don't like shorter shifts as they're paid less  | Individuals (win & lose)  | Win-win for more involvement with community<br>Win-lose for staff as get less money |          |
|  | More night time sporting activities                         | Cooler<br>No cancer<br>Out of the sun  | Less time to socialise after evening<br>Work the next day<br>Use more lighting/ power   | Cost to council and sporting clubs<br>Increase in power use and CO2 emissions<br>Win to sporting clubs/sector because of increased participation<br>Win to individuals with increased health/ fitness | >Win-lose<br>>Lose<br>Win-win<br>Win-win  |          |
| <b>COMMUNITY AND HUMAN RESOURCES 2</b> | Higher turnover of workforce (due to heat/climate movement) | Easier to establish change management<br>Innovation<br>New ideas<br>New work culture | Transient population<br>↓<br>Social impacts<br>↓<br>Community instability<br>Lack of support mechanisms<br>Impacts on schools<br>Planning in constant state of flux<br>Established leaders cannot be easily influenced by incoming population | Community wins and loses  | High-regrets  |          |

## Appendix I Workshop Session 4 results: Barriers and enablers to adaptation

| SECTOR    | 'Desirable' adaptation option description:    | Barriers   | Enablers   | Any unintended consequences?   |  |  |
|-----------|---|--|--|--|--|--|
|           |   | What makes it hard to achieve this adaptation option?                    | What would make it easier, how could this barrier be overcome? | What possible disadvantages are there to overcoming this barrier?                              | What extra advantages come from overcoming this barrier?                                       | What are the points of disagreement & why? |
| WATER     | Water efficiency                              | Cultural change  | Incentives for early adopters                                  | Capex req'd  | Conserve the resource  | Complacency<br>cost                        |
|           |   | Initial cost   | Education<br>Corporate policy<br>Contracting outside expertise | Design complications<br><br>Requires changes<br>compliance<br>> internal<br>> external         | Corporate reputation<br>Community recognition<br>Sustainable business<br>\$ + culture/attitude |  |
| ENERGY    | Solar hybrid concept                          | Agreement by political parties<br>Stakeholder engagement<br>\$\$ funding | Improvements in technology<br>Understanding and education      | Customer decides to stay with existing network   | Reliability of supply In the event of fire, customer has supply<br><br>Less potential risk     | Misunderstanding and political barriers    |
| TRANSPORT | Poly binder for bitumen roads                 | Capital cost   | Economic analysis to show long term benefits                   | 1 – CO2 emissions?<br>2 – risk of product functionality<br>3 – transport – mobility of product | Long life of road construction   | Could fail                                 |
|           | Clearing - greater road verge -vegetation     | 1 – public not supportive<br>2- cost<br>3 – maintenance                  | Public support may result from loss of lives (road crashes)    | Loss of vegetation habitat   | 1-fire control<br>2-flood control<br>3-less fauna killed                                       |  |
| MINING    | Produce efficient machinery and new machinery | Might not have technology<br>Time required to develop                    | Money<br>Government support<br>Research support                | More intensive mining exploiting the environment<br>Product function (new technology)          | New technology might not have been investigated<br>Could be used in other areas                | Consequences to the environment            |

| SECTOR                        | 'Desirable' adaptation option description:                     | Barriers  | Enablers   | Any unintended consequences?                                      |   |  |
|-------------------------------|--|---|--|---|---|--|
|                               |  | What makes it hard to achieve this adaptation option? | What would make it easier, how could this barrier be overcome? | What possible disadvantages are there to overcoming this barrier? | What extra advantages come from overcoming this barrier?            | What are the points of disagreement & why?                       |
| ENVIRONMENTAL                 | Early detection and control program for invasive/feral species | Humane feral animal control                           | Using ethical methods  | Inadvertently harming other animals                               | Preserving areas of biodiversity                                    | Ethics<br>Further destruction of other species<br>Safety aspects |
|                               |  | Access issues   | Implementing management plan and ecology surveys               |   | Being able to manage feral outbreaks our self                       |  |
|                               |  | Reducing disturbance to other organisms               | Support from neighbouring properties                           |   |   |  |
|                               |  | Collaborations eg with neighbors                      |  |   |   |  |
|                               |  | Costs   |  |   |   |  |
|                               |  | Compliance  |  |   |   |  |
| COMMUNITY AND HUMAN RESOURCES | Shorter shifts   | Cost  | Flexible management  | Cost\$\$  | New ideas   | Management ideas   |
|                               |  | Company policy  | Paradigm shift   |   | Innovation  | Management focus   |
|                               |  | Commitment  |  |   | More leisure hours  | Management cost  |
|                               |  |   |  |   | More community involved   |  |
|                               | Sporting activity at night                                     | Social time is discretionary                          | Standard rostering   | Community desire and impact                                       | Less heat<br>Less activity during the day<br>More use of facilities | Function and dysfunction of community desires                    |

| SECTOR                        | 'Dysfunctional' adaptation option description:     | Barriers   | Enablers  | Any unintended consequences?   |  |   |
|-------------------------------|--|--|---|--|--|---|
|                               |  | What makes it hard to AVOID this adaptation option?  | What would make it easier to avoid, how could this barrier be overcome?             | What possible disadvantages are there to overcoming this barrier?          | What extra advantages come from overcoming this barrier?   | What are the points of disagreement & why?  |
| WATER                         | Re-use of water                                    | Freely available and cheap resource  | True cost of treating water / replacement of equipment (corrosion)                  | Increased production cost  | Corporate reputation   | Cost  |
|                               | Hyper saline for dust<br>→ corrosion<br>→ veg loss | Works well<br><br>(helps bind road)  |   | More rapid degradation of road   | Regulatory compliance  | Easier now - versus<br>Damage to equipment and Environment                        |
| ENERGY                        | Nuclear power station                              | Fear for safety and environment  | Education and consultation  | Long term effect of the disposal of waste                                  | Lower cost and more reliable power   | Political views<br>Environmental views<br>State and Federal legislation           |
| TRANSPORT                     | Win lose<br><br>User pays                          | Gov commitment   | Community and industry lobbying   | Roads will deteriorate   |  |   |
| MINING                        | Alternative rehab models                           | If temp and water availability changes environment will change, then need to change rehab model<br><br>Difficult to maintain rehab standards with conditions now | Continued monitoring of environment and Research into best practice rehab           | Costly<br>Labor intensive<br>Which means companies wouldn't implement them | Reaching an improved environmental outcome<br><br>May not be original state but better than no rehab | Buy-in, convincing people (re) different model                                    |
| ENVIRONMENT                   | Engineering option for coastal erosion             | Lack of coastal engineering knowledge<br><br>Difficult to combat coastal erosion in a non physical way<br>Cost and design constraints                            | Technological advancement<br><br>Contracting experts to provide alternative options |  | Aim to have less impact on the coast as a whole  | Impact on visual amenity<br><br>Environmental impacts<br><br>Public access issues |
| COMMUNITY AND HUMAN RESOURCES | Shorter shifts                                     | Cost<br>Company policy<br>Commitment   | Flexible management<br>Paradigm shift   | Cost\$\$\$   | New ideas<br>Innovation<br>More leisure hours<br>More community involved                             | Management ideas<br>Management focus<br>Management cost                           |
|                               | Sporting activity at night                         | Social time is discretionary   | Standard rostering  | Community desire and impact  | Less heat<br>Less activity during the day<br>More use of facilities                                  | Function and dysfunction of community desires                                     |

# Appendix J G-E region energy supply

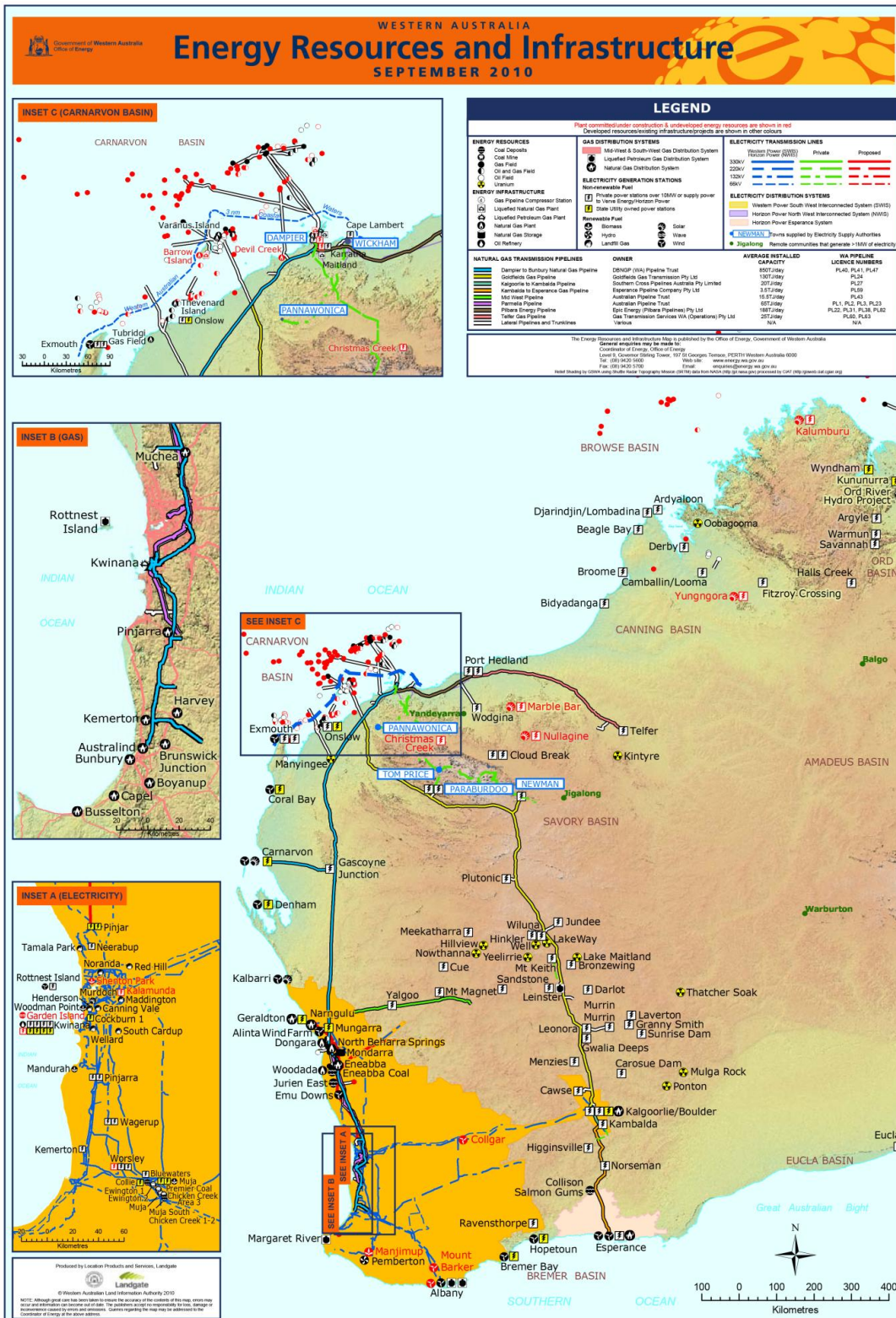


Figure 14 WA energy infrastructure map showing the South West Integrated System (SWIS) and gas pipelines

Source: WA Department of Finance – Public Utilities Office 2013





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