

Climate change adaptation, energy futures and carbon economies in remote Australia: a review of the current literature, research and policy

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Contents

Executive summary	1
Key findings	3
General	3
Liveability	4
Vulnerability and adaptive capacity	5
Energy	6
Carbon	6
Climate, energy and carbon assessment methods	7
Government Policies	8
Introduction	10
Section 1: Climate scenarios	13
Section 2: Liveability	21
Section 3: Vulnerability and adaptive capacity	29
Section 4: Energy needs	36
Section 5: Energy costs	38
Section 6: Alternative energy sources	40
Section 7: Carbon: storage and abatement	43
Section 8: Carbon – social and economic benefits	46
Section 9: Government policies	49
Government policies: Climate change	49
Government policies: Energy cost	51
Government policies: Carbon economies	54
Section 10: Methods	55
Methods: Climate change	55
Methods: Climate change adaptation	58
Methods: Energy scenarios	60
Methods: Carbon scenarios	62
Conclusions	64
References	69
Appendix 1: Search methods	83

Tables

Table 1: Present (1964–2003) and projected number of days above 35°C at eight remote Australian towns under low (L) and high (H) emission scenarios	16
Table 2: Present (1964–2003) and projected number of days below 0°C at eight remote Australian towns under low (L) and high (H) emission scenarios	16
Table 3: The likelihood of percent changes to temperature and rainfall for four sites in remote Australia as indicated by the CSIRO RCF tool	20
Table 4: Access to basic infrastructure and services	22
Table 5: Regional and community infrastructure and services	24
Table 6: Potential adaptations responses of the grazing system to climate change vulnerability	34
Table 7: Number of renewable power stations greater than 3kW and total capacity by remoteness. Source: Data on locations and characteristics of generators from Geoscience Australia, compiled October 2010 (Australian Government Department SEWPaC 2010)	41
Table 8: Weaknesses and strengths of regionalisation tools	57
Table 9: Approaches to climate change assessment	59
Table A10: Summary of searches conducted through Web of Science database with search criteria which included literature related to <i>climate adaptation</i> in remote communities (date of search 13 July 2011)	84
Table A11: Summary of searches conducted using the Web of Science database with search criteria which included literature related to <i>energy</i> in Australian remote communities (date of search 13 July 2011)	84

Figures

Figure 1: Remoteness classes for Australia	11
Figure 2: The ‘desert drivers’ that critically determine how deserts work	12
Figure 3: Average temperature changes for 2070 relative to 1990, from 15 models using low, medium and high emission scenarios	14
Figure 4: Average percentage rainfall changes for 2070 relative to 1990, from 15 models using low, medium and high emission scenarios	15
Figure 5: Annual rainfall change for 2070 from baseline 1990 under low, medium and high emission scenarios	17
Figure 6: Annual temperature change for 2070 from baseline 1990 under low, medium and high emission scenarios	18
Figure 7: Areas in remote Australia for which the likelihood of global warming was calculated using the CSIRO RCF tool	19
Figure 8: Transport infrastructure, towns and settlements in remote Australia	26
Figure 9: Renewable power stations greater than 3kW and total capacity in remote and very remote Australia	40
Figure 10: Links between broad categories of models and scenarios involved in producing local climate change information	55
Figure 11: Four major phases of the adaptation cycle	58

Executive summary

This report is a review of current literature and research on climate change projections, impact, vulnerability, adaptation, energy futures and carbon economies in remote Australia. It is intended to inform research frameworks and directions for the research project Climate Change Adaptation, Energy Futures and Carbon Economies in Remote Australia within the Cooperative Research Centre for Remote Economic Participation (CRC-REP).

Remote Australia is defined to include both Remote and Very Remote Australia according to the Australian Bureau of Statistics (ABS) (ABS 2012). Remote Australia has notably different characteristics from the rest of Australia. In the 2006 census (ABS 2006), remote Australia was home to 470,000 people – including 2.3% the Australian population overall, but 24% of Australia's Aboriginal and Torres Strait Islander population. While diverse, remote Australia has shared systemic properties as well as a shared history of persistent disadvantage and poverty, particularly among many of its Aboriginal and Torres Strait Islander residents. These systemic, remote-region characteristics will interact with climate change and energy futures, resulting in impacts, vulnerabilities and opportunities different from those in coastal regions of Australia.

Key conclusions:

- The individuals and communities of remote Australia are expected to be more vulnerable to climate change scenarios. Most Aboriginal and Torres Strait Islanders are understood to be especially vulnerable because of their current positions of social and economic disadvantage, but this needs investigation at a local level on a case-by-case basis; and a typology of vulnerability and adaptive capacity is required to facilitate future development of adaptation pathways.
- Vulnerability and adaptive capacity of the pastoral industry have been assessed in some detail, but other industries and businesses have received scant attention and their needs are known only in a generic sense.
- There have been no detailed case studies of remote settlement liveability under climate change scenarios. Increasing temperatures and more frequent heat waves have been identified as the most significant influences on future liveability of remote communities. Existing extensive and chronic health issues are generally expected to worsen, especially for socio-economically disadvantaged individuals and communities. Vector-borne diseases are likely to increase in incidence and prevalence, but there is limited understanding on causal pathways and no agreement on likely increase in prevalence or new incidence of some of the pathogens.
- Mobility and transport is critical to all social and economic activity in remote Australia and increasing transport energy costs will be experienced disproportionately by remote Australians, yet there have been few studies (e.g. Raicu et al. 2011) on the impacts and opportunities arising from escalating transport costs.
- Business models for viable renewable energy generation facilities to service remote communities are not well developed. Many community facilities require subsidies, do not have personnel providing on-site maintenance needed for guaranteed continuity of supply, and lack depreciation plans for future capital replacement.
- Many studies report the enterprise potential for large-scale renewable energy production in remote Australia, with transmission to distant markets. The limited economic analyses, however, suggest the high costs of transmission mean that viable large-scale generation is likely to be limited to the fringes of remote Australia.

- Carbon-based enterprises have been found to offer a significant opportunity for wellbeing of remote Australians. Especially in higher rainfall zones, and assuming that future carbon prices do not devalue dramatically, carbon farming has potential to be the most valuable economic activity on lands that have low potential for forestry or pastoral grazing, as demonstrated by the WALFA savanna burning project in western Arnhem Land. There is a clear need for business models of all other biophysically possible combinations of carbon farming activities and ecosystem types.
- Carbon farming generates significant health, social and cultural benefits for Aboriginal and Torres Strait Islander people because of the close alignment of traditional Law and land management practice with carbon farming activities and because it is encouraged by government policy. These ‘co-benefits’ also have an economic value as a price premium on carbon offsets – recently up to \$2 per tonne CO₂-equivalent.
- There is strong government policy for climate change adaptation action plans at national and state levels, but impacts at the local level are variable. There has been limited reporting of adaptation at community and local-government levels in remote Australia. Energy policies do not form a coherent body and are often contradictory, for example, simultaneous promotion and subsidies of fossil fuels and renewable energy technologies. Carbon policy is relatively integrated at the national level through the Clean Energy Future plan, but is not yet fully implemented and thus remains untested.
- There has been extensive work by the Bureau of Meteorology, CSIRO and others to develop national-scale forecasts of climate change. Downscaling models for regional and local forecasts exist but have high requirements for historical data, and application of these models in remote Australia has been hampered by lack of suitable input data. Infrastructure is expected to deteriorate more rapidly and suffer more frequent major damage due to extreme events, leading to higher replacement, depreciation and insurance costs, which are likely to be costed through higher service charges and higher taxation. Coastal ecosystems are expected to be sensitive to sea-level. There is speculation about range shifts for terrestrial biodiversity, and different species are likely to shift at different rates, but there have been no detailed studies in remote Australia. Southern pastoral areas have been identified as most vulnerable to changing climate, while northern pastoral areas are more likely to have higher potential productivity, but this may be offset by higher impacts of pests and diseases.
- In remote Australia, energy needs will be driven by the interaction of demography, poverty alleviation, increased cooling demands, increased telecommunications and increased mining. Net projections have been calculated for the mining industry and at state/territory level, but there has no local or community-scale assessment that links to opportunities for alternative energy supplies.
- The magnitude of emissions abatement through fire management in higher rainfall savannas is well understood and is formalised as a model-based methodology for the Carbon Farming Initiative. At low rainfall, rates of carbon sequestration and emissions reductions may be marginal compared with management and monitoring costs; research is required to see whether the constraints are outweighed by the opportunities offered by large management areas.
- Methodologies for measuring climate and detecting climate change are well-developed nationally and internationally through IPCC and participating research organisations, but data are relatively sparse for much of remote Australia because of the low population density. Measurement of ecosystem carbon pools and fluxes is highly underdeveloped, due to limited past research and the very high spatial variability (patchiness) of carbon in most ecosystem types, which necessitates large numbers of analysed samples to achieve confidence in any one measurement. Extensive current research activity is addressing the need for carbon farming methodologies to be applied to other carbon farming activities and in other ecosystems, in readiness for the start of the formal carbon market in July 2012.

Key findings

As this literature review is broad and comprehensive, key points and observations relevant to remote Australia are compiled below to help the reader identify areas of interest within the report. Note that very remote areas of Australia are included in our definition of remote Australia for the purposes of this report. Detailed information is provided in the main body of the report which has Climate scenarios in Section 1, Liveability in Section 2, Vulnerability and adaptive capacity in Section 3, Energy in Sections 4, 5 and 6, Carbon in Sections 7 and 8, Government policies in Section 9 and Methods in Section 10.

General

1. Climate change will interact with and likely amplify many of the shared systems characteristics of outback Australia. The likely amplifying effects of climate change on remoteness characteristics, as well as interaction with historical disadvantage and persistent poverty, particularly among many Aboriginal and Torres Strait Islander Australians in remote Australia, may have significant equity implications and can make efforts to close the gap between Aboriginal and Torres Strait Islanders and other Australians even harder and more complex than it is currently.
2. All is not gloom with climate change. Greenhouse gas mitigation and renewable energy development efforts can enhance some existing, and provide new livelihood and enterprise opportunities for Aboriginal and Torres Strait Islanders and other land managers. These opportunities will be in improved and expanded management of land, soil, fire, feral animals and weeds for both biodiversity and greenhouse gas mitigation outcomes. Aboriginal and Torres Strait Islander people will be able to build on their knowledge, skills and customary practices of caring for country, thereby providing an expanded opportunity to be and do what they value (Maru & Chewings 2011). Current efforts on ranger programs and work by West Arnhem Land Fire Abatement (WALFA) and Centrefarm to engage with carbon economies are encouraging examples.
3. Currently, remote Australia is heavily dependent on fossil fuel for its energy needs. Notwithstanding institutional barriers, remote Australia has a vast potential for production of renewable energy for both domestic use and supply to coastal regions and possibly to Southeast Asia. Current work by the Centre for Appropriate Technology (CAT) with many remote communities is laudable. Scaled-up renewable energy production and transmission from remote Australia assists a low carbon economy and is a significant opportunity for employment, livelihoods and development in remote Australia (Pittock 2011). Capturing these opportunities would require research support on technical, institutional, legal, financial, cultural and behavioural barriers to production, transmission and adoption of renewable energy sources.
4. Remote Australia will be hotter, particularly in inland regions. It will experience more intense and frequent droughts, heatwaves and fires. There will be more intense storms, floods, rainfall events and tropical cyclones. Coastal regions of remote Australia will experience inundation from sea-level rise.
5. At a coarse regional level, there are online facilities provided by the Department of Climate Change and Energy Efficiency and by CSIRO that assist in simulating climate change projections of locations in Australia. However, there is a need for downscaling to improve the climate change predictions for local impact assessment.
6. Some downscaling methods have high quality, historical regional data requirements that may not be available in remote regions. Decisions about using regionalised climate change information need to consider the feasibility and added value to be gained from downscaling.

7. There is a need to facilitate stakeholder-based regional future scenarios that account not only for climate change but also other drivers and stressors such as land use, population and economic growth. Such exercises, as exemplified by a system dynamics modeling workshop on climate change in Alice Springs and facilitated by a team of researchers from Charles Darwin University (Livelihood and Policy Group 2008), will be important to stakeholders for creating a systemic and shared view about the future as well as an awareness of the role of climate change in the future of the region, and to explore collaborative pathways for adaptation.

Liveability

8. This review has found limited detailed study on how climate change is likely to affect the liveability of Aboriginal and Torres Strait Islander settlements in remote Australia. However, gradual change in climate and likely increases in intensity and/or frequency of extreme events are expected to interact with and exacerbate the existing poor state of basic infrastructure and services such as housing, water, energy sewerage and transport systems adversely affecting liveability of remote settlements.
9. Damage to transport infrastructure from impacts of climate change and likely increases in extreme events will increase disruption to the provision of goods and services. Remoteness, and limited alternative routes, may result in significant delays and failures of emergency, rescue and relief efforts.
10. The likely increase in the intensity and/or frequency of some types of extreme events (e.g. heat waves, fires and flooding) is likely to increase the rates of depreciation of transport and other basic settlement infrastructure.
11. Increased hardship and decline in liveability from climate change will further reduce attractiveness of remote regions to recruit and retain educators, health workers and other employees and employers as well as businesses.
12. There are limited detailed health impact and vulnerability studies, particularly on desert remote Australia. The broad health impact studies indicate that climate change and likely increases in attendant extreme events will have significant direct and indirect adverse health impacts on remote Australia, mainly because of interactions with pre-existing extensive and chronic health issues, limited and inadequate health services, and chronic socio-economic disadvantage, particularly among Aboriginal and Torres Strait Islander residents.
13. Although the extent and types of extreme events will vary between remote settlements, each event can have a direct impact on lives causing injuries, death and displacement from settlements, and further indirect impact through damage and disruption to already poor basic services and infrastructure.
14. Although specific pathways are not yet fully known, climate change and extreme events will alter habitats and environments for pathogens, causing likely increases in the incidence and prevalence of several vector-, water-, food- and air-borne diseases.
15. Deaths, destruction to sacred and highly valued places and items, loss of livelihood sources and displacements are likely to increase psycho-social health problems, particularly among Aboriginal and Torres Strait Islander people with strong attachment to country, and among other remote residents such as pastoralists who depend on livelihoods that are sensitive to climate change.
16. We did not find any studies on the risks of climate change for the education sector. A general potential impact statement is that climate change and attendant increases in extreme events are likely to damage education facilities such as schools, particularly those in remote coastal regions and low-lying plains prone to flooding. It is likely that an increase in average temperature and extreme events will damage

and further limit access to educational facilities and significantly reduce the safety, attendance and attentiveness of students.

Vulnerability and adaptive capacity

17. Most national and regional climate change–related work relevant to communities, sectors and businesses in remote Australia contains general assessments, statements and speculations about potential impacts.
18. We did not find any specific vulnerability studies on remote tourism operations, but a national-level of climate change impacts on tourism included the Kakadu National Park (Pham et al. 2010), which lies in remote Australia. National-level studies note that climate change is very likely to have significant adverse impact on remote tourism businesses and associated economic activities, particularly in regions where there are limited alternative livelihood activities that are climate change insensitive.
19. The potential impacts and responses of different terrestrial and aquatic organisms, habitats and ecosystems are still unknown, particularly in desert Australia. However, based on existing understanding and model projections (Ferrier et al. 2012), on balance, climate change will have significant adverse impact in biodiversity and ecosystem function. The literature suggests there is need for biodiversity conservation efforts to create connectivity and corridors to support adaptation of plants and animals (Steffen et al. 2009).
20. General climate change impact assessments are often not adequate to develop community adaptation actions and plans. While a relentless drive for accuracy and precision may not be warranted, given the uncertainties in projections of some climate change elements (Green et al. 2009) and in indicators used for assessment (Adger & Vincent 2005), context-specific vulnerability assessments are recognised as essential parts of adaptation planning and action (Berrang-Ford et al. 2011).
21. The vulnerability of a system to climate change is often defined as being a function of three factors: exposure and sensitivity of the system to climate change (the potential impact) as well as its adaptive capacity. However, interpretations of these concepts vary, with implications for how vulnerability is assessed (Preston & Stafford Smith 2009, Maru et al. 2011).
22. There are several national and regional studies that make general statements about the elderly, disabled persons, low-income households and Aboriginal and Torres Strait Islander peoples as groups vulnerable to different elements of climate change and likely increases in extreme weather events. These general assessments are often based on general understanding of the low socio-economic status or disadvantage of these groups of people, plus assumptions about high sensitivity and likely exposure to climate change due to pre-existing health conditions.
23. We found few detailed vulnerability assessments conducted on or covering sectors in remote Australia. Those most relevant are Cobon et al. (2009) on potential impacts, adaptive capacity and vulnerability in grazing systems of northern Australia, and Nelson et al. (2010) on the vulnerability of Australian rural communities to climate variability and change, including pastoralism in remote regions. These theoretically principled assessments highlighted that impact assessments, while important for awareness, may provide inadequate (even at times misleading) information for the decisions that support adaptation measures in policy, as the assessments depend only on examination of the likelihood and/or consequences of exposure, and often leave out sensitivity and adaptive capacity of the system. Nelson et al. (2010) found pastoral regions most exposed to climate change and variability were not necessarily the most vulnerable.

24. A case study by Petheram et al. (2010) with Aboriginal and Torres Strait Islander communities highlighted that analysing community vulnerability and adaptation to climate change may not rate as the highest priority for communities grappling with multiple internal and external socio-economic and political perturbations. This finding means that climate change as a perturbation needs to be analysed in conjunction with context-specific and priority issues.

Energy

25. Remote Australia is still highly dependent on fossil fuels for transport and household and public service energy needs. For example, over 31 million litres of diesel fuel were used to generate electricity for major remote communities in the NT in 2009, and demand is expected to increase by 25% over the next three years. Household consumption of energy is rising, and use of air-conditioning will increase with increasing temperatures in inland Australia, which will lead to even higher demand for energy to maintain current lifestyles and to address the changing requirements of an ageing population. Energy price is likely to continue to rise as the cost of production of fossil fuel increases and approaches peak oil, and gas utilities – which generate electricity using fossil fuels, including natural gas – will be obliged to purchase emissions permits under the Clean Energy Act 2011.
26. In remote Australia, there is vast potential for generating alternative renewable energy, including from solar, geothermal, wind and tidal sources. Currently there are some significant community-level renewable energy initiatives in remote Australia (e.g. Bushlight, Horizon Power and Alice Solar City). However, in the shorter term, increasing demand for energy is likely to outstrip supply from alternative energy sources even though these are becoming more efficient.
27. There are suggestions that remote Australian communities produce alternative energy and be linked to the national electricity grid, with potential to export energy to Asia. However, there are still significant barriers to switching to renewable energy for widespread production, use and export of renewable energy from remote Australia. These barriers include high initial investment costs; perceptions; and technical challenges, including daily and seasonal intermittence of supply, and shortage of skilled labour in renewable energy installations and maintenance. Another issue common to different renewable sources is scaling up as demand increases. It is noted that large-scale renewable energy projects in areas of sparse population may not be feasible in a strict economic sense, and that there is a need for cost–benefit analysis to consider employment, environmental and health benefits.

Carbon

28. The Australian Government legislated for a carbon pricing scheme to begin from July 1, 2012. Its key parameters are well known for the first three years, but the consequences of a floating price from mid-2015 are poorly understood.
29. In remote Australia, long-term net carbon sequestration and/or greenhouse gas emissions abatement ('carbon farming') can be achieved best by management of the ecosystem fluxes of carbon dioxide and other greenhouse gases such as methane and nitrous oxide, through a range of activities. The diversity of ecosystem types and range in productivity lead to location-specific sets of options for engaging with a carbon economy.
30. Savanna fire management provides a significant opportunity for land owners and managers in northern Australia to generate carbon credits and earn income on carbon markets. It is the best researched opportunity to date and is one of the first methodologies approved by the Domestic Offsets Integrity Committee. There is a need for a savanna burning methodology for mean annual rainfall < 1000 mm

(currently under development), and for assessment of the feasibility of obtaining carbon benefits through managed burning in more southern, fire-prone ecosystems.

31. Exploratory preliminary assessments have been made (or are currently being made) of tropical forest plantations (e.g. Richards et al. 2011), arid-zone forest plantations (e.g. Centrefarm 2010), altered cattle-rumen microbial flora and cattle diet (see Cottle et al. (2011), reductions of feral camels (e.g. Drucker 2008) and bioenergy (e.g. Morrow 2003), but none has yet reached a stage at which understanding could underpin contractual arrangements for carbon credits.
32. The potential carbon farming opportunity through restoration of historically degraded rangelands (net sequestration through revegetation and soil rehabilitation) is not well understood. Such work needs to include tradeoffs and synergies between carbon sequestration and cattle production, as well as the extent to which carbon farming income can be used as a lever to achieve general rangeland restoration.
33. Uncertainty about opportunities and threats posed by the carbon market has been expressed by landowners in remote Australia because of a lack of knowledge about critical biophysical processes.
34. Despite the uncertainty mentioned above, many Aboriginal and Torres Strait Islander peoples in remote Australia are well situated to develop carbon sequestration and greenhouse gas abatement enterprises because they own much of the land with storage and abatement potential, and many groups have established effective natural resource management capacity.
35. Participation by Aboriginal and Torres Strait Islander people in carbon farming has the potential to provide an avenue to pursue culturally appropriate activities that meet their local livelihood and economic development aspirations. The Federal Carbon Farming Initiative explicitly recognises the need for market recognition of Aboriginal and Torres Strait Islander social, cultural and environmental co-benefits. Principles for such co-benefits have been developed, but no implementable scheme is yet available. Historically, existing international co-benefit standards suggest a carbon offset price premium of only \$1.50–\$2.00 per t CO₂-e.

Climate, energy and carbon assessment methods

36. General Circulation Models (GCMs) are the primary tools for climate change projections. However, they currently do not provide reliable information on scales below about 200 km and fail to account for some important regional feedbacks (e.g. effect of aerosols on rainfall in north-western Western Australia), as well as regional phenomena, including the atmospheric effects of the aerosols, smoke and pollution produced in Asia.
37. There are two broad categories of downscaling methods that assist in producing regional climate change information: dynamical and statistical downscaling. While each category has its own strengths and weaknesses, dynamical downscaling is computationally intensive and can account for regional mechanisms, while statistical downscaling is computationally inexpensive and readily applicable to outputs of different GCMs.
38. Downscaled regional-level climate change information is required for detailed climate change risk and vulnerability assessment, but a decision for downscaled information requires consideration of the added value that comes from this exercise.
39. There are three broad categories of approaches to climate change assessment commonly applied to framing the problem or analysing the impacts: hazard or impact-based, vulnerability-based, and integrated assessment approaches.
40. While the progression through the sets of hazard or impact-based, vulnerability-based and integrated assessment approaches has contributed to significant awareness of potential impact and vulnerability

of different entities of interest to climate change, they are still not well connected to exploring effective adaptation pathways.

41. So far, the focus of climate change assessments has been on impact, vulnerability and, to a limited extent, adaptive capacity assessments, which are all useful for framing and analysing problems. There has been little or no focus on the other phases: adaptation planning and decision making. There is now recognition of the limitations of current methodologies in providing relevant information for these phases; these challenges are faced by many governments, sectors and communities.
42. Given a propagation of high levels of uncertainty along the assessment process, from climate change projections to potential impacts to interactions with other biophysical and socio-economic and political changes, there are those who note the futility of detailed and precise assessments, but prefer robust approaches that assist in exploring adaptation options (Wilby & Dessai 2010).
43. While action research-oriented case studies are required for linked vulnerability assessment and adaptation planning, there is a need for comparability and generalised learning at larger scales. A distribution of case studies can be guided by a broad categorisation or typology of vulnerability of regions in remote Australia. This would require a typology study of vulnerability, but if there are time and resource limits, a quick typology can be developed by a group of experts building on previous regionalisation studies, for example, Holmes (1997); Maru and Chewings (2008) and perhaps also considering regionalisation developed by the Bureau of Meteorology for statistical downscaling (Timbal et al. 2008).

Government Policies

44. Australia recognised early the importance of adaptation to climate change (Australian Government Department of Climate Change 2010, PMSEIC Independent Working Group 2007) and is currently noted as doing better than other developed countries (Moser 2012).
45. However, significant inadequacies are identified through recent evaluation of adaptation plans (Preston et al. 2011) and assessment of articles on adaptation action (Berrang-Ford et al. 2011) in developed countries.
46. These findings raise significant concerns about the likelihood of effective adaptation given the speed of climate change and the limited window of opportunity for action (Adger & Barnett 2009). It also illustrates that the high adaptive capacity typically assumed for developed nations will not necessarily translate into effective adaptation action.
47. Broad Australian Government adaptation plans, such as the National Climate Change Adaptation Framework (Council of Australian Governments 2007), and state/territory adaptation action plans, such as those from the Northern Territory, Queensland, Western Australia and South Australia, all relevant to remote Australia, have been assessed as needing significant improvements (Moser 2012). Plans and actions at grass roots level have not been subject to similar review, but it is likely that significant attention is needed to improve adaptation planning and action at all levels. Thus, there is a need to assess the current state of adaptation plans and actions in remote Australia and devise expansion and improvement.
48. Climate change adaptation is mainly about policy and practice, so the science needs to be end-user led and the practice thoroughly participatory and negotiated to ensure efficient and effective adaptation measures and a fair distribution of benefits and burdens.
49. Government policies are a rapidly changing area, covering the intertwined issues of addressing increasing energy demand, energy conservation, reduced greenhouse gas emissions, 'cleaner' fossil

fuels and energy generation from renewable sources. State policies are changing in response to changing Australian Government policies and initiatives.

50. The Australian Government Clean Energy Future plan includes the carbon pricing scheme and an emissions trading scheme. The initiative includes several programs with opportunities for remote communities, especially Aboriginal and Torres Strait Islander communities: (1) the \$40m Remote Indigenous Energy Program for installing renewable energy generation systems in remote communities; (2) the ongoing \$22m Indigenous Carbon Farming Fund, linking to the Carbon Farming Initiative; (3) the \$946m Biodiversity Fund; and (4) the Low Carbon Communities programme (Clean Energy Future 2012).
51. Some government policies favour the use of – and provide subsidies for – energy from fossil fuels, even if this seems contradictory to renewable energy policy. There is a tendency to encourage a move to gas generation of electricity, which, while not renewable, leads to lower greenhouse gas emissions than generation from coal or diesel.
52. In discussions around pricing renewable energy technologies, DeLaquil (1996) and McHenry (2009) suggest that benefits need to be evaluated against the Triple Bottom Line, and that the non-economic consequences of fossil fuel energy need to be highlighted.
53. There is uncertainty around government policies, with compromises in some areas, and uncertainty in markets and for investors. We did not find any studies where the current mix of state and federal policies gives a clear (unconfused) message as to where investment in energy should be targeted.
54. In most cases, implications for remote Australia tend to be implicit rather than explicit. Even the NT's energy policy, which identifies the need for improved access to more efficient public transport in remote communities, fails to indicate what types of policies would be necessary to achieve this ambitious aspiration.
55. The Australian Government's Clean Energy Future (2011) plan provides a relatively complete and integrated policy environment for carbon management in Australia, including a requirement for the largest carbon-emitting industries to offset at least part of their emissions, a price for carbon offsets (set to rise annually over the three years from 1 July 2012), an emissions trading scheme, and a clean energy regulator to administer a variety of policy elements, including the pricing mechanism and the Carbon Farming Initiative.
56. The carbon legislation has yet to come fully into effect. There is no way to assess whether the policy will achieve its goals, whether the emissions trading scheme will generate a carbon price sufficient to sustain carbon farming, whether access to international carbon credits will have negative impacts on local carbon offset production, whether subsidies to businesses will undermine effective function of the market, and whether selection for perverse behaviours and outcomes will occur.
57. For land management under the Carbon Farming Initiative, there is the additional question of ownership of carbon rights, which falls under state and territory government administration. Policy is explicit that carbon rights belong to the landowner with freehold title. However, on Crown Land the question is less clear-cut at present. This is critical for remote Australia where a significant proportion of the land is Crown Land, including pastoral leases. There are also apparently unresolved issues of Native Title questions for carbon farming activities on Crown land.

Introduction

The initial literature search was focused on remote Australia and used terms from the original 14 Terms of Reference provided by CRC-REP for this project. As this process returned a limited amount of material for reporting purposes, we have grouped together those terms of reference whose subject is the same topic in different industries; this results in ten sections.

- S1. The most likely climate scenarios for remote Australia over the next 50–100 years, including gaps in data or analysis for this region.
- S2. Liveability of remote Aboriginal and Torres Strait Islander settlements under the climate scenarios for remote Australia, including impacts on health and education.
- S3. The vulnerability and adaptive capacity of individuals and communities, especially Aboriginal and Torres Strait Islander people, as well as of remote infrastructure, ecosystems, industries and businesses under these climate scenarios.
- S4. Within predicted climate and population scenarios, the energy needs of remote Australia, from household to regional scale.
- S5. The impacts of increasing energy costs on the individuals, communities and businesses of remote Australia.
- S6. The potential for and social and economic benefits of harnessing alternative sources of energy for remote Australia.
- S7. The opportunities for carbon storage and emission abatement in remote Australia, including scale of the biophysical capacities and any gaps in data for this region.
- S8. The social and economic benefits of carbon storage and emission abatement enterprises in remote Australia, especially those relating to employment in Aboriginal and Torres Strait Islander traditional land management practices.
- S9. The effects of government policies on climate change adaptation ability, energy cost and potential for carbon storage and emission abatement enterprises in remote Australia.
- S10. Commentary on the previous and current methodologies used in measuring and analysing climate change, energy scenarios and carbon, including the strengths and weaknesses of the different approaches.

For the purpose of this paper, remote Australia includes both Remote and Very Remote Australia based on the remoteness structure developed by the Australian Bureau of Statistics (ABS 2012). The remoteness structure, updated each census, classifies Collection Districts (CDs) that share common characteristics of remoteness into broad geographical regions called Remoteness Areas (RAs). The criteria used to delimit RAs are based on the Accessibility/Remoteness Index of Australia (ARIA). ARIA measures the remoteness of a point based on the physical road distance to the nearest Urban Centre.

There are six RAs (including Migratory), and relevant spatially explicit regions are presented in Figure 1. These are Very Remote Australia, Remote Australia, Outer Regional Australia, Inner Regional Australia and Major Cities of Australia.

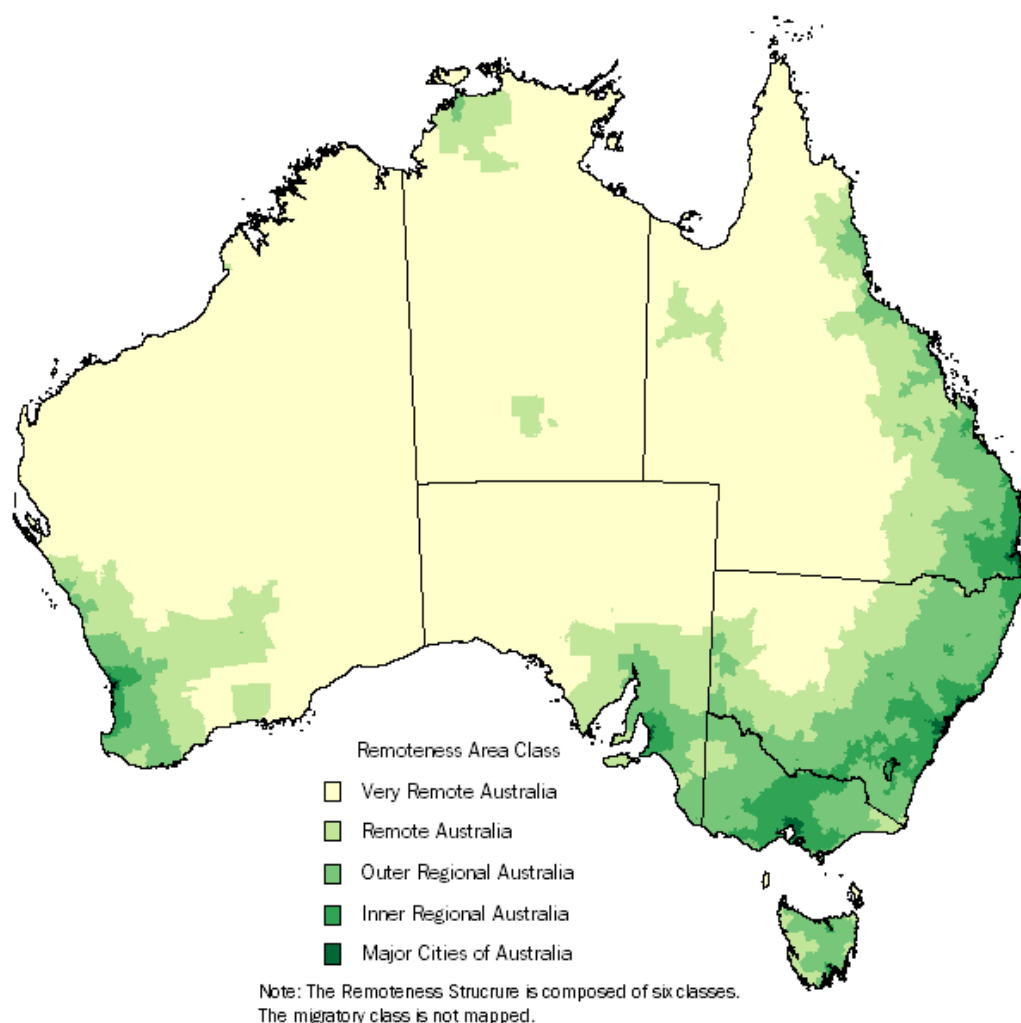


Figure 1: Remoteness classes for Australia

Source: ABS 2012

Remote Australia (both remote and very remote) has notably different demographic and socio-economic characteristics compared with the rest of Australia. At the time of the 2006 census (ABS 2006), remote Australia was home to 470,000 people (2.3% of the Australian population). Over 124,000 Aboriginal and Torres Strait Islander people, representing 26% of the total number of Aboriginal and Torres Strait Islander Australians, were residents of remote Australia. In 2006, the median age of the Australian population was 37 years. In contrast, the median age for Remote Australia was 35 years and for Very remote Australia the median age was 30.1 years.

Between 1996 and 2006, Australia's population grew by 2.4 million people, an average annual growth rate of 1.2%. In contrast, the population declined in Remote (-0.4%) and Very Remote (-0.3%) areas. The population declines in these areas were particularly evident in areas that were affected by drought.

More than a quarter (26%) of the Aboriginal and Torres Strait Islander population lived in Remote and Very Remote Australia, compared with 2% of other Australians living in these areas. As a result, Aboriginal and Torres Strait Islander people comprised 48% of the total population in Very Remote areas, and 16% of the total population in Remote areas.

In 2006, Remote and Very Remote areas had the highest percentage of children (aged 0–14 years) as a proportion of the population. This is likely to be partly due to the younger age profile of Aboriginal and Torres Strait Islander Australians and the relatively high fertility rates of women in remote areas. Very Remote areas also had the highest proportion of young adults (aged 20–34 years).

While culturally diverse and physically dispersed, remote Australia has shared systemic properties as well as a shared history of persistent disadvantage and poverty, particularly among many of its Aboriginal and Torres Strait Islander residents. These systemic characteristics are outlined in Figure 2 as causally linked factors found in both Australian deserts (Stafford Smith & Huigen 2009) and the Australian tropical north (Larson 2010) – together approximately constituting remote Australia.

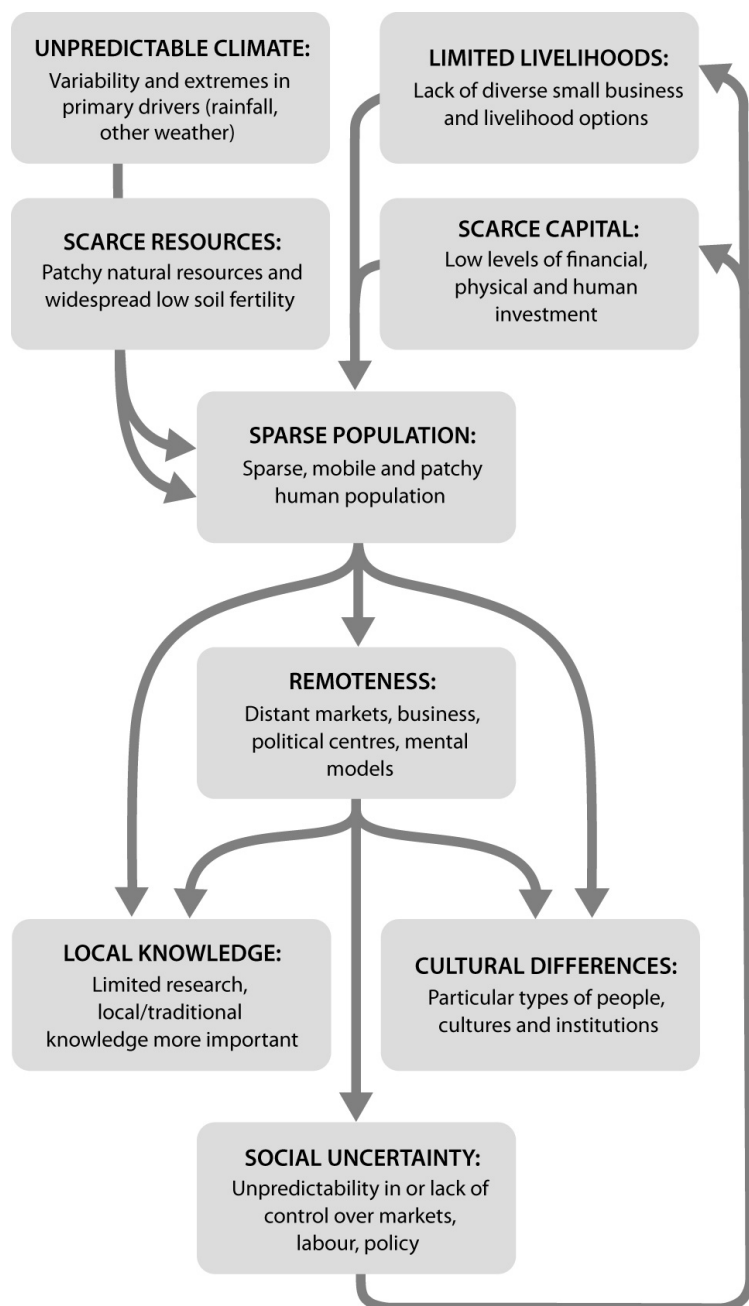


Figure 2: The ‘desert drivers’ that critically determine how deserts work

Source: Stafford Smith and Huigen (2009)

These systemic and broad remote region characteristics will interact with climate change and energy futures, resulting in impacts and potential opportunities for remote communities that are likely to be different from those in coastal regions of Australia.

Having these unique characteristics and possible different interactions with climate change and energy in mind, we now review the state of literature and current research. A description of the search methods and results used for the review are given in Appendix 1. In Sections 1–10 the results are compiled and discussed, with gaps and limitations in research work identified. The last section contains concluding remarks.

Section 1: Climate scenarios

SI. The most likely climate scenarios for remote Australia over the next 50–100 years, including gaps in data or analysis for this region.

Current understanding

General Circulation Models (GCMs) use a range of estimates of greenhouse gas and sulphate aerosol emission from scenarios developed in a Special Report on Emission Scenarios (SRES) for the IPCC (IPCC 2000). Four qualitative storylines underpin four ‘families’ of quantitative emission scenarios, named A1, B1, A2 and B2. The set of scenarios consists of six scenario groups drawn from the four families: one group each in A2, B1, B2, and three groups within the A1 family, characterising alternative developments of energy technologies: A1FI (fossil fuel intensive), A1B (balanced), and A1T (predominantly non-fossil fuel).

Temperature

The Australian average annual temperature has increased by 1°C since 1910, and most of this warming has occurred since 1950. The IPCC Fourth Assessment Report (IPCC 2007) concluded that ‘most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations’. A climate change update report by CSIRO and Bureau of Meteorology (2007) supports this statement, and on the basis of information since 2006 notes a higher confidence in the extent to which humans have influenced global temperature.

Recent national-level climate change projections for Australia (CSIRO & Bureau of Meteorology 2007, IPCC 2007, Whetton 2011) indicate similar results. There is a high level of certainty that average annual temperature will increase in the future. Allowing for emission scenario uncertainty, by 2030 warming will be at least 0.4°C in all regions of Australia and could be as large as 1.8°C in some inland regions. Model projections suggest a median estimate of annual average warming by 2030 (above 1990 temperatures) of around 1.0°C across Australia, with warmings of 0.7–0.9°C in coastal areas and 1–1.2°C inland. Projected warming by 2050 ranged from 0.8° to 1.8°C and by 2070 warming was projected to be between 1.8°C (low emissions: B1 scenario) and 5°C (high emissions: A1FI scenario).

As shown in Figure 3, by 2070 least warming occurs in Tasmania and coastal areas with the exception of the north-west coastal regions (Suppiah et al. 2007). Consistently higher increases in average annual temperatures are projected for inland Australia compared with the coastal areas, with the exception of coastal regions of north-west of Western Australia, where higher warming similar to that in some inland regions is expected. Maximum temperatures rise faster than minimum temperatures in the south, with the reverse expected in the north (Hennessy & Overton 2011).

Projected warming for 2050 and 2070 regional variation follows the pattern seen for 2030, with less warming in the south and north-east and more inland. By 2070, the risk of greater than 4°C change exceeds 30% over inland Australia, as does reaching a warming of 3°C in the south coast under the A1FI scenario. However, under the B1 scenario the risk of exceeding 2.0°C is less than 20% around the coast, except in the north-west. By 2070, the best estimate for annual warming over inland Australia ranges from around 1.8°C for the B1 scenario to around 3.4°C for the A1FI scenario. There is clearly a substantial decrease in risk of high warmings under the B1 scenario, representing significant curtailment of the growth of future emissions, compared to that under A1B or A1FI (Suppiah et al. 2007).

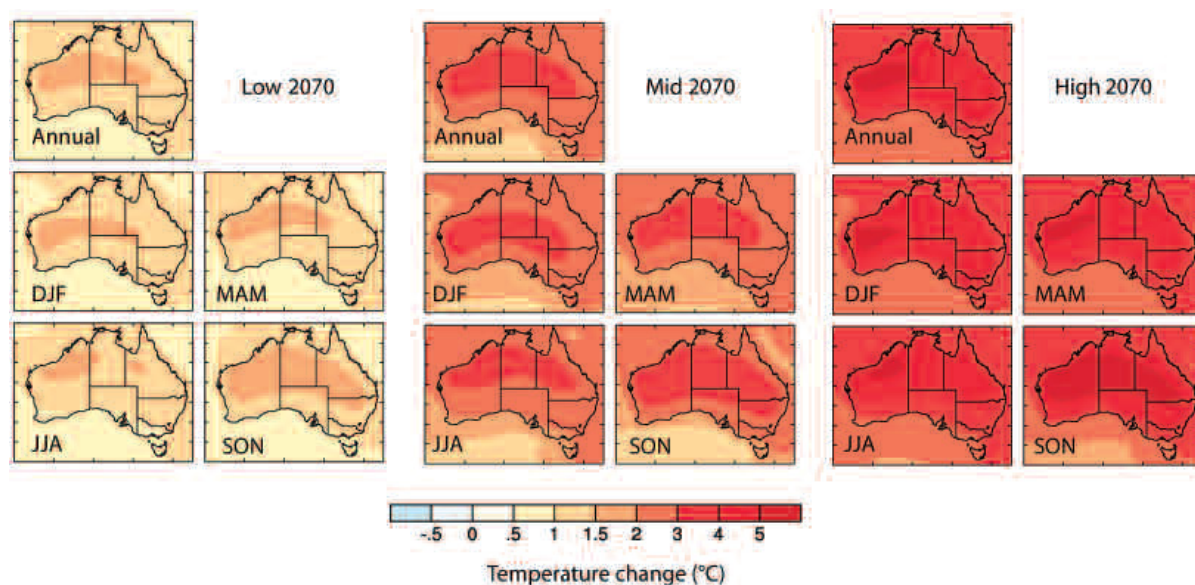


Figure 3: Average temperature changes for 2070 relative to 1990, from 15 models using low, medium and high emission scenarios

Source: Suppiah et al. (2007)

Rainfall

There is high level of uncertainty in the direction of projected rainfall, particularly in inland and northern Australia. Rainfall is likely to decrease in southern areas of Australia, especially in winter, and in southern and eastern areas in spring (see Figure 4), caused by the contraction in the rainfall belt towards the higher (more southern) latitudes. Rainfall is very likely to decrease in south-western Australia in winter. Future changes in summer tropical rainfall in northern Australia are uncertain, as some results show increasing rainfall and others decreasing rainfall (IPCC 2007). Increases in evaporation are likely throughout Australia, which, combined with a general decline in precipitation in many parts, provides a strong indication that the Australian environment is generally becoming drier under enhanced greenhouse conditions (Frederiksen et al. 2011, IPCC 2007).

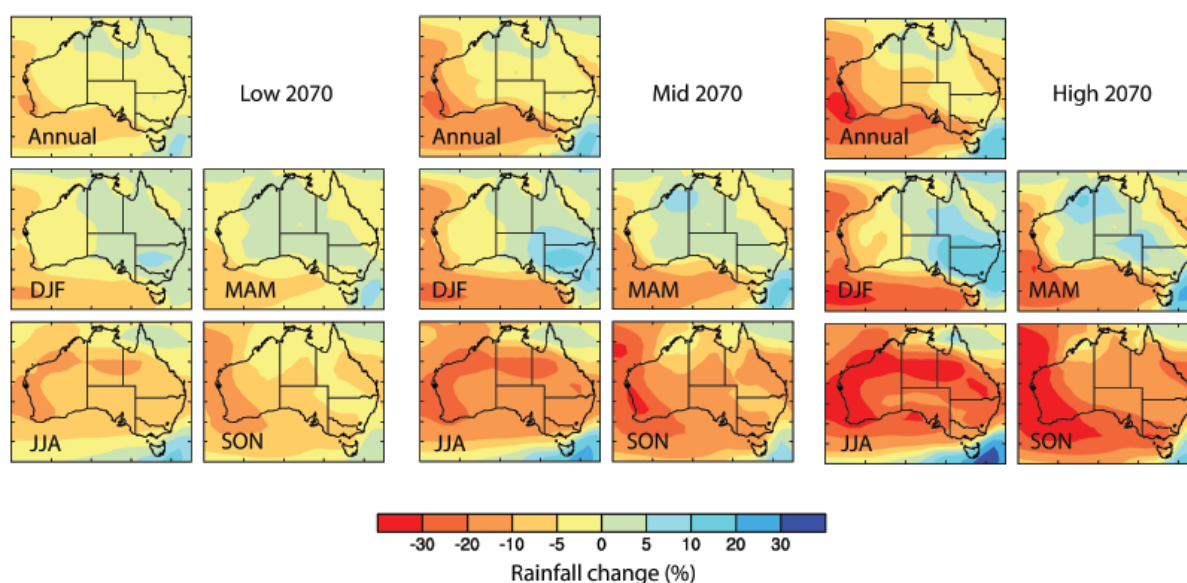


Figure 4: Average percentage rainfall changes for 2070 relative to 1990, from 15 models using low, medium and high emission scenarios

Source: Suppiah et al. (2007)

Sea-level rise

The IPCC 2007 report projected an average global sea-level rise of up to 79 cm by 2100 relative to 1990 sea level (IPCC 2007). Recent estimates reported at the 2009 Copenhagen climate congress noted an ocean warming about 50% greater than that estimated in the IPCC 2007 report, and a revised estimate of sea-level rises of around a metre or more by 2100 (Richardson et al. 2009). The Australian Government Department of Climate Change (Department of Climate Change 2009) considered a mid range of 1.1 m sea-level rise by 2100 for an assessment of climate change risks to Australia's coasts. This report notes that even with a mid range sea-level rise of 0.5 m in the twenty-first century, events such as storm surges that now happen every 10 years may happen about every 10 days in 2100. The report also notes the lack of information on adaptive capacity of remote Aboriginal and Torres Strait Islander communities in the north of Australia and that communities living on the low-lying Torres Strait Islands are particularly vulnerable to sea-level rise.

Extreme weather events

More socio-ecological impacts are to be expected from likely changes in extreme events than gradual average changes in climate elements (Hennessy 2011). There are a number of Australian studies on projected changes to the number and intensity of extreme weather events in temperature, rainfall, flooding, fire and cyclones, and storms that may affect remote Australia (Alexander & Arblaster 2009, Hennessy et al. 2008, Perkins & Pitman 2009).

Temperature

Studies on projected changes for temperature extremes found that there will be more extremely high temperatures, more warm nights (90th percentile of minimum temperature), fewer extremely low temperatures (fewer frosts below 0°C), and longer heatwave duration (period of at least five consecutive days with the maximum temperature at least 5°C above the 1961–90 mean) likely throughout Australia (Alexander & Arblaster 2009, Perkins & Pitman 2009). Projected estimates of the number of hot (>35°C)

and cold ($< 0^{\circ}\text{C}$) days for inland towns (Suppiah et al. 2007) are shown in Table 1 and Table 2. Values are rounded to the nearest integer.

Table 1: Present (1964–2003) and projected number of days above 35°C at eight remote Australian towns under low (L) and high (H) emission scenarios

Town	Present	2020		2030		2040		2050		2060		2070		2080	
		L	H	L	H	L	H	L	H	L	H	L	H	L	H
Alice Springs	89	94	114	96	125	99	129	101	153	104	173	106	191	108	207
Broome	54	61	90	64	119	69	163	72	208	80	258	84	293	87	316
Charleville	65	70	91	72	105	75	108	77	135	80	157	82	177	83	195
Cobar	41	44	57	45	65	47	68	48	92	50	111	51	127	52	144
Halls Creek	156	164	189	166	205	172	218	175	241	179	268	182	290	185	307
Kalumburu	140	153	197	158	230	167	262	171	291	178	320	185	337	187	346
Longreach	115	121	147	123	163	129	164	131	199	134	222	136	239	139	256
Woomera	51	54	64	56	70	58	78	59	88	60	104	62	120	63	135

Source: Suppiah et al. 2007

Table 2: Present (1964–2003) and projected number of days below 0°C at eight remote Australian towns under low (L) and high (H) emission scenarios

Town	Present	2020		2030		2040		2050		2060		2070		2080	
		L	H	L	H	L	H	L	H	L	H	L	H	L	H
Alice Springs	16	14	8	13	5	11	3	10	1	9	0	9	0	8	0
Broome	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Charleville	13	11	5	10	3	9	2	8	1	7	0	6	0	6	0
Cobar	2	2	0	1	0	1	0	1	0	1	0	1	0	1	0
Halls Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Kalumburu	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Longreach	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Woomera	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: Suppiah et al. 2007

Rainfall

Extremes of daily rainfall are very likely to increase, with smaller increases in the south of Australia and larger increases in the north (Rafter & Abbs 2009). The effect may be offset or reversed in areas of significant decrease in mean rainfall, perhaps in southern Australia in winter and spring.

Drought

There is a likely increase in the risk of drought in southern areas of Australia. Hennessy et al. (2008) have examined the implication of future climate change on the current exceptional circumstances (EC) standard of a one in 20–25-year event. They concluded that taking exceptionally low rainfall events as a sole trigger for EC declarations and using the high emissions scenario (which the world is currently tracking) EC declarations would likely be triggered about twice as often and over twice the area in all regions of Australia. If EC declarations were to be triggered based on exceptionally low soil moisture, then EC declarations would likely occur almost twice as often in most regions and almost four times as often in south-west Western Australia.

Other extreme events

The literature notes other likely climate change–related extreme events: 1) decrease in frequency (Knutson et al. 2010) but increases in intensity of cyclones (IPCC 2007), and 2) increases in frequency and intensity of storm surges, floods, heatwaves and bush fires (Alexander & Arblaster 2009, Lucas et al. 2007) with significant negative implication on lives, health, settlements, livelihoods and service provision.

Regional climate change projections

Current climate change information for remote Australia is derived from national efforts based on Global Climate Models, which have coarse resolution (100–500 km). We found no refined regional climate projections for entire regions in remote Australia. There are now multiple downscaling efforts to produce climate change projections at refined regional and local scales for different purposes. Examples include downscaling work done for the Murray Darling Basin and for different parts of Tasmania up to 10 km resolution – each of which cover some part of remote Australia (Whetton 2011).

There are online facilities that assist developing climate change information for areas of interest, albeit at a coarse level. The Climate Change in Australia website¹ allows users to select state- or national-level projections for several climate variables. Maps are displayed as percentiles: the 50th percentile is the ‘best estimate’ result, the 10th percentile shows the lowest 10% of results, and the 90th percentile the highest 10%, providing an indication of uncertainty. Projections are relative to the period 1980–1999 (referred to as the 1990 baseline for convenience). Emission scenarios are from the IPCC Special Report on Emission Scenarios (IPCC 2000). Low emissions use the B1 scenario, medium uses A1B and high uses A1FI. Projections for 2070 using 23 models for rainfall and temperature are shown in Figure 5 and Figure 6.

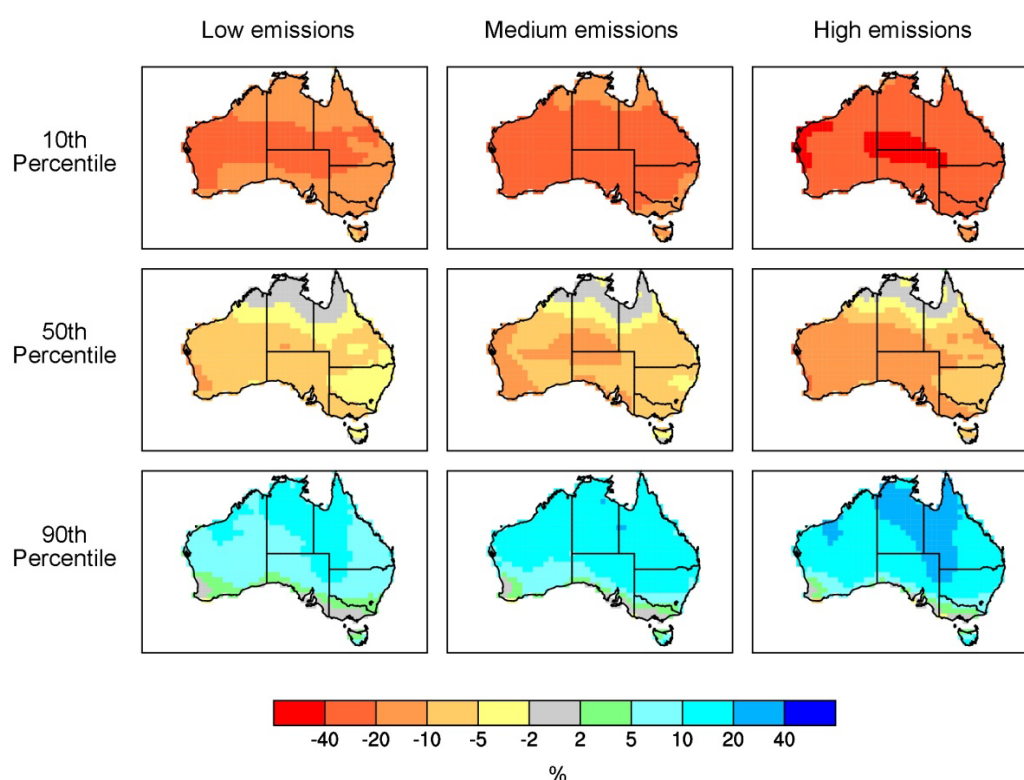


Figure 5: Annual rainfall change for 2070 from baseline 1990 under low, medium and high emission scenarios

Source: <http://www.climatechangeinaustralia.gov.au/natrain15.php>

¹ <http://www.climatechangeinaustralia.gov.au/>

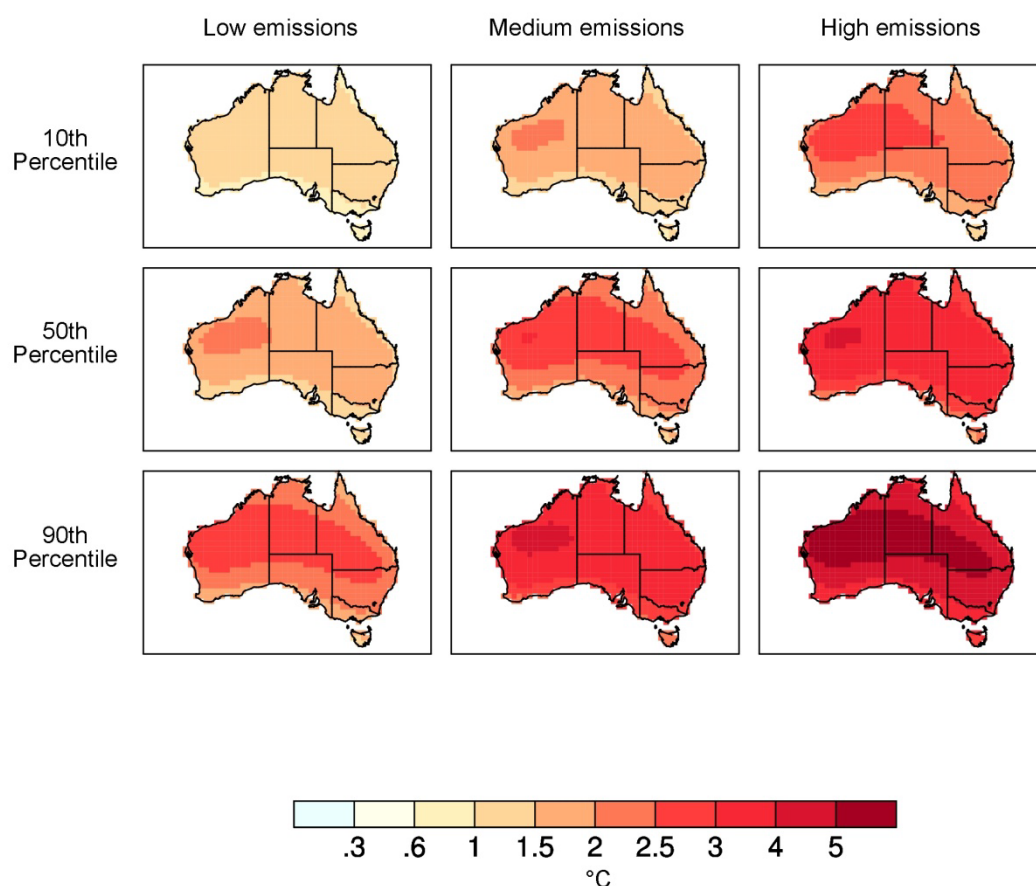


Figure 6: Annual temperature change for 2070 from baseline 1990 under low, medium and high emission scenarios

Source: <http://www.climatechangeinaustralia.gov.au/nattemp15.php>

CSIRO is developing a Representative Climate Futures Tool (RCF) (Clarke et al. 2011, Whetton et al. 2012), which allows users to explore a number of models for selected time periods at once. The models are ranked, and the most likely and least likely are readily identified for changes in annual and seasonal rainfall, surface temperature and other climate variables of interest. The tool also provides a useful way to understand the effect of changing parameters with season. We used the tool to generate results for four sites in remote Australia using A1B and A1F1 scenarios. These are in central Australia (CA) grid centred at 22.5°S 131.5°E, the north-west coast of Western Australia (WA) grid at 17.5°S 126.5°E, northern Queensland (Qld Nth) at 12.5°S 141.5°E, and an area in southern Queensland (Qld Sth), grid centred at 27.5°S 141.5°E. (Figure 7).

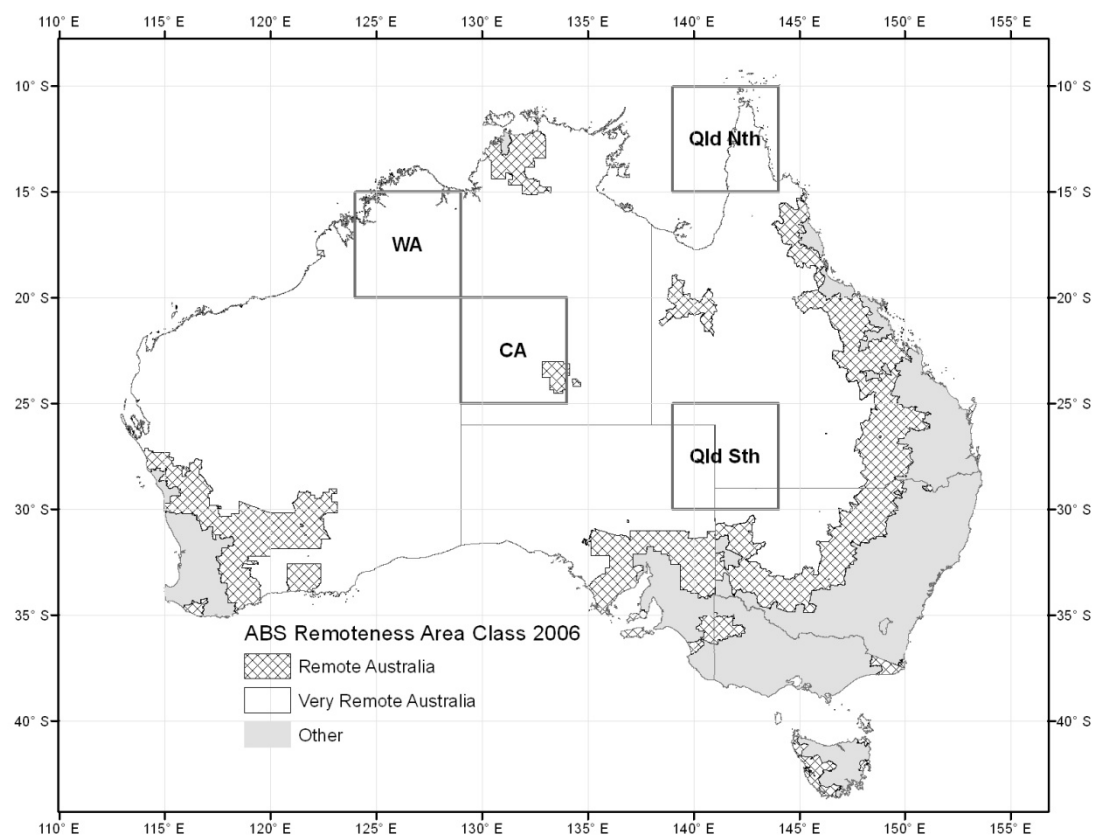


Figure 7: Areas in remote Australia for which the likelihood of global warming was calculated using the CSIRO RCF tool

Table 3: The likelihood of percent changes to temperature and rainfall for four sites in remote Australia as indicated by the CSIRO RCF tool

Values show the proportion of 24 global climate models that fall into projected rainfall and temperature change categories by 2030 and 2070 under two emission scenarios (A1B and A1FI).

Rainfall – Annual (% change)	Surface temperature – Annual (°C change)							
	A1B (medium emission scenario)				A1FI (high emission scenario)			
	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
CA 2030								
<-15								
-15 to -5		39%	8%			43%	4%	
-5 to 5		52%				52%		
5 to 15								
> 15								
CA 2070	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15			26%	8%				52%
-15 to -5			21%	8%			8%	13%
-5 to 5			17%	4%			8%	4%
5 to 15			13%					8%
> 15							4%	
WA 2030	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15								
-15 to -5		26%				26%		
-5 to 5		65%	4%			65%	4%	
5 to 15		4%				4%		
> 15								
WA 2070	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15			17%	4%			4%	21%
-15 to -5			17%					13%
-5 to 5			26%	8%			17%	17%
5 to 15			21%				13%	8%
> 15			4%					4%
Qld Sth 2030	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15		4%						
-15 to -5		43%	4%			47%	4%	
-5 to 5		30%				39%		
5 to 15		17%				8%		
> 15								
Qld Sth 2070	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15			34%	8%			8%	43%
-15 to -5			17%				4%	13%
-5 to 5		4%	17%				8%	
5 to 15			17%					4%
> 15			4%				13%	4%
Qld Nth 2030	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15								
-15 to -5		4%				4%		
-5 to 5	4%	86%			8%	82%		
5 to 15		4%				4%		
> 15								
Qld Nth 2070	<0.5	0.5 to 1.5	1.5 to 3	> 3	<0.5	0.5 to 1.5	1.5 to 3	> 3
<-15		4%					4%	
-15 to -5		8%	21%			4%	30%	4%
-5 to 5		13%	30%				21%	4%
5 to 15			17%				26%	
> 15		4%					4%	

Gaps

Downscaled climate change information is not available for any remote regions of Australia, but some of the regional work (such as for the Darling Downs Basin) extends to the fringes of southern remote regions. Regionalised climate change information may be required for impact and adaptation work in remote Australia. However, any proposed investment along these lines would require assessment of expected added value and feasibility given that long-term and reliable historical data may not be available for model parameterisation in remote areas.

Conclusion

Climate change projections consistently show that there will be greater warming in inland regions of remote Australia than in coastal regions and more to the west than to the east. It is very likely that increasing temperature, rising sea levels, changing rainfall patterns and an increase in the intensity and/or frequency of extreme weather events will have significant implications for lives and liveability in different parts of remote Australia. Regional-level climate change information may be required for context-sensitive and detailed climate change risk assessment and adaptation actions.

Section 2: Liveability

S2. Liveability of remote Aboriginal and Torres Strait Islander settlements under the climate scenarios for remote Australia, including impacts on health and education.

Definitions

Liveability refers to the many mainly physical characteristics that make a settlement or a region the type of place people want to live now and in the future (SoE 2011). It is ‘the extent to which the attributes of a particular place can, as they interact with one another and with activities in other places, satisfy residents by meeting their economic, social, and cultural needs, promoting their health and wellbeing, and protecting natural resources and ecosystem functions’ (National Research Council 2002, p. 24). Liveability is influenced by the attributes of a place and their interactions, interactions with activities in other places and by global changes such as climate that can have significant impact.

Current understanding – settlements, infrastructure and services

Aboriginal and Torres Strait Islander people in remote areas currently live with a highly variable climate and harsh living conditions, and their settlements have limited basic services and infrastructure. According to the Australian Bureau of Statistics census in 2006, more than 80,000 Aboriginal and Torres Strait Islander people (15% of Australian Aboriginal and Torres Strait Islander population) lived in 1,112 discrete Aboriginal and Torres Strait Islander Communities in remote areas of Australia. Of those, 3,400 (4%) had no permanent dwelling and lived in temporary sheds and humpies. Those living in permanent dwellings were also facing significant housing issues. One third of dwellings needed either major repairs (24%) or replacement (9%). Overcrowding was a significant issue with 57% of remote Aboriginal and Torres Strait Islander residents needing at least one extra bedroom to adequately accommodate all residents. In the Northern Territory, where the greatest proportion of Aboriginal and Torres Strait Islander

people live in remote communities, 66% of the Aboriginal and Torres Strait Islander people lived in overcrowded houses (ABS 2008a).

Access to basic infrastructure and services that feature prominently in assessing liveability – such as water, power, sewerage, health and education – is significantly lacking in remote Aboriginal and Torres Strait Islander settlements, as shown in Table 4.

Table 4: Access to basic infrastructure and services

Basic infrastructure and services	Access/Experience as proportion of Aboriginal and Torres Strait Islander living in remote communities of Australia (%)
1. Water	
a. Source	
i. town supply	28.3
ii. bore water	54.0
iii. rain water tank	2.9
iv. river/reservoir	12.0
b. Interruptions in supply ^a	59.0
2. Power	
a. Main source of electricity	
i. State grid	28.5
ii. Community generators	62.3
iii. Domestic generator	2.5
iv. Solar/solar hybrid	4.5
v. No organised supply	0.4
b. Interruptions in supply ^a	80.9
3. Sewerage	
a. Main type	
i. Town system	30.0
ii. Water-borne system	37.7
iii. Septic tanks	28.3
iv. Pit toilets	3.2
v. No organised system	0.3
b. Overflows or leakages ^a	39.7
4. Health	
a. Hospital in/near a community	10.0
b. Health care centre in a community	75.0
c. Access or visit by a nurse on daily basis	77.0
d. Access or visit by a doctor on daily basis	20.0
5. Education	
a. Pre-primary school in community	54.0
b. Primary school in community	74.0
c. Primary school located > 250 km away	1.0
d. Secondary school up to year 12 in community	26.0

^a Interruptions in supply and overflows and leakages are given for communities with a total population of 50 or more

Source: ABS 2008a

This review has found no detailed assessment of how climate change is likely to affect the liveability of Aboriginal and Torres Strait Islander settlements in remote Australia, although there are a few broad studies on communities in the Tropical North (Green et al. 2009) and on communities of the Kakadu

region (Cook & Woodward 2010). However, the background poor state of services and infrastructure shown in Table 4 may accentuate the impacts of climate change. In this section we draw on a few Aboriginal and Torres Strait Islander-specific studies and some general nation- or sector-wide assessment reports that are applicable to aspects of Aboriginal and Torres Strait Islander or remote settlements (such as impacts on settlements, water, energy and transport) that can significantly affect liveability in remote regions of Australia.

Settlement

Predicted climate change is likely to increase the intensity and/or frequency of extreme events such as coastal inundation, floods, storms, cyclones, droughts, fires and heatwaves in remote Australia. Although the extent and set of extreme events will vary depending on the location of settlements, each event can have a direct impact on lives, causing injuries, death and displacement from settlements and further indirect impact through damage and disruption to already poor services and infrastructure.

Some regions are highly sensitive to extreme events. In particular, settlements across the coastline of remote Australia extending from the north-west of western Australia, through the Northern Territory, to far north Queensland and the Torres Strait, have already been exposed to severe natural hazards such as tropical cyclones and associated storm surge, flooding and coastal erosion without the compounding effects of climate change (Allen Consulting Group 2005). Expected likely increases in intensity and/or frequency of severe weather events are likely to have a significant impact on buildings and settlements, particularly those with little coping capacity (Green et al. 2009). Many communities across the coasts of remote Australia, and in particular some in the Torres Strait, are affected by current king tide conditions, and even very small levels of sea-level rise are likely to have a major impact on these communities (Department of Climate Change 2009, Walker et al. 1981).

A report by the Department of Climate Change and Energy Efficiency (DCCEE 2011a) on Climate change risk on buildings and infrastructure along the coast estimated a potential exposure to a loss of more than a quarter of a billion Australian dollars in commercial, industrial, road and rail, and residential assets from inundation and erosion hazards at a sea-level rise of 1.1 m by 2100. Climate change impacts on infrastructure are expected to include accelerated degradation of materials and foundations of buildings and facilities. Projected increases in temperature and solar radiation may also reduce the life of building and facilities due to increases in expansion and degradation. Increased humidity in the coastal zone will also affect the rate of corrosion and material degradation. Projected sea-level rises, and an increase in the intensity and/or frequency of extreme storm events will increase fatigue and damage to foundations with possible structural failure (DCCEE 2011a).

Impacts on infrastructure in the coastal regions will have broader consequences for the communities. A preliminary analysis of the location of infrastructure and community services reveals a large number of facilities within 200 m or 500 m of the coastline, and potentially at risk under a changing climate (Table 5) (DCCEE 2011a, Department of Climate Change 2009). Of concern is the number of hospitals, police, fire and ambulance stations very close to the coast. While heavy concentrations of these facilities are in non-remote Australia, many of these facilities also serve remote residents.

Table 5: Regional and community infrastructure and services

Facility	Within 200 m of the coastline	Within 500 m of the coastline
Regional infrastructure		
• Ports	120	120
• Power stations/substations	5	11
• Water treatment plants	3	3
• Bridges	1,800	2,795
Community services and facilities		
• Police, fire and ambulance stations	258	702
• Hospital and health services	75	199
• Government administration facilities	46	107
• Universities, colleges and schools	360	992
• Retirement/nursing homes	102	296
• Emergency services facilities	11	35

Source: Department of Climate Change (2009)

Energy

Depending on their location, remote settlements will face increased damage and disruption to their energy supply from extreme events, including sustained heatwaves and severe weather events such as cyclones, storms, floods and fires (Allen Consulting Group 2005).

Climate change is also expected to increase household and settlement energy demands in many remote settlements situated in warm and hot climates. For example, climate change will have a significant impact on house heating/cooling (H/C) energy requirements of existing housing stock (Wang et al. 2010). In a cooling-dominated hot or warm climate, such as in Darwin and Alice Springs, the increase in the cooling energy requirement is much more than the decrease in the heating energy requirement, resulting in a significant increase in the total annual H/C energy requirement. House designs that performed well in terms of reducing energy requirement for cooling during summer were found to require more energy for heating in winter (Duell et al. 2006). In Alice Springs the total annual H/C energy requirement of a 5-star house, which represents the average energy efficiency of new residential houses, may rise 66% by 2050 and 212% by 2100 (Wang et al. 2010).

Water

In the future, climate change and an increase in the demand for water by a growing population may combine to make water scarcity one of the most pressing issues in Australia (Hennessy 2011). Despite a projected increase in heavy rainfall events over most of Australia, future water availability, particularly in southern and eastern Australia, is likely to decline due to reduced average rainfall and higher rates of evaporation (CSIRO & Bureau of Meteorology 2007). Increasing temperatures and an overall likely decline in precipitation in southern regions of the rangelands are likely to markedly affect water resources in remote Australia in terms of quantity and quality (Allen Consulting Group 2005).

Climate change-induced increases in intensity and frequency of extreme weather events are likely to reduce the reliability and quality of water supplies to remote Aboriginal and Torres Strait Islander settlements (Green et al. 2009). An increasing incidence of floods and drought will also impact on the safety and sustainability of the water supply. With respect to supply from ground water, a source of water supply for many remote settlements and enterprises, there is a high level of uncertainty around future climate change impacts on recharge (Barron et al. 2010).

The northern regions of the Northern Territory are also classed as moderate risk areas from salinisation. The low-lying freshwater wetlands of the northern coasts of remote Australia are projected to suffer from salt water intrusion (Green et al. 2009). World Heritage areas such as Kakadu National Park and Mary River Catchment are particularly vulnerable. These wetlands are major conservation zones for plants, fish, reptiles and migratory birds and are significant tourist destinations (Allen Consulting Group 2005).

Transport

Transport options for Aboriginal and Torres Strait Islander Australians in remote communities are limited (Currie & Senbergs 2007). In 2008, a majority (71%) of Aboriginal and Torres Strait Islander adults living in remote Australia had no access to public transport, and 15% of them were unable to reach places when needed due to lack of transport (ABS 2010). Moreover, nearly one-third (32%) of Aboriginal and Torres Strait Islander people in remote areas had no access to a motor vehicle. This limitation in transport facility is compounded by the low-grade quality of road networks, which together with other factors contributes to a high level of car accident and fatalities in remote Australia. As shown in Figure 8, roads to settlements are mainly tracks and unsealed roads.

We did not find any studies on how and by how much climate change may impact on transport infrastructure in remote Aboriginal and Torres Strait Islander communities. However, as noted by Green et al. (2009), more intense and perhaps frequent extreme events such as cyclones, storm surges, flooding, heatwaves and bushfires will have significant negative impact on transport infrastructure such as roads, airstrips and communication facilities, especially in remote and isolated communities. This will disrupt and limit the provision of goods and services, with a likely increase in costs.

Maintenance, repairs and replacement costs of damaged transport infrastructure are likely to be high due to the difficulty and expense of getting materials and labour to remote areas. This will exacerbate existing difficulties of delivery and access to basic infrastructures, services and goods (Green et al. 2009), creating a positive feedback loop.

Taylor and Philp (2010) noted that the major impacts of climate change on land-based transport arise mainly from sea-level rise and the increase in frequency and intensity of extreme events. They also outlined possible implications of climate change on land-based transport infrastructure. As raised in the settlements section above, increases in temperature and solar radiation will increase asphalt softening as well as the expansion of stress movements on steel bridges and rail tracks, concrete joints, protective cladding, coatings and sealants on bridges and roads. This will reduce the effective life of asphalt roads and increase the embrittlement of the surface chip seals that are on more than 90% of the rural sealed roads in Australia. Increases in temperature and extreme events may also limit the ability of workers to undertake maintenance activity and construction due to heat stress conditions.

Some extreme events may require significant emergency evacuations of many people at the same time. The combination of damaged or deteriorating conditions of roads, traffic disruption, congestion and reduced visibility, and vehicle problems due to increased extreme events are likely to increase the risk of potential accidents involving property damage, injuries and fatalities. At times of extreme weather events, damage to major routes, airports and airstrips in the sparse network of remote transport is likely to have a significant impact on emergency evacuation and relief work, particularly among the most isolated remote settlements as there may be little or no alternative reliable routes.

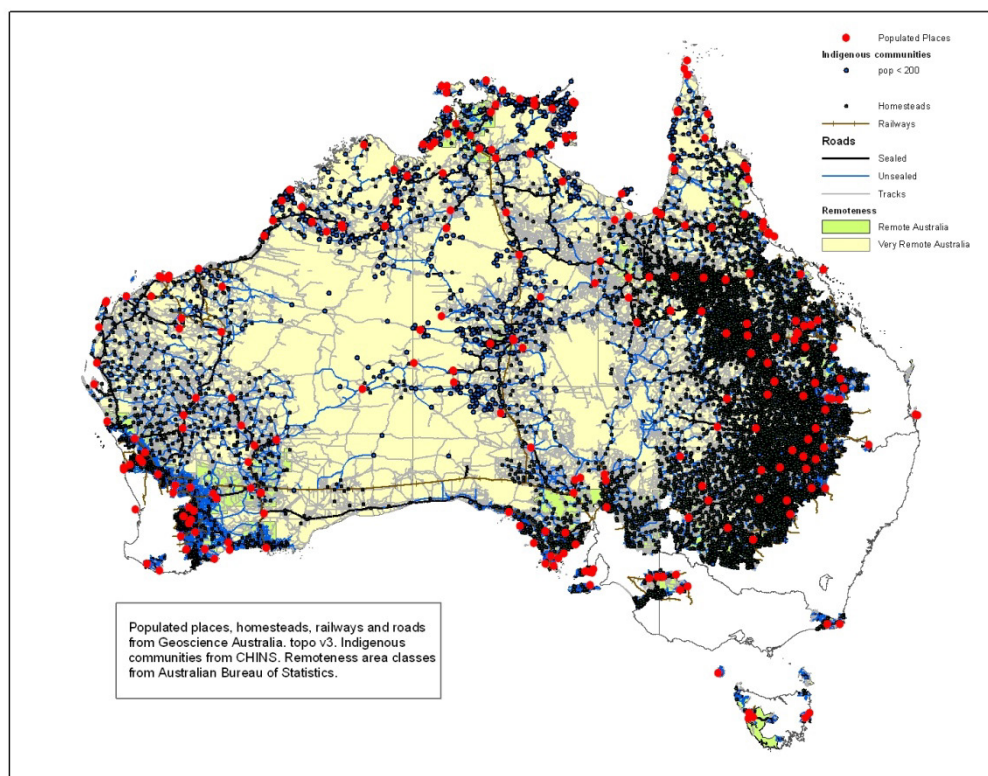


Figure 8: Transport infrastructure, towns and settlements in remote Australia

Source: Figure generated by author Chewings.

Gaps

There have been few studies on the impacts of climate change on settlements, basic infrastructure and services such as water, energy, transport and overall liveability of remote regions.

Conclusion

There are high risks of adverse effects of climate change on settlements and on the liveability of remote regions given the current chronically inadequate levels of services and infrastructure in remote regions and high levels of projected warming, particularly in north-western and inland regions of remote Australia. Deterioration of settlement conditions and liveability are likely to be experienced the most by Aboriginal and Torres Strait Islander people in remote Australia, as they already suffer from extensive and persistent socio-economic disadvantage.

Current understanding – health

We found some review studies on the impacts of climate change on the health of Aboriginal and Torres Strait Islander peoples in the tropical north (Green 2006, Green et al. 2009) and desert Australia (Campbell et al. 2008), on rural and remote Australia (van Iersel & Bi 2009), on health in western Australia (Spickett et al. 2008), on the likely impact on transmission of specific diseases relevant to remote Australia (Hanna et al. 2011, Harley et al. 2011, Russell et al. 2009, Tong et al. 2007), on mental health (Fritze et al. 2008), national health (Hennessy et al. 2007) and health services and the workforce (Blashki et al. 2010).

Health systems are already under pressure to cope with existing health needs of Aboriginal and Torres Strait Islander people in the north (Green et al. 2009) and in the rest of remote Australia (Campbell et al. 2008). These pressures may increase with climate change. Impacts of extreme events as a result of climate change are also going to require more emergency evacuations. This may well be against a background of isolation and inadequate levels of health services in remote Australia compounding the vulnerability of people living in this area.

Heat waves and exposure to prolonged high levels of temperatures are expected to increase the levels of dehydration, respiratory illness, heat stress, stroke, heart attack and death, particularly among vulnerable groups such as children, the elderly and those with chronic health conditions (Blashki et al. 2010, McMichael et al. 2002) and the socio-economically disadvantaged who have less access to resources for coping with the increasing climatic extremes (Hennessy et al. 2004). Heat stress is also likely to lead to an increase in crime, particularly involving aggression (Spickett et al. 2008). The impact of heat waves can be worse in remote areas given residents' inadequate access to health care systems, early warning information, communication and transport facilities (van Iersel & Bi 2009). Aboriginal and Torres Strait Islander people in the region will also be vulnerable given the high rate of pre-existing health issues such as heart disease, diabetes and obesity (Campbell et al. 2008, Green 2006, Green et al. 2009) as well as substandard and overcrowded housing (ABS 2008a).

The incidence and prevalence of vector-borne diseases such as Dengue fever and malaria, as well as the transmission of diseases such as melioidosis, may increase under projected climate change scenarios in different parts of remote Australia (Campbell et al. 2008, Green 2006, Green et al. 2009). Although Dengue fever and malaria are no longer endemic to Australia, the diseases have been imported by travellers returning from Asia. Outbreaks have often been reported in Queensland and the Northern Territory. However, the significance and direction of climate change impacts on some vector-borne diseases, for example Dengue fever in Australia, is disputed (Russell et al. 2009). Though the direction is not clear, climate change may affect vector-borne diseases such as Ross River virus (Australian Human Rights Commission 2008, Green 2006, Green et al. 2009), Barmah Forest virus, Murray Valley encephalitis and other exotic diseases (Spickett et al. 2008).

While a likely increase in the incidence of salmonella is projected, rotavirus in children is predicted to decrease (Harley et al. 2011).

Higher temperatures, humidity, and disruptive extreme events such as flooding and cyclones are likely to increase food- and water-borne diseases through increasing microbial growth, interfering with food preservation and increasing contamination of water from inadequate or malfunctioning sewerage systems.

Climate change is also likely to exacerbate respiratory diseases and allergic reactions due to reduced air quality through dust, pollutants and smog ozone levels (Campbell et al. 2008, Hennessy et al. 2007, Spickett et al. 2008).

Poor nutrition, overcrowded housing and the lack of adequate water supplies frequently found in Aboriginal and Torres Strait Islander communities increase vulnerability and reduce adaptive capacity to climate change (Campbell et al. 2008, Green et al. 2009). Indirect impacts such as reduction in bush food yields, disruption of fisheries, loss of livelihoods, and population displacement due to sea-level rise are also clearly significant for physical health and Aboriginal and Torres Strait Islander wellbeing, although no quantitative analysis of these impacts has been undertaken to date (Green et al. 2009).

Campbell et al. (2008) note more indirect impacts of climate change on health among people resident in Australian desert regions. They note that shallow groundwater supplies may dry up and become

contaminated more often during dry periods. Decreased water availability and quality could result in more cases of dehydration, increased water-borne diseases, exacerbated impacts of poor household hygiene, and skin diseases from inadequate personal hygiene and swimming in infected and contaminated waterholes. Likewise, increasing temperatures coupled with poor living conditions could promote flies and other pests affecting food, increasing the likelihood of food poisoning from organisms such as *Salmonella* and *Campylobacter*. Depression and mental illness are also expected to rise given heat, humidity, and human and material losses to extreme events; for example, drought can cause significant livelihood losses among pastoralists; and it can cause loss of connection to country, sacred sites and a way of life among Aboriginal and Torres Strait Islander people (Fritze et al. 2008). The holistic concept of human health articulated by many Aboriginal and Torres Strait Islander people may be a source of vulnerability in that disruptions that affect sacred sites and hunting grounds may be felt strongly and adversely affect psycho-social as well as physical wellbeing (Green 2006).

Climate change and attendant extreme weather events are likely to worsen liveability in remote Australia. This will exacerbate the difficulties in delivering health services and in recruiting health professionals to remote areas (van Iersel & Bi 2009), thereby compounding existing and anticipated vulnerability of health in remote communities (Blashki et al. 2010, Spickett et al. 2008).

Gaps

There are several general reports but limited detailed studies on the health impacts and adaptation pathways to climate change in remote Australia, particularly in inland arid Australia.

Conclusion

Climate change is likely to have significant direct and indirect health impacts due to reinforcing multiple socio-economic and environmental factors, particularly among Aboriginal and Torres Strait Islander peoples in different regions of remote Australia. These factors include:

- Pre-existing extensive and chronic health issues
- Inadequate health infrastructure and limited access to health services
- Significant socio-economic disadvantage and living conditions that reduce ability to respond to climate change and attendant increased extreme events
- Strong connection to country and natural systems in many parts of remote Australia and livelihoods that are dependent on climate-sensitive sectors that when disrupted can lead to psychosocial health problems.

Current understanding – education

This literature review has found no assessment of climate change impact on education and education facilities in remote settlements. This echoes similar finding two years ago by Green et al. (2009) who found no material that examined the effects of climate change on education provision in north Australia. However, it can be expected that an increase in average temperature and extreme events may damage and further limit access to education facilities and significantly reduce safety, attendance and attentiveness of students.

Green et al. (2009) described incidents and presented case studies that demonstrate damaging impacts of extreme events that may be related to climate change. These included the potential damage to property, such as the Northern Territory Maningrida school roof being ripped off during Cyclone Monica in 2008,

and the difficulties of retaining school teachers and providing a comfortable temperature for students in the hotter months in Western Australian Yakanarra schools. Extreme weather events can also further reduce the attractiveness of remote education facilities to teachers and other staff and increase their turnover, particularly among those unaccustomed to hotter conditions (Green et al. 2009).

Gaps

There are no studies on the impacts of climate change on the existing limited access to educational facilities and low level of educational status in remote regions of Australia.

Conclusion

Climate change is likely to exacerbate the poor education status of remote regions of Australia due to likely damage to educational infrastructure and disruption to teaching and training programs from extreme events, as well as creating further difficulty in recruitment and retention of educators due to increasingly harsh living conditions.

Section 3: Vulnerability and adaptive capacity

S3. The vulnerability and adaptive capacity of individuals and communities, especially Aboriginal and Torres Strait Islander people, as well as of remote infrastructure, ecosystems, industries and businesses under these climate scenarios.

Definitions

Vulnerability of a system to climate change is often defined as being a function of three factors: 1) exposure of the system to climate change, 2) sensitivity of the system to climate change 3) the system's adaptive capacity. Both exposure and sensitivity determine the potential impact of climate change on the system (Adger 2006, Allen Consulting Group 2005). Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential changes, to take advantage of opportunities, or to cope with the consequences (IPCC 2007). Therefore, vulnerability is the potential impact of the perturbation (in this case climate change) minus the adaptive capacity of the system. Although this is a widely accepted definition (Adger 2006), the literature provides several interpretations of vulnerability, with significantly different implications on its measurement (Maru et al. 2011, O'Brien et al. 2007, Preston & Westaway 2010).

Current understanding – pastoralism

While there are a number of qualitative impact assessments of some sectors, we found very few detailed vulnerability assessments conducted on, or covering sectors in remote Australia. Studies include an assessment of vulnerability of Australian rural communities to climate variability and change (Nelson et al. 2010) and vulnerability of key elements of the livestock grazing systems in northern Australia (Cobon et al. 2009). Before we discuss these vulnerability-related articles, we continue to outline potential impact statements on sectors reported in the literature.

Several studies reported on potential impacts of climate change on pastoralism in remote Australia. These impacts include:

- Given the projected decline, or little change in rainfall and increase in temperature across the rangelands, McKeon et al. (2009) estimate a decline in a Safe Livestock Carrying Capacity². The most arid and least productive rangelands may be the most severely impacted by climate change, while the more productive eastern and northern rangelands may provide some opportunities for slight increases in production (Stokes & Howden 2008). Carbon dioxide fertilisation will also improve pasture production in the short term, but this will be more than offset by accompanying changes in temperature, rainfall, pests and the availability of nutrients (Hennessy 2011, McKeon et al. 2009).
- More frequent droughts, more intense rainfall events, greater risks of soil erosion, reduced surface water availability and increased competition from woody vegetation will result in declines in pasture productivity and reduced forage quality and reliability (Howden et al. 2008).
- Climate change is most likely to increase water demands for both animal needs and for growing forage. It is also likely to increase livestock heat stress and problems with pests, diseases and weeds (Stokes & Howden 2008).
- All these impacts from different climate change elements could lead to decreased productivity per head (beef and wool) and gross margin, increased risks of interruption to various pastoral social and economic activities including trade (Stokes & Howden 2008), and adverse impacts on biodiversity in grazing systems of northern Australia (Cobon et al. 2009).

Gaps

While there are significant qualitative impact studies at a national level and a few focusing on pastoralism in northern Australia, the following research gaps are identified:

- A rigorous analysis of the regional variation in impacts of climate change on rangelands still needs to be conducted (Stokes & Howden 2008).
- Participatory research that involves pastoralists and farmers in assessing vulnerability, identifying adaptation options and limits is needed (Stokes & Howden 2008).
- A quantitative study of known uncertainties, for example, carbon dioxide effects on forage production and quality; future role of woody plants, including effects of fire; climatic extremes; and management for carbon storage (McKeon et al. 2009).
- A study to identify the most vulnerable regions, and to inform policy in time to facilitate transitional change and enable land managers to implement those changes (Cobon et al. 2009).

Conclusion

While there may be gains from climate change from increased carbon dioxide fertilisation that may improve pasture growth in the short term, this will be more than offset by changes to precipitation, pests and the quality and composition of forage. Climate change and extreme events are more likely to have significant adverse effects on pastoralism in remote Australia

Current understanding – tourism

Various studies report on a comprehensive study on the economic and non-economic impacts of climate change on the tourism sector in five Australian regional tourism destinations: Kakadu National Park, the Cairns region (including the Great Barrier Reef and Wet Tropics rainforest), the Blue Mountains, the

² Safe Livestock Carrying Capacity refers to an estimate of the capacity of the pasture resources of land to sustainably carry livestock (and other herbivores) in the long term (>30 years).

Barossa Valley and the Victorian Alps (Pham et al. 2010, Turton et al. 2010, Turton et al. 2009). Findings that may be applicable to tourism destinations in remote Australia include:

- In all regions, tourism demand could be reduced by changes that affect the character of the landscape, the region's economy, or the strength of community spirit.
- Although economic impacts of climate change have been analysed at a national level, impacts on tourism have been overlooked.
- The climate change induced–economic impact on tourism, as measured by impact on gross regional product and projected rates of growth in domestic and international tourism, will be significant. This will be particularly the case at regional and/or destination level (e.g. Kakadu) and where tourism has a larger share of the economic activity and outputs of a region.
- Most tourism-reliant regions at the destination level, as examined in the studies, do not have obvious alternative sources of economic activity that might enable them to diversify their economies in response to climate change–induced impacts. This lack of diversification has implications for policy making.

Gaps

We found no reported study on the impact of climate change in remote tourism destinations other than at Kakadu.

Conclusion

Climate change can have significant adverse impact on remote tourism and associated economic activities, particularly in regions where there are limited alternative livelihood activities that are insensitive to climate change.

Current understanding – ecosystems

Our ISI Web of Science search results picked few relevant articles on the impacts of climate change. Relevant articles related mainly to natural resources focused on the longevity and dynamics of soil seed banks of plants from arid Australia (Ooi et al. 2009); on ecological range shifts (Shoo et al. 2006); on rainforest birds of the Australian wet tropics (Shoo et al. 2006); and on water resource management in arid and semi-arid regions (Ragab & Prudhomme 2002). We also found reviews on impact of climate change on natural resource management in the Northern Territory (Cook & Meyer 2010); on biodiversity through change in fire regimes (Williams et al. 2009a); and on ecosystem impacts of climate change in the tropical north (Green et al. 2009), in some national-level studies such as the Garnaut (2008) report, Department of Climate Change (2009), Morton et al. (2009) and Steffen et al. (2009).

Green et al. (2009) speculate the likely impacts of climate change on ecosystems of tropical northern Australia to include:

- adverse direct impacts on coral reefs and marine ecosystems from expected ocean acidification
- indirect impacts such as shifts in species distribution and range, and shifts in breeding patterns
- changes to predator–prey relationships, greater susceptibility to disease, and community dynamics and ecosystem function.

The Garnaut (2008) report also notes that added stressors from climate change would have negative impacts on Australia's ecosystems through:

- exacerbating existing environmental problems from invasive species and from the loss, fragmentation and degradation of habitat; unsustainable use of natural resources; inappropriate fire regimes
- reduced rainfall that will result in even larger decreases in stream flows and changes to aquatic environments.

Similarly, Morton et al. (2009) identified various direct and indirect effects of climate change including:

- range shifts of species, range fragmentation or shrinkage, extinctions and changes in the structure of ecosystems
- potentially greater vulnerability to biological invasions
- alteration of fire regimes
- changes in linkages between ecological and socio-economic systems.

A study on climate change risks on Australia's coasts notes that sea-level rise, increases in sea surface temperature and ocean acidification are likely to have significant negative impact on terrestrial and aquatic plants and animals that rely on coastal habitats (Department of Climate Change 2009). This study also notes that an increase in intensity and/or frequency of extreme weather events is likely to increase the risk of beach loss, salinisation of wetlands, inundation of low-lying areas and submersion of reefs. It is expected that initial responses from animals and plants in coastal ecosystems in response to climate change will be migration, either inland or pole-ward. Change in coastal ecosystems is already occurring, with southward migration of some species being observed, particularly along the south-east coast of Australia (Department of Climate Change 2009).

Hennessey and Overton (2011) note that future climate change is likely to have impacts on the ecosystems within Australia through increased temperatures and increased variability in rainfall but with a tendency for less rainfall. Major threats to ecosystems include extended drought periods, invasive weeds and pests, altered fire regimes, land-use changes including water storages, direct temperature effects, increases in salinity and other water quality issues, and changes in water availability.

A national study on impacts of climate change on Australia's biodiversity (Steffen et al. 2009) summarises understanding on the current state and implications of future climate change under three greenhouse emission scenarios and suggests adaptation measures for different regional ecosystem types. These scenarios are 1) recovery (optimistic); 2) stabilisation (realistic); and 3) runaway (pessimistic). One of the regional ecosystem types identified matches desert Australia. The study speculates that species will move increasing distances across flat landscapes and therefore identifies the need to facilitate refugia crucial for scenarios 1 and 2, and notes that this adaptive strategy will be overwhelmed under scenario 3. Hennessey and Overton (2011) also suggest the need to ensure habitat connectivity among Australia's 9,000 protected areas, including national parks, nature reserves, private conservation reserves and Indigenous Protected Areas, so that native species can readily relocate between protected areas as climatic conditions change. One project that seeks to achieve large-scale ecosystem connectivity in readiness for climate change response is the Eco-Link Project, which is a joint venture between the Northern Territory and South Australian governments and which extends north-south across much of the central third of remote Australia (Government of South Australia 2012, Northern Territory Government 2012).

With regard to short term (0–5 years) adaptive strategies, the report by Steffen et al. (2009) identify that the policy option of investing in remote area stewardship will result in multiple benefits. As an integrated response package, the report estimates significant biodiversity outcomes and ancillary cultural and wellbeing benefits from modest stewardship payments and from recognised and valued Indigenous Protected Areas. In addition, the report notes the importance of climate-related education, governance and investment measures. In education, the report identifies the importance of encouraging and valuing naturally functioning systems and practical training in biodiversity conservation. With regard to governance and investment, the report suggests encouraging and supporting stewardship contractual management, as well as conservation and Aboriginal and Torres Strait Islander programs mainly funded by the government with likely additional support from carbon markets.

Gaps

There is very limited reported work on research and plans to support remote ecosystem and wildlife adaptation to climate change.

Conclusions

The impact statements from different reports reviewed here identify direct and indirect adverse effects of climate change and associated increase in intensity and/or frequency of extreme events on diverse sets of ecosystems across remote Australia. This vast arid area is likely to experience the greatest warming and drying trends within the rangelands. This will further stress many enterprises that are already only marginally viable and where few opportunities for adaptation exist. Some of the reports (e.g. Steffen et al. 2009) suggested investment in stewardship arrangements to maintain and expand diverse sets of conservation activities that provide multiple biodiversity and livelihood outcomes and enhance connectivity of habitats as part of supporting adaptation of ecosystems to climate change.

Current understanding – climate change vulnerability and adaptive capacity of the grazing industry in remote Australia

A study by Cobon et al. (2009) focuses on the grazing industry of northern Australia (north of 29°S) and a time frame extending to 2030. It has both climate change impact (discussed above) and vulnerability assessment. The study identifies 12 essential elements of the grazing system in northern Australia. Table 6, reproduced from Cobon et al. (2009), provides a general vulnerability of the grazing system to 13 climate change variables. The main findings are that parts of northern Australia will experience more droughts and lower summer rainfall. This poses a serious threat to the rangelands, even after accounting for adaptive responses. Although the impacts and adaptive responses will vary between ecological and geographic systems, climate change is expected to have noticeable detrimental effects: reduced pasture growth and surface water availability; increased competition from woody vegetation; decreased production per head (beef and wool) and gross margin; and adverse impacts on biodiversity.

Table 6: Potential adaptations responses of the grazing system to climate change vulnerability

Climate change variable	Pasture growth	Surface cover	Wool per head	Beef per head	Gross margin (relative CPI)	Biodiversity
1. Elevated CO ₂	Manage cattle/sheep to utilise extra pasture; Maintain cattle/sheep for pasture recovery; Monitor C3/C4 ratio	Manage cattle/sheep/fire to maintain existing cover; Maintain cattle/sheep for pasture recovery	Use supplements and rumen modifiers; Use early season growth and destock sooner; Lengthen recovery time of pastures; Monitor C3/C4 ratio	Use supplements and rumen modifiers; Use early season growth and destock sooner; Lengthen recovery time of pastures; Monitor C3/C4 ratio	Monitor feed availability, quality and C3/C4 species and trade animals before critical thresholds are reached; Use feedlots to finish animals	Manage invasive plant species; Maintain refugia
2. Increased evaporation	Decrease cattle/sheep in the warm/ dry season to maintain pastures; Maintain groundcover to preserve soil moisture and tree strips to reduce landscape evaporation	Decrease pasture utilisation to maintain ground cover	Increase shade for animals, e.g. plant/retain suitable trees for shade; Increase number of water points	Provide shade for animals where required; Increase number of water points; Use adapted animal breeds	Combination of the adaptation responses (to the left)	Manage invasive plant species; Maintain refugia
3. Higher minimum temperature	Manage cattle/sheep to utilise extra pasture; Maintain cattle/sheep for pasture recovery	Manage cattle/sheep to maintain existing cover; Maintain cattle/sheep for pasture recovery	Manage sheep in winter to utilise extra pasture; Maintain sheep for pasture recovery; Monitor micron of wool; Use mulsing and fly-resistant bloodlines	Manage cattle in winter to utilise extra pasture; Maintain cattle for pasture recovery; Use tick-/fly-resistant breeds/ bloodlines	Use BMP to monitor incidence of disease in winter; Use insect baiting programs in winter before numbers build up; Monitor micron of wool in winter	Manage invasive plant species; Maintain refugia
4. Less frost	Manage cattle/sheep to utilise extra pasture; Maintain cattle/sheep for pasture recovery	Manage cattle/sheep to maintain existing cover; Maintain cattle/sheep for pasture recovery	Manage sheep in winter to utilise extra pasture; Maintain sheep for pasture recovery; Monitor micron of wool; Use mulsing and fly-resistant bloodlines; Offset by decrease in winter rainfall	Manage cattle in winter to utilise extra pasture; Maintain cattle for pasture recovery; Use tick-/fly-resistant breeds/bloodlines; Offset by decrease in winter rainfall	Combination of adaptation responses (to the left)	Manage invasive plant species; Maintain refugia
5. Higher maximum temperature	Decrease cattle/sheep in the warm/ dry season to maintain pastures; Manage utilisation early in the growing season	Decrease TGP to maintain cover	Implement BMP, e.g. lamb in autumn; Wean in late winter/early spring; Shear in spring; Use Merinos bred for harsh conditions; Manage non-domestic grazing pressure	Implement BMP, e.g. use controlled joining to calve in autumn; Use adapted breeds	Monitor fringe pasture and animal species for mortality and production; Identify and use better adapted species/breeds; Use feedlots to finish animals	Manage invasive plant species; Maintain refugia
6. More days over 35°C	Decrease cattle/sheep in the warm/ dry season to maintain pastures; Manage utilisation early in the growing season	Decrease TGP to maintain cover	Implement BMP, e.g. lamb in autumn; Wean in late winter/early spring; Shear in spring; Use Merinos bred for harsh conditions; Manage non-domestic grazing pressure	Implement BMP, e.g. use controlled joining to calve in autumn; Use adapted breeds	Monitor fringe pasture and animal species for mortality and production; Identify and use better adapted species/breeds; Use feedlots to finish animals	Manage invasive plant species; Maintain refugia
7. More droughts	Decrease cattle/sheep to maintain pastures; manage climate variability, e.g. MJO, ENSO, PDO to help adjust animal numbers; Manage non-domestic grazing pressure	Decrease TGP to maintain cover; Manage climate variability, e.g. MJO, ENSO, PDO to help adjust animal numbers	Decrease sheep to utilise less pasture; Decrease sheep for pasture recovery; Use climate forecasts to destock early	Decrease cattle to utilise less pasture; Decrease cattle for pasture recovery; Wet season spelling of pastures; Use climate forecasts to destock early	Combination of adaptation responses (at left); Explore alternative land-use; Grants for adaptation; Loans for further education and business development	Manage invasive plant species; Maintain refugia – especially wetlands
8. Increased storm intensity – same total rainfall	Decrease cattle/sheep in the warm/dry season to maintain pastures; Maintain biomass for optimal infiltration	Decrease TGP to maintain cover; Use erosion mitigation strategies	Decrease sheep to utilise less pasture; Decrease sheep for pasture recovery	Decrease cattle to utilise less pasture; Decrease cattle for pasture recovery	Maintain cover to maximise water infiltration into soil; Use other erosion mitigation strategies	Manage invasive plant species; Maintain refugia

Source: Cobon et al. (2009, Table 3). Refer to the source for references for each cell

In a study integrating the potential impacts of climate change with adaptive capacity of farming systems, Nelson et al. (2010) have assessed the vulnerability of Australian rural communities (including some remote pastoral and farming communities) to climate variability and change. The exposure of Australian rural communities to climate change was measured using model projections of expected changes in rainfall, pasture growth and farm incomes to 2030. Adaptive capacity of rural communities was assessed as an emergent property of the diverse forms of human, social, natural, physical and financial capital³ that support rural livelihoods, and the flexibility to substitute between them in response to external stresses such as climate change. This assessment was premised on the assumption that farm households, with their diverse assets and activities, are likely to have adaptive capacity because they can substitute between alternative livelihood strategies in times of stress.

Rural communities vulnerable to climate variability and change were identified as those for which high or moderate exposure coincides with low to moderate adaptive capacity. Exposure to impacts of climate change on rainfall, pasture growth and farm income by 2030 were estimated using the MPI-ECHAM5 climate model for the A1FI scenario, GRASP pasture growth model and AgFIRM income model respectively (Nelson et al. 2010).

They found that exposure to a moderate or high reduction in rainfall in most of remote Australia was not directly related to a reduction in pasture growth and income as these are affected by a range of other factors. Simulated pasture growth showed a variable response to climate change, except in the Northern Territory where an increase was expected. For most of remote Australia, farming-simulated pastoral growth responses to climate change were associated with a negligible income loss to an increase in income.

Nelson et al. (2010) found that adaptive capacity was low across many of Australia's rangeland communities that remain dependent on the wool industry. However, in some pastoral communities such as the Gascoyne Murchison region of Western Australia, which are dependent on wool production, a greater degree of adjustment has been possible because of a greater emphasis on meat production, opportunities for live export and proximity to the mining industry. This has contributed to higher levels of adaptive capacity than other wool-dependent pastoral areas.

Nelson et al. (2010) noted that the relative size of extensive beef properties of northern Australia is also helping to boost the adaptive capacity of this region. They also estimated a low adaptive capacity across Cape York and speculate that this may partly reflect the declining emphasis on agricultural productivity in these regions, as the land is increasingly managed for a broader range of Aboriginal and Torres Strait Islander, environmental and mining values.

Nelson et al. (2010) found that rural communities that are most exposed to climate change are necessarily the most vulnerable. Australian rural communities that are vulnerable to climate variability and change are vulnerable for a complex set of environmental, economic and social reasons. Vulnerable communities include those in inland Australia that lack alternative livelihood options to contend with a long-term decline in the international demand for wool. For rural communities associated with grain and beef production, multiple drivers of change and constraints on adaptive capacity contribute to vulnerability. For example, in the wheat-sheep zone, climate variability and the prospect of a drier future is likely to accelerate an ongoing process of structural adjustment in response to declining terms of trade.

³ These capitals are the core components of the sustainable livelihoods framework (DFID 1999).

Gaps

There is a need:

- for detailed regional and local assessments of pastoralism under worst-case climate change scenarios to inform decision makers of future risks and enable climate change adaptation needs to be incorporated into planning approaches
- to check alignments of existing disaster risk-reduction strategies with adaptation plans at different scales and a need for improved information to support adaptation ecosystems in pastoral systems; there is particularly a need for decisions on what assets need to be protected and how this should be done, given that this will inevitably involve trade-offs
- to identify whether, and under what conditions, this combined impetus for change from climate and other drivers is likely to exceed incremental coping capacity, and require more transformative changes in farming systems, land use and industries; there is also a need for further research and development to identify the most vulnerable regions, and to inform policy in time to facilitate transitional change and enable land managers to implement those changes.

The risk- or livelihood analyses-based vulnerability assessments are well advanced approaches but still require consideration of change on capitals in response to climate change impacts and validation of assessments through a participatory process with stakeholders, as well as a tight linkage with adaptation policy or community measures.

Conclusion

Although there are still uncertainties in quantifying the effect of carbon dioxide – on, for example, forage production and nutrient cycling – on balance it appears that climate change is more likely to have adverse impacts on pastoralism in remote Australia. Despite high exposure to likely impacts of climate change and extremes, pastoral regions in remote Australia (particularly those in the north, north-west and central Australia) are estimated to have higher adaptive capacity than those in the south, south-east and south-west Australia. These analyses show that potential climate change impact assessment, while important for raising awareness, is an incomplete story in terms of vulnerability assessment, which is useful for adaptation planning. Climate impact assessment cannot account for adaptive capacity of the system, and could be misleading if it were used to target support for adaptation.

Section 4: Energy needs

S4. Within predicted climate and population scenarios, the energy needs of remote Australia, from household to regional scale.

Current understanding

Demand

Demand for energy in remote Australia is increasing (Syed et al. 2010). As elsewhere, energy demands in remote Australia are the product of several factors, including increasing per capita demographic, sectoral and industry energy needs. On the demography side, Grantham (2010), in a review of the literature on household energy consumption, concluded that socio-demographic variables (income, age, household characteristics, education and gender) influence energy consumption. An aging population will have more

health issues (van Iersel & Bi 2009), which, combined with more extreme temperatures in much of remote Australia, will mean that more energy will be required for air-conditioning in order to maintain a desired quality of life, particularly for households with young children or the elderly (Bi et al. 2011). Details of heating and cooling are mentioned in Section 2 on liveability.

Modernisation of the Australian outback, in the form of better communications, roads, television and radio, has driven remote Aboriginal communities in the Northern Territory and South Australia to demand the appliances that their urban dwelling counterparts accept as essential (Lowe & Lloyd 2001). Similarly, McKenzie and Howes (2006) found that the corporatisation of rural properties, including pastoral stations, has led to increasing demands for appliances and air-conditioning.

For industries in remote regions, mining will have the greatest growth in energy consumption, notably in Western Australia and Queensland (Syed et al. 2010). Nationally, energy consumption by the mining sector is expected to grow 6.1% by 2030, compared with agriculture (1.7%), transport (1.2%), commercial and residential (1.1%), electricity generation (0.9%) and manufacturing (0.7%). The mining sector is expected to account for 13% of primary energy consumption by 2029–30. Much of this will be required for large new capital expenditure projects for mineral extraction and processing for export (Syed et al. 2010).

Supply

Remote Australia currently depends mainly on fossil fuels for electricity and other domestic, commercial and public service energy needs, as does the rest of Australia (Syed et al. 2010). This is in spite of vast potential for generating alternative renewable energy, including solar, geothermal and tidal energy. For Australia as a whole, non-renewable energy sources account for 95% of the primary energy used (Syed et al. 2010). Over 31 million litres of diesel fuel were used to generate electricity for major remote communities in the NT in 2009, and this amount was expected to increase by 25% over the next 3 years due to growing populations and increased per capita use of electricity (Green Energy Taskforce 2010).

Energy supply from renewable sources contributes a small proportion of the total supply of energy in remote Australia. This is despite a long history of use of renewable and hybrid energy electricity generation on remote pastoral properties, including wind and solar generation in tandem with battery storage. Bushlight (CAT n.d.) and other organisations are providing solar energy services to remote Aboriginal communities. An issue common to several sectors is scaling up of energy sources as demand increases.

The increasing demand for energy is likely to outstrip supply from alternative energy sources, even though these are becoming more efficient. This is likely to compound issues around peak oil, a term used to indicate when oil production reaches its maximum annual rate of production for any area (ASPO n.d.). Estimates are that we might reach peak oil between 2008 and 2013 (CSIRO 2008). This issue is particularly important for remote Australia, where most of the energy for transport and energy supply still comes from fossil fuels.

Gaps

Household

- The effects on energy demand from consumer responses to new lifestyle technologies and incentives for conservation measures are not clear.

Regional

- There is little understanding about the impact of peak oil on the technical, social and economic aspects of future transport in remote Australia.

- Some small hybrid electricity generation systems do not readily scale up when there is increased demand.
- It is not clear how the increasing energy demand will be met and delivered in remote Australia.
- Increasing temperatures in inland Australia will lead to a higher demand for energy to maintain current lifestyles and to address the changing requirements of an aging population.
- There will be an increasing demand for energy, for example, for air conditioning and telecommunications in modernising communities, and it is not clear to what extent it will be feasible to counterbalance this growth with conservation measures (e.g. in more efficient housing design).
- The mining sector has large and growing requirements for energy in remote Australia. There is potential for the sector to use renewable energy, but there are issues around infrastructure availability and cost.

Conclusion

- In remote Australia, energy needs will be driven by the interaction of increased population; increased per capita energy consumption through poverty alleviation; increased temperature driving air-conditioning demands; increased telecommunications infrastructure; and increased heavy industry, especially mining.
- Net projections have been calculated for the mining industry and at state/territory level, but there has been no local- or community-scale assessment that links to opportunities for harnessing alternative energy sources.

Section 5: Energy costs

S5. The impacts of increasing energy costs on the individuals, communities and businesses of remote Australia.

Current understanding

The price of energy is likely to continue to rise as the cost of producing fossil fuel increases and approaches peak oil; and as gas utilities, which generate electricity using fossil fuels including natural gas, will be obliged to purchase emissions permits under the *Clean Energy Act 2011*. Garnaut (2011a, p. 130) suggests that global forecasts for oil are now in the range of US \$120–130 barrel, with the potential to go much higher.

The cost of renewable energy sources affects uptake in remote Australia. Barriers include pricing (especially high transformational costs), perceptions, relatively immature technology and distance between energy sources and markets (Ellis & Peake 1996, Harrison et al. 1996, Lloyd 2001, Marinova & Balaguer 2009, McHenry 2009). There are high costs of repair associated with remote locations, and immediate economic returns are rare. Areas with a small population are sometimes unable to justify upfront and maintenance costs. McHenry (2009) found that the main drivers for surveyed pastoralists to switch to renewable energy sources included subsidies and escalating conventional fuel costs, in addition to a desire for quiet, 24-hour energy supply. By contrast, a survey of accommodation operators in Queensland found that a smaller proportion of operators in the inland region (included in remote Australia) were interested in renewable energy compared with those in the coastal regions, despite the availability of subsidies. To

buffer the initial installation costs, there are ranges of government incentives for people to shift to renewable energy. A recent community-level government-funded initiative is the Alice Solar City program, launched in 2008 (Alice Solar City 2012). Further details on some government policies that impact on energy costs are provided in Section 9 of this report.

Transport is one of the major sectors with a high demand for energy, and the cost of transport affects the viability of remote businesses. The future fuel mix used in the transport sector is likely to change substantially in response to the increasing cost of oil and the need to reduce greenhouse gas emissions (CSIRO 2008, Graham et al. 2008). There will likely be a diverse mix of fuels in road, rail, air and sea passenger and freight travel. It is likely that electricity, LPG and natural gas will be the first fuels to expand use, due to their existing production and distribution infrastructure (CSIRO 2008). In the longer term (beyond 2020) biofuels and synthetic fuels will come into production. Any increase in transport costs will adversely impact on low income Australians, particularly in the urban fringe, regional and remote areas. Transport-dependent areas such as tourism and mining are vulnerable to a decline in international oil supplies.

Details of future projections of costs associated with electricity generation technologies are available in CSIRO's and other contributions to the Garnaut 2011 review (Garnaut 2011b). Energy consumption from renewable energy sources is rated under different scenarios over 20 years as the technology matures, and forecasts are at the national scale. As time goes by the cost of producing energy decreases, but initial costs are still high given the small population sizes in remote areas.

Gaps

- We did not find any studies on the gap between likely peak oil and the relatively slow rate of renewable technologies becoming cost efficient (due to cost and consumer behaviour) and the impact on transport and service delivery in remote Australia.
- There are considerable uncertainties around renewable technologies in areas of development, implementation and cost recovery for small communities in remote Australia.

Conclusion

Although there are a number of renewable energy initiatives, remote Australia remains highly dependent on fossil fuels. Household consumption of energy is rising, even though prices are already high. The costs of deriving energy from fossil fuels will keep increasing, and a substantial reduction in costs of deploying alternative sources of energy will take time, due to the rates of technology development and adoption. This is particularly an issue for remote Australia, which has a sparse population, has high demands for transport, and presents additional challenges for critical components of any renewable energy sector, for example, a charging network for electric vehicles. The time it will take to develop and deploy affordable renewable energy on the one hand and the increasing prospects of peak oil as time goes by on the other hand could have a negative impact on service delivery and transport in remote Australia.

Section 6: Alternative energy sources

S6. The potential for and social and economic benefits of harnessing alternative sources of energy for remote Australia.

Current understanding

Harnessing alternative sources of energy

The current alternative renewable energy sources in remote Australia include solar, wind and geothermal (see Figure 9). An analysis of renewable energy sources appropriate for the Northern Territory (Green Energy Taskforce 2011) found that wind is likely to be of marginal value as the resource is of low quality in the NT; geothermal has significant long-term potential but the technology is relatively immature; hydro power is undeveloped and likely to be marginal; and there is some potential and activity for development of tidal power. Biofuels and biomass have significant difficulties; solar thermal is approaching the stage when it could be deployed but costs are still high (although decreasing); and solar photovoltaic is relatively developed and there is abundant resource in NT, although intermittence and cost remain major barriers in the short term.

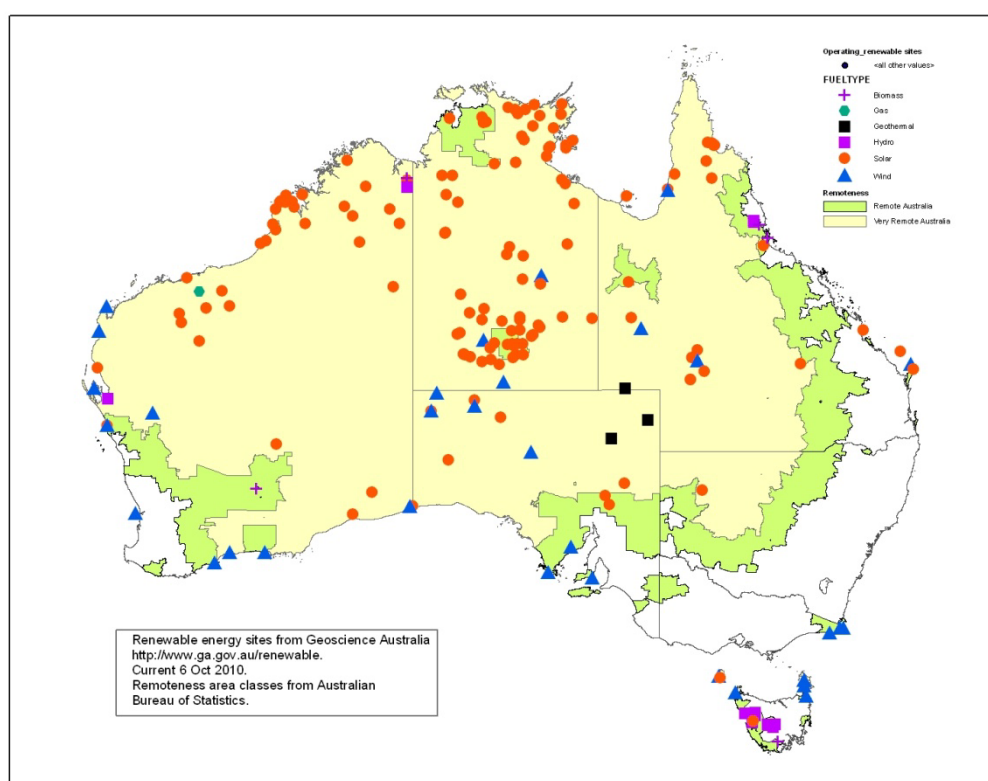


Figure 9: Renewable power stations greater than 3kW and total capacity in remote and very remote Australia

Source: Data on locations and characteristics of generators from Geoscience Australia, compiled October 2010 (Australian Government Department SEWPaC 2010).

Solar power has potential over vast areas of remote and very remote Australia (Geoscience Australia and ABARE (2010). Large solar installations are found in some towns such as Alice Springs (Alice Solar City 2012), while remote Aboriginal and Torres Strait Islander communities receive support for predominantly

solar energy from several organisations including Bushlight (which provides ongoing support to 220 communities in central and northern Australia) and Horizon Power (which installs and provides support to systems in Western Australia).

There are a number of hydro power stations in locations with sufficient and reliable rainfall (Geoscience Australia and ABARE 2010, see Figure 9), while development of biofuels requires sufficient water supplies and is currently limited. Geothermal research and understanding is in an immature stage, although this source has the potential to supply Australia's energy needs for many years (Geoscience Australia and ABARE 2010). There is one operational plant in Birdsville, in remote Australia.

However, renewable energy sources are not without their problems. Most renewable energies have low energy density and the energy content is more dispersed than fossil fuels (Marinova & Balaguer 2009). They are not stored forms of energy (with the exception of biomass), and are usually available as kinetic energy (e.g. wind, wave) or solar energy. Transportation of renewable energy is a challenge, particularly in remote Australia. Alternative sources of energy for transport include electric vehicles, as the associated technology is rapidly evolving due to huge investments by governments. However, Syed et al. (2010) do not expect electric cars to make a significant contribution to the Australian road transport fuel mix by 2030 due to technological limitations and the requirement for an extensive charging network.

Table 7 shows the number of operational renewable energy generators and total capacity by remoteness.

Table 7: Number of renewable power stations greater than 3kW and total capacity by remoteness. Source: Data on locations and characteristics of generators from Geoscience Australia, compiled October 2010 (Australian Government Department SEWPaC 2010)

	Biomass	Gas	Geothermal	Hydro	Solar	Wind	Ocean	Total	Capacity kw total
Remote and very remote									
NSW					2			2	52
Vic						3		3	30
Qld	2		1	2	25	7		37	97,566
SA			2		7	8		17	228,780
WA	1	1		2	39	12		55	188,413
Tas	1			12	2	6		21	1,281,060
NT					75	3		78	2,046
Not remote									
NSW	35			40	48	13	1	137	4,750,707
Vic	27			24	36	22	2	111	2,104,199
Qld	44			8	16	2		70	998,737
SA	9			2	9	14		34	1,014,485
WA	15			2	6	7	1	31	230,854
Tas	4			21	3	1		29	1,318,147
NT	1							1	1,100
ACT	2			2	8			12	3,543

Potential for social and economic benefits

In conventional cost–benefit analysis of energy sources, the social and environmental benefits are often not highlighted. Moreover, evaluating returns for renewable energy in remote Australia is challenging due to a wide range of objectives, including reduced carbon emissions and local employment opportunities. For example, subsidies for biofuels can improve farmers’ income, reduce emissions and result in local remote and rural employment (Ellis & Peake 1996). Training and employment of local community residents and community education are regarded as necessary for appropriate renewable energy installations (Green 1999, Jennings 2009). These are important components of services provided by some organisations supporting renewable energy development, such as Bushlight (CAT n.d.) and Horizon Power (Horizon Power n.d.).

Capacity building of stakeholders through improving the level of education and awareness in general about switching to renewable energy sources is seen as important, as are user training upon installation and access to skilled professionals. Lloyd (2009) describes the results of a survey of users of hybrid remote area power systems (RAPS) (n=29). The survey found that only two-thirds of the systems were in working order at the time of visit and that users can have unrealistic expectations, due to misunderstandings around ‘free’ energy which still requires replacement parts. There is a shortage of skilled professionals trained in renewable energy installations and maintenance, and an absence of training for engineers in broader social, environmental and economic issues (Lloyd 2001).

Pittock (2011) suggests that given the widespread potential for solar across remote Australia and limited employment opportunities in providing energy services to remote communities, scaling up to large facilities is required. These larger renewable energy facilities could be used to develop diverse local economies, help solve employment problems faced by Aboriginal and Torres Strait Islander communities and provide broader benefits. Pittock (2011) discusses the possibility of remote Australia becoming a net exporter of energy by developing infrastructure for generation capacity and a transmission network that links eastern and western Australia to take advantage of time-zone differences in supply and demand, and a north-south linkage to help overcome seasonal differences. In the long term, energy could be exported to Southeast Asia via an undersea HVDC cable. An example of a proposed energy infrastructure for the future with grids linking Asia and Australia through remote Australia for geothermal, gas and fibre optic is described by Grenatec (Grenatec n.d.). However, Wright and Hearps (2010) provide a recommendation for development of a renewable energy grid that sees generation sites only on the fringes of remote Australia, in order to minimise transmission distances and costs, and thus any social and economic benefit (as well as environmental impact) need not be widely distributed across remote Australia.

Some policy areas that may need to be addressed for development of renewable technologies include ‘right of access’ to sources of renewable energy, land tenure and land use limitations, and environmental assessments for renewable energy projects (for the NT see Green Energy Taskforce 2011).

Gaps

There is a lack of analysis of the environmental impact (such as on water) of potential renewable energy developments in remote Australia, especially those with larger spatial footprints such as thermal solar power plants and national electricity grids.

There is a need for a broader review of the institutional needs and implications for effective renewable energy development across remote Australia. Despite the availability of technologies and recent support for installations in remote communities, there is a gap in understanding of what is required for self-

sustaining remote renewable energy systems, and a need to overcome high system failure rates and high continuing external inputs for maintenance.

Given adverse repercussions from peak oil (albeit with significant uncertainties), and increases in energy demands from population growth and climate change, there is a research need to develop viable pathways for expanding renewable energy use and to improve the feasibility of large-scale renewable energy development in remote Australia.

Conclusion

There are encouraging initiatives for generating alternative energy from different sources at different scales (e.g. Bushlight, Horizon Power for communities). There are widely varying views about the viability of proposals for large-scale generation connected to long-range distribution networks, with development on the fringes of remote Australia currently seen as the most likely scenario.

Current renewable energy developments have a narrow economic cost–benefit analysis, and it is mainly on this narrow basis that scenarios identify development of large-scale renewable energy development only at the fringes of remote Australia. There is no cost–benefit analysis that considers a wide range of social and cultural costs and benefits, although education, training and broader social benefits are seen as essential to effective installation and long-term maintenance of renewable generation facilities in remote Australia. However, there are still significant institutional, financial, technical, social, cultural and behavioural barriers for the widespread production, use and export of renewable energy from remote Australia.

Section 7: Carbon: storage and abatement

S7. The opportunities for carbon storage and emission abatement in remote Australia, including scale of the biophysical capacities and any gaps in data for this region.

Definitions

Carbon storage and abatement can be achieved through two main pathways: geosequestration and ecosystem management. Geosequestration is the pumping of carbon dioxide into permanent below-ground reservoirs, usually porous geological strata, and relies on a concentrated carbon dioxide source such as a power plant burning fossil fuels, a situation not currently relevant to remote Australia.

In terrestrial ecosystems, long-term net carbon sequestration and/or greenhouse gas emissions abatement ('carbon farming') can be achieved by management of the ecosystem fluxes of carbon dioxide and other greenhouse gases such as methane and nitrous oxide, through activities such as:

- reforestation and revegetation*
- native forest protection*
- forest management
- reducing methane emissions from livestock and feral animal digestion*
- manure management
- reducing fertiliser pollution
- reducing pollution or increasing carbon storage in agricultural soils (soil carbon)*
- reducing pollution from rice cultivation

- savanna fire management*
- reducing pollution from burning of stubble and crop residue
- reducing pollution from legacy landfill waste.

(Commonwealth of Australia 2011)

Activities marked with asterisks are particularly pertinent to remote Australia where agricultural practice is mostly extensive rather than intensive.

In Australia, carbon farming is becoming formalised through criteria and methodologies within the Australian Government's Carbon Farming Initiative (CFI), which prepared for the beginning of the formal carbon market. To qualify for carbon credits under the CFI, land management actions for sequestration or greenhouse gas emissions abatement must be:

- additional (the consequence of new actions, not only an extrapolation of existing actions)
- permanent (defined as 'for at least 100 years')
- accounting for leakage (cryptic losses of carbon)
- measurable and auditable
- conservative
- internationally consistent
- supported by peer-reviewed science.

(Commonwealth of Australia 2010)

Meeting these criteria will be critical to the development of any ecologically and economically robust carbon farming projects in remote Australia.

Current understanding

With regard to terrestrial land management opportunities, remote Australia includes major climatic and ecological gradients, including the north–south gradient from winter and summer rain, and arid shrublands and grasslands to tropical forests, all lying across a mosaic of different soil types. This diversity of ecosystem types and range in productivity leads to location-specific sets of options for engaging with a carbon economy.

There have been varying degrees of research on the biophysical aspects of carbon farming opportunities. Savanna fire management provides a significant opportunity for landowners and managers in northern Australia to generate carbon credits and thus earn income on carbon markets, and is the best researched opportunity to date. Savanna burning is one of the first methodologies approved by the Domestic Offsets Integrity Committee (DCCEE 2011b), as a result of more than a decade of research on carbon cycling in relation to fire in Australia's northern savannas (Dyer 2001, Williams et al. 2009b, Williams et al. 2002) (also see Tropical Savannas CRC n.d.). The key principle of savanna fire management for greenhouse gas emissions abatement is to increase early dry season small-scale burning in a strategic way that greatly decreases late dry season large-scale fires, because early dry season fires release much lower amounts of methane and nitrous oxide into the atmosphere. The methodology at present applies only to savanna ecosystems with mean annual rainfall > 1000 mm (DCCEE 2011b), and thus is limited in geographic scope to less than 10% of remote Australia (the far north). The Department of Climate Change and Energy

Efficiency is supporting new research efforts to extend the methodology to lower-rainfall rangelands further to the south, or develop a new methodology better suited to these drier savannas.

The Western Arnhem Land Fire Abatement project (WALFA) is the best developed example of savanna fire management in northern Australia (Russell-Smith et al. 2009 and chapters therein). In 2006, a 17-year voluntary offsets agreement was signed between Darwin Liquefied Natural Gas (a subsidiary of the energy company, ConocoPhillips), the Northern Territory Government, and local landowners. The project operates across 28,000 km² of the Arnhem Plateau, adjoining Kakadu and Nitmiluk National Parks (Commonwealth of Australia 2010). The project abates approximately 150,000 t CO₂-e per year, on average, and the offsets are sold at around \$10 per tonne CO₂-e. NAILSMA is developing a regional approach to dissemination and coordination of this model on other Aboriginal and Torres Strait Islander lands (NAILSMA n.d.).

The WALFA project has also provided evidence that savanna fire management for carbon credits has biodiversity benefits ('co-benefits') that are consequences of ecosystem response to patchy fire according to the principles of the 'intermediate disturbance hypothesis' (Russell-Smith et al. 2009 and chapters therein).

For other carbon farming approaches, exploratory preliminary assessments have been made (or are currently being made) of tropical forest plantations (e.g. Richards et al. 2011), arid-zone forest plantations (e.g. Centrefarm 2010), altered cattle-rumen microbial flora and cattle diet (see review by Cottle et al. 2011), reductions of feral camels (e.g. Drucker 2008) and bioenergy (e.g. Morrow 2003), but none has yet reached a stage at which understanding could underpin contractual arrangements for carbon credits.

A preliminary assessment of carbon storage potential in rangeland soils is under way, using a predictive approach based upon the CENTURY model of soil carbon dynamics (Leigh Hunt, CSIRO, pers. comm.); the main outcomes of this analysis will be identification of climate zones and soil types with greatest soil carbon sequestration potential and thus the best targets for future research. More detailed assessment of rangeland soil carbon pools and storage potential is intensive and time-consuming (for example, see Brown et al. 2010 in the USA) and scarcely begun for the ecosystems of remote Australia.

Gaps

With the exception of savanna fire management for reduced methane and nitrous oxide emission in northern savannas, there are significant biophysical knowledge gaps around all carbon-market opportunities in remote Australia. Some issues are the subject of research in progress, but many gaps remain:

- Understanding to underpin a savanna burning methodology for savanna ecosystems with mean annual rainfall < 1000 mm (currently under development).
- Feasibility of reduced methane and nitrous oxide emission through managed burning in even more southern, fire-prone ecosystems other than savanna e.g. spinifex- and mulga-dominated ecosystems. These ecosystems are subject to relatively low long-term mean plant production and thus fuel loads for fires, and greater interannual variability in these parameters, due to multi-year climate cycles such as El Niño. There is large uncertainty in the ability to achieve whole-ecosystem reduction in net greenhouse gas fluxes that are both long-term and verifiable, within the high variability.
- Magnitude of the potential carbon farming opportunity through restoration of historically degraded rangelands, especially net sequestration opportunity through revegetation (increased mean plant biomass) and soil rehabilitation (increased soil carbon storage). Issues of additionality, permanence

and leakage are important for the CFI, as is a requirement for cost-effective verification when mean sequestration rates are likely to be very low in lower rainfall regions and patchily distributed across large land management units. This work needs to include any trade-offs and synergies between carbon sequestration and cattle production in both the short and long terms.

- Magnitude of the potential carbon farming opportunity through sequestration by reforestation and forest management in sub-humid and semi-arid regions of remote Australia. Multi-year cycles of productivity and unpredictable fire regimes that are difficult to manage at local scales present challenges to meeting permanence and leakage criteria critical to CFI.
- Occurrence and magnitude of any biodiversity co-benefits of land management actions for carbon farming in remote Australia's ecosystems other than savannas with mean annual rainfall > 1000 mm.

Conclusion

Remote Australia offers varying biophysical opportunities for greenhouse gas emissions abatement and carbon sequestration according to climate, soils and vegetation. The basis of carbon farming through fire management in higher-rainfall savanna is well established, and to a lesser degree so is the magnitude of the opportunity for forest plantations in higher rainfall zones and for feral ruminant animal control (especially camels). In all other ecosystem types, and for all other emissions abatement and carbon sequestration approaches, there is insufficient understanding to quantify the likely long-term rates and to demonstrate the ability of carbon farming proposals to meet the essential criteria around permanence and leakage, given the low and highly variable productivity of most ecosystem types and the consequent extreme fire regimes in remote Australia. Consequently, there is widely expressed uncertainty among many landowners and managers (including Aboriginal and Torres Strait Islander peoples, and pastoralists) about realistic participation in carbon markets.

Section 8: Carbon – social and economic benefits

S8. The social and economic benefits of carbon storage and emission abatement enterprises in remote Australia, especially those relating to employment in Aboriginal and Torres Strait Islander traditional land management practices.

Current understanding

The Australian Government legislated for a carbon pricing scheme to begin from July 1, 2012 (Commonwealth of Australia 2011). The scheme will cover around 500 companies, which are the largest emitters of greenhouse gases within Australia. For the first three years, it will operate as a fixed price scheme, with liable emitters required to purchase carbon permits from the government for a price of \$23/t CO₂-e (rising to \$24.15 in 2013 and \$25.40 in 2015). These prices are substantially higher than most existing carbon credits contracted on the voluntary market (e.g. Low Carbon Australia & CarbonLab 2012) and thus this formal market is likely to overshadow, or at least subsume, most voluntary market activity in Australia. From 1 July 2015, the scheme is intended to switch to a flexible price mechanism; from this point, the price will fluctuate as emitters' trade permits.

Offset usage within the Australian compliance market will be limited to 5% of total emissions for the first three years of the scheme (Commonwealth of Australia 2011). This places an upper limit on demand. The maximum that anyone is likely to be willing to pay for a carbon offset in the compliance market is \$23 in

2012–13, given the fixed price nature of the scheme. Depending on supply, offsets could trade for substantially less than \$23. From 2015 the price becomes much harder to forecast, as it will be determined by the market. From this point, international permits are scheduled to be allowed into the Australian market, with companies allowed to use them to meet up to 50% of their total permit obligation. The 5% cap on offset use will be removed. This will allow offsets created internationally to be imported into the Australian compliance market, greatly increasing the potential supply of offsets. It is simply not possible to reliably forecast carbon market prices from 2015 onwards (Andy Reeson, CSIRO, pers. comm.).

Given this pricing outlook, economic analysis of emissions abatement and carbon sequestration proposals through ecosystem management in remote Australia is easy to do for the short term and difficult to do for the long term. Currently there is a high degree of uncertainty about the long-term economic value of carbon farming (Jotzo 2012). There are also likely to be substantial transaction costs involved in participating in the carbon offset market, including registration as an offset provider, demonstration of meeting standards for the CFI, ongoing monitoring and reporting every five years, and legal and brokerage costs associated with sales of credits (Andy Reeson, CSIRO, pers. comm.). There are potential economies of scale in these costs; while brokerage costs accrue per permit, registration and accreditation costs accrue at the scale of the project or provider.

Despite the current economic uncertainty, many Aboriginal and Torres Strait Islander peoples in remote Australia are well situated to develop carbon sequestration and greenhouse gas abatement enterprises (Robinson 2011a, 2011b; Whitehead et al. 2009). Much of the land with storage and abatement potential is owned by Aboriginal and Torres Strait Islander peoples (Heckbert et al. 2009) and some groups have established effective natural resource management (NRM) capacity for the provision of ecosystem services that could be expanded into carbon farming (Altman et al. 2007, Whitehead et al. 2008). Robinson et al. (2011b) state that Aboriginal and Torres Strait Islander groups have identified that their participation in carbon farming projects offers long-term funding that aligns with activities undertaken through government-funded NRM programs.

The Western Arnhem Land Fire Abatement project (WALFA) demonstrates the potential for integrated market and non-market values in carbon farming by Aboriginal and Torres Strait Islander communities (Russell-Smith et al. 2009 and chapters therein). The project sells 150,000 t CO₂-e of carbon credits per year, on average, with the offsets sold on a voluntary-market basis to Darwin Liquefied Natural Gas (a ConocoPhillips subsidiary) at around \$10 per tonne CO₂-e (Commonwealth of Australia 2010). The project has provided opportunities for Indigenous rangers to work on country more extensively than was previously possible, thereby fulfilling their customary land management obligations around traditional fire management practices and related activities, as well as protecting biodiversity and reducing risk of damage to properties. The WALFA project clearly illustrates that carbon farming can have much greater benefits than physical abatement of greenhouse gas emissions.

Aboriginal and Torres Strait Islander participation in carbon farming has the potential to provide an avenue to pursue culturally appropriate activities that meet their local livelihood and economic development aspirations (Whitehead et al. 2009, Robinson 2011a). Consequently, the CFI explicitly recognises the need for market recognition of Aboriginal and Torres Strait Islander social, cultural and environmental benefits beyond emissions abatement and carbon sequestration in a strict sense (Commonwealth of Australia 2011). Aboriginal and Torres Strait Islander *co-benefits* are defined as social, cultural and environmental benefits that can be demonstrated to traditional owners and managers of land (see Gerrard 2008, Hill et al. 2010, Robinson et al. 2011b). Thus, if pricing uncertainty is reduced in the future, carbon farming has potential to be an economic activity that provides benefits for Aboriginal and Torres Strait Islander peoples and the

broader Australian community through mutual cultural exchange, capacity building, technology transfer, sustainable economic development, social wellbeing, biodiversity protection and conservation, and sustainable land management (Altman et al. 2007, Jocelyn Davies CSIRO pers. comm.) undertook a preliminary assessment of many of these dimensions in participatory research projects exploring fire management for carbon credits in the Northern Tanami region of the Northern Territory. The CFI anticipates that such co-benefits have potential additional market value in the form of a price premium on each carbon offset unit.

There are several international co-benefit standards, the most prominent of which are the Gold Standard (The Gold Standard Foundation 2011) and the Climate, Community and Biodiversity Standard (CCBA 2008). They have been used implicitly in negotiations between carbon offset producers and purchasers on the voluntary market. The criteria and requirements for an Aboriginal and Torres Strait Islander co-benefits scheme to underpin the Carbon Farming Initiative and Australia's emissions trading scheme has recently been assessed by Robinson et al. (2011b), but an implementable scheme or standard will require further development. In 2008, the World Bank analysed the global price-premium value of Indigenous co-benefits in the marketplace and concluded that it is in the order of €1.00–1.50 (c.\$1.50–\$2.00) (Capoor & Ambrosi 2008), and Peters-Stanley et al. (2011) suggest that little has changed in the following three years.

Gaps

The greatest limitation in understanding the social and economic benefits of carbon storage and emission abatement enterprises in remote Australia is the uncertainty about long-term carbon pricing. Economic analysis of prospective projects can be undertaken based on pricing that is 'known' for only three years, when full project implementation and effectiveness may take more than three years.

Beyond the pricing uncertainty, the most significant knowledge gaps are:

- development and pricing of an implementable scheme or standard for Aboriginal and Torres Strait Islander co-benefits that meets the needs of Aboriginal and Torres Strait Islander people, can be approved by the DCCEE, and is robust in the market place
- support systems to empower Aboriginal and Torres Strait Islander people to make informed decisions about joining the carbon offset market as providers
- analysis of social, cultural and environmental co-benefits for landowners other than Aboriginals and Torres Strait Islander people
- assessment of the economic and social synergies and/or tradeoffs between pastoral grazing and carbon farming. This is currently a point of concern in the pastoral industry where grazing and carbon are sometimes interpreted as mutually exclusive.

Conclusion

The Australian Government's decision to implement a formal carbon pricing and trading scheme from 1 July 2012 has brought sharp focus to the economic and social dimensions of ecosystem management for carbon farming. As a result, key principles have been clearly articulated for economic frameworks and for social and cultural co-benefits. The scheme recognises the need to empower Aboriginal and Torres Strait Islander landowners to participate in the carbon market through carbon farming practices; thus there is government funding provided to support both participation and development of an Aboriginal and Torres Strait Islander co-benefits methodology. The scheme also recognises the potential for carbon farming to be a lever to protect biodiversity, and funding is provided to encourage a scheme with both carbon and

biodiversity outcomes. However, further work is required to permit implementation of both economic models at the scale of individual properties, and social/cultural and biodiversity co-benefit schemes.

Section 9: Government policies

S9. The effects of government policies on climate change adaptation ability, energy cost and potential for carbon storage and emission abatement enterprises in remote Australia.

Government policies: Climate change

Adaptation – meaning

Adaptation refers to a process of an entity's or a system's adjustment or/and transformation to a stimulus (perturbation). In the context of climate change, it is mainly intended to reduce vulnerability to climate variability and climate change (Nelson et al. 2007), as well as take advantage of any opportunities that may arise (Adger et al. 2007).

Adaptation can be 1) autonomous (endogenous reactive) or planned (proactive), 2) positive or negative (Davies 1996), 3) underpinned by generic or specific adaptive capacity (Adger et al. 2004).

The utility of some of these categories has been questioned by some authors. For example, Green et al. (2009), in their comprehensive review work on climate risks to Aboriginal and Torres Strait Islander peoples in northern Australia, raised the issue that if the focus is on adaptation response to climate change, then endogenous and planned adaptations need to be seen as forming a continuum that emerges from nested scales of social organisation and adaptive capacities that cannot be neatly separated into different categories. While Green et al. (2009) make an important observation, there may be circumstances that warrant making conceptual distinctions that have practical implications. For example, endogenous adaptive capacity of graziers can be bolstered by state and federal subsidies as is the case in exceptional drought situations; however, the sustainability of adaptive capacity that results from such arrangements is questionable, particularly with expected increases in magnitude and frequency of extreme events, including drought (Hennessy et al. 2008).

From research and development work on livelihoods in developing countries, positive and negative types of coping and adaptation strategies of communities are identified (Davies & Hossain 1997). Positive adaptations are by choice and are often reversible if fortune changes. They lead to reduction of vulnerability and sometimes increase in wealth. In contrast, negative adaptations are often undertaken out of necessity, with individuals or households having no other options. They may be maladaptive and frequently fail to contribute to a lasting reduction of vulnerability.

Adaptations can also be specific or generic depending on corresponding types of adaptive capacities that generate them and the specific and general nature of vulnerabilities addressed (Adger et al. 2004, Preston & Stafford Smith 2009). A specific adaptive capacity of a system is an ability to adapt to a particular threat such as domestic water scarcity or the threat of the new incidence of a vector-borne disease. Generic adaptive capacity refers to a broad ability to cope with, respond to, and recover from impact of a broad range of hazards.

These conceptual and empirical categories help us recognise that some adaptation measures such as risk management strategies can fail and even become maladaptive, and that some members of a society may lack effective adaptation options. This raises equity and justice implications of adaptation (Adger 2001),

particularly in places such as very remote Australia where communities already suffer from chronic disadvantage (Maru & Chewings 2011).

Adaptation depends on the adaptive capacity of the system in question. In a remote Aboriginal and Torres Strait Islander context, the need for generic adaptive capacity (the ability to respond nimbly to a variety of perturbations) instead of specific adaptive capacity is emphasised, with generic capacity conferred by effective capacity at a series of nested scales (Green et al. 2009). While there is a need to work out the material, institutional and behavioural changes required to increase nimbleness, building the generic adaptive capacity of remote communities is important because there are high levels of uncertainty about the future, and demand for further specificity and precision in vulnerabilities can only delay action against a narrowing window of opportunity (Adger & Barnett 2009). However, a focus on building generic adaptive capacity need not preclude work on special adaptive capacity, for example, developing specific adaptation plans for new levels of water scarcity or incidence of disease outbreaks. What is important is that for specific adaptation measures there is systemic consideration of the consequences that will affect the system as whole.

Current understanding

Australian Governments have recognised the importance of adaptation to climate change (Department of Climate Change 2009, PMSEIC Independent Working Group 2007) and developed various initiatives to help the nation efficiently and effectively adapt. These initiatives include a Climate Change Adaptation Framework formulated in early 2007 by the Council of Australian Governments and subsequent establishments of a Climate Change Adaptation Program, with an overall aim of improving understanding of the impacts of climate change and strengthening the capacity of decision makers to respond to and address major areas of national vulnerability (DCCEE 2012). This program helped establish an Australian Centre for Climate Change, a new National Research Flagship on Climate Adaptation within CSIRO, and a National Climate Change Adaptation Research Facility hosted at Griffith University that developed different climate change adaptation research plans and funded research projects. The National Climate Change Adaptation Program also commissioned major national climate change-related assessments, such as the National Coastal Risk Assessment and a Biodiversity Vulnerability Assessment. State and Territory governments also formulated complementary initiatives to guide and help sectors, business and communities to adapt to climate change impacts. At a local level, there has been planning and action-oriented projects funded by the Department of Climate Change and Energy Efficiency, such as the Integrated Assessment of Human Settlement sub-program, the Coastal Adaptation Decision Pathways Program and the Local Adaptation Pathways Program. Although some island, coastal and a few inland communities in remote Australia have obtained funding from these programs, the majority of research and action-oriented support has been to non-remote coastal areas with high population concentrations (AECOM Australia 2010).

Because of those multiple initiatives at different levels, Australia has been noted as doing better than many other developed countries (Moser 2012). However, recent evaluation of planning and action in developed countries, including Australia, reveals significant weaknesses. Out of 57 adaptation plans reviewed, there were 18 from Australia (Preston et al. 2011). Australian plans assessed for adequacy of adaptation planning were typically initiated by governments at different levels. Broad federal government adaptation plans, such as the National Climate Change Adaptation Framework (Council of Australian Governments 2007), and state/territory adaptation action plans, such as from the Northern Territory, Queensland, Western Australia and South Australia, are relevant to adaptation efforts in remote regions of Australia, but according to the study they also need significant improvements.

Among the 39 articles reviewed for adaptation action, most were about the Arctic (Berrang-Ford et al. 2011). There were only three articles on adaptation action in Australia (two on coastal and urban adaptation; the third on Aboriginal and Torres Strait Islander communities). They found minimal reporting on socio-economically disadvantaged groups, and no articles focusing on adaptation action with regards to women, the elderly or children. This is surprising as a lot of political rhetoric is given about differential vulnerability to climate change and that adaptation plans are often preceded by impact or vulnerability assessments. These deficiencies in adaptation planning and action are worrying given the typical long gestation period from problem identification to adaptation actions and the fact that taking action does not guarantee success (Berrang-Ford et al. 2011). None of the studies examined how to formally assess the success of interventions or considered how adaptations would perform under different climate scenarios. This is of concern given the projected speed and magnitude of climate change and a narrowing opportunity for effective adaptation action (Adger & Barnett 2009).

Similar to demands to make climate change risk or vulnerability assessment a part of existing risk assessments practices by businesses, governments and communities, there has been a call to mainstream adaptation into existing risk management and development strategies (Huq et al. 2003).

Gaps

- There is limited reported support for remote communities to adapt to climate change and no material on what remote communities are doing to adapt to climate change.
- There is a need to take stock and assess the current state of adaptation plans and actions in remote Australia and devise ways to expand and improve these.

Conclusion

There is now a growing awareness of the importance of adaptation as a tactical and central strategic response to climate change. Despite assumptions about the high adaptive capacity of developed countries such as Australia, reported actual planning and actions to adapt are limited and inadequate. The literature on adaptation plans and articles on adaptation action may have had a bias towards high-level accessible materials, potentially missing grass roots plans and actions. Nonetheless, they are indicative of a need for significant attention on improved adaptation planning and action at all levels. Adaptation has to be a continuous process instead of one activity. Adaptation planning has to be adaptive, and monitoring and evaluation integral to the adaptation process. This is not currently the case, an issue further discussed in the methodology section.

Government policies: Energy cost

Current understanding

Government policies are a rapidly changing area, covering the intertwined issues of addressing increasing energy demand, energy conservation, reduced greenhouse gas emissions, 'cleaner' fossil fuels, and generation from renewable sources. State policies are changing in response to changing Australian Government policies and initiatives.

The Australian Government's carbon emissions reduction target is to reduce by 2020 Australia's greenhouse gas emissions by 25% compared with 2000 levels, 'if the world agrees to an ambitious global deal capable of stabilising levels of GHGs in the atmosphere at 450 ppm (parts per million) carbon dioxide equivalent (CO₂-eq) or lower'; if global agreement falls short of this mark, Australia will still reduce its

carbon emissions unconditionally by 5% and by up to 15%. By 2050 the aim is to reduce greenhouse gas emission levels by 80% compared with 2000 levels (DCCEE 2011c).

The Australian Government Clean Energy Future plan includes the carbon pricing scheme and an emissions trading scheme. The initiative includes several programs with opportunities for remote communities, especially Aboriginal and Torres Strait Islander communities: (1) the \$40m Remote Indigenous Energy Program for installing renewable energy generation systems in remote communities; (2) the ongoing \$22m Indigenous Carbon Farming Fund, linking to the Carbon Farming Initiative; (3) the \$946m Biodiversity Fund; and (4) the Low Carbon Communities program (Clean Energy Future 2012).

The Australian Government Renewable Energy Target was designed to deliver on the Government's commitment to ensure that 20% of Australia's electricity supply will come from renewable sources by 2020. The target is for the amount of electricity coming from sources such as solar, wind and geothermal to be around the same as all of Australia's current household electricity use in 10 years time. Initiatives include the Large-scale Renewable Energy Target (LRET) and the Small-scale Renewable Energy Scheme (SRES), which includes solar credits to households, small business and community groups that install small renewable energy generation units (DCCEE 2011d).

Garnaut (2011a, p. 116) notes that the carbon price will make it profitable for firms to invest in research and development of low-emissions technologies, although it is not possible to predict where the investment will occur. He argues that substantial public support is required to take advantage of the innovation opportunities that result.

Some areas of transport will be included in the carbon price, which will probably have significant implications for remote Australia. Clean Energy Future (2011) states: 'A carbon price will not apply to household transport fuels, light vehicle business transport and off-road fuel use by the agriculture, forestry and fishing industries. Some off-road transport will face an effective carbon price, through changes to the current fuel tax regime. An effective carbon price will be applied to domestic aviation, domestic shipping, rail transport, and non-transport use of fuels. Users of these fuels can opt-in to the mechanism under the Opt-in Scheme.'

At the state level, the Queensland Renewable Energy Plan (Queensland Government 2009) aims to leverage up to \$3.5 billion in new investment, create up to 3500 new jobs and reduce greenhouse gas emissions by more than 40 million tonnes by 2020. The package includes incentives to attract renewable energy generators to Queensland, particularly to Renewable Energy Zones; pilot zones are in remote regions near Mt Isa, in the Surat Basin and central Queensland. The plan's solar hot water scheme aims to reduce Queensland household electricity bills by 20–30% annually for three years from July 2009 (Queensland Government 2009). Under the Queensland Gas Scheme, Queensland electricity retailers and other liable parties are required to source a prescribed percentage (currently 15%) of their electricity from gas-fired generation. The scheme aims to encourage a greater use of gas, and development of new gas sources and infrastructure (Queensland Government 2011), which is likely to have significant impacts on economic development of coal-seam gas production areas which largely lie in remote Queensland (e.g. the Surat Basin).

In Western Australia a State Government strategic energy initiative, Energy2031, is currently under development. The Directions Paper (Office of Clean Energy 2011) notes that energy costs are rising and peak electricity load is rising faster than base load; peak load requires inefficient investment in infrastructure that is rarely used. The paper does not come to any conclusion specifically for remote parts of Western Australia.

South Australia's Strategic Plan includes a target to have renewable energy comprise 20% of the state's electricity production by 2014 and 33% by 2020. For dwellings, the target is to increase the energy efficiency of dwellings by 15% by 2050 (South Australian Government 2011). In October 2011, more stringent energy efficiency requirements for air-conditioners and new homes appropriate to the state's three climate zones were introduced, with the remote parts of South Australia primarily falling within the most northerly of the three zones.

An aspirational goal for the Northern Territory Government is to reduce carbon emissions by 60% by 2050 (Northern Territory Government 2009). Target 11 aims by 2020 to replace diesel as the primary source of power generation in remote towns and communities, and to use renewable and low-emissions energy sources instead. Wholesale electricity purchasers will meet their national 20% Renewable Energy Target from NT sources, and central Australia will be developed as a world-leading solar energy centre. The NT established its Green Energy Taskforce in 2009 to advise on renewable energy options for the NT. One of the recommendations was the integration of solar photovoltaic capacity into 46 smaller diesel power stations, to reduce diesel use by 17% (Green Energy Taskforce 2010).

Transport contributes 9% of NT greenhouse gas emissions. The NT energy policy (Northern Territory Government 2009) was written when an emissions trading scheme was still being discussed, but the document highlights future fuel issues, including the expected increased cost in freighted goods, possible negative impacts on tourism in the NT, requirements for more public transport and efficient fuel, and social issues around providing transport services for rural and Aboriginal communities. The policy has a focus on replacing the NT fleet with energy efficient vehicles, encouraging walking, cycling and use of public transport, and on increasing the efficiency of public transport in urban centres and to remote communities.

Some government policies favour the use of, and provide subsidies for energy from fossil fuels, even if this seems contradictory to renewable energy policy. There is a tendency to encourage a move to gas generation of electricity in WA, NT and Qld. While not renewable, gas generation of electricity leads to lower greenhouse gas emissions than coal or diesel generation.

Schlapfer (2009) argues that rather than trying to make policy decisions in an ad hoc manner (e.g. supporting 'clean coal' technology or nuclear power technology), the Australian Government should do a comprehensive life cycle analysis of all potential energy technologies, including nuclear, coal and renewable energy, as the basis of policy setting.

A number of papers discussed the issue of pricing renewable energy technologies, for example, DeLaquil (1996) and McHenry (2009). They suggest that benefits need to be evaluated against the Triple Bottom Line, and the non-economic consequences of fossil fuel energy need to be highlighted. These papers argue that subsidies for fossil fuel energy should be removed, and more subsidies and rebates for renewable energy technologies introduced. There were calls for more government support, funds for renewable energy research and switching to renewable sources, and for disincentives such as placing a tax/cap on fossil fuel-based energy. If adopted, such policies could increase the availability and reduce the price of renewable energy in remote Australia.

Gaps

- There is uncertainty around government policies, with compromises in some areas, and uncertainty in markets and for investors. We did not find any studies where the current mix of state and federal policies gives a clear message as to where investment in energy should be targeted.

- There is a gap in information about the costs involved in a transition towards renewable energy. The impacts of emerging policies on costs to individuals, businesses and other consumers are not clear.
- An issue not being addressed is whether the current mix of policies provides enough incentives for innovation in renewable energy to reduce costs so that the technologies can be adopted rapidly.
- In most cases, implications for remote Australia tend to be implicit rather than explicit. Even the NT's energy policy, which identifies the need for improved access to more efficient public transport in remote communities, fails to indicate what types of policies would be necessary to achieve this ambitious aspiration.

Conclusion

- There are a number of government policies and programs that are designed to alter consumer behavior and meet international and national targets.
- A mix of market forces and government policies and incentives are rapidly changing consumer behaviour.
- Government programs for subsidies influence adoption of renewable energy sources in remote Australia.
- There is a need for an analysis on the effects of the mix and interactions of government policies on future energy costs and adaptation behaviour.

Government policies: Carbon economies

Current understanding

In contrast with government policy on energy supply and cost, the Australian Government's Clean Energy Future (2011) plan provides a relatively complete and integrated policy environment for carbon management in Australia, including a requirement for the largest carbon-emitting industries to offset at least part of their emissions, a price for carbon offsets (set to rise annually over the three years from 1 July 2012), an emissions trading scheme, and a clean energy regulator to administer a variety of policy elements, including the pricing mechanism and the Carbon Farming Initiative (Commonwealth of Australia 2010). In terms of developing carbon economies in remote Australia, the Carbon Farming Initiative is likely to be most important, and its critical elements (activities, criteria, emerging methodologies) are described in Sections 7 and 8 above.

However, in contrast to both climate change and energy policy, the legislation has yet to come fully into effect and thus is untested. Prior to 1 July 2012, there is no empirical way to assess whether the policy will achieve its goals, whether the emissions trading scheme will generate a carbon price sufficient to sustain carbon farming, whether access to international carbon credits will have negative impacts on local carbon offset production, whether subsidies to businesses will undermine effective function of the market, and whether perverse behaviours and outcomes will result from interactions between the various components of the plan and other policy. Certainly, the first (trial) phase of the foundational European Union Emissions Trading Scheme has been criticised on all of these grounds (e.g. Ellerman & Joskow 2008).

For land management under the Carbon Farming Initiative, there is the additional question of ownership of carbon rights, which falls under state and territory government administration. Policy is uniformly explicit that carbon rights belong to the landowner with freehold title. However, on Crown Land the question is less clear-cut at present. This is critical for remote Australia where a significant proportion of the land is

Crown Land, including pastoral leases. For example, in Western Australia the *Carbon Rights Act (2003)* assigns carbon rights on Crown Land to the Crown, but the Western Australian Government Department of Regional Development and Lands is currently considering the question of carbon rights management on pastoral leases in its review of rangeland tenure options under the *Land Administration Act (1997)* (see Government of Western Australia 2011). One option is for the Minister to be able to transfer carbon rights to a pastoral leaseholder, perhaps in the manner of the Carbon Sequestration Agreements possible under *Victoria's Climate Change Act (2010)* (State of Victoria 2011). There are also apparently unresolved issues of Native Title questions for carbon farming activities on Crown land (e.g. see DCCEE 2011e).

Gaps

The key limitation to interpreting carbon economies policy as applied to remote Australia is the very newness of the legislation that has been implemented and which will overshadow previous policy.

The key gaps relate to carbon farming activities on Crown lands, for example, pastoral leasehold land. There is no current analysis or determination on how carbon rights assignment or transfer systems will affect the viability of management for carbon sequestration or greenhouse gas emissions reduction.

Section 10: Methods

S10. Commentary on the previous and current methodologies used in measuring and analysing climate change and energy scenarios and carbon, including the strengths and weaknesses of the different approaches.

Methods: Climate change

Definitions

Methodologies for measuring and analysing climate change involve models and scenarios.

Figure 10 shows the link between the broad categories of models and scenarios involved in producing local climate change information. We will describe each of these broad categories in this section.

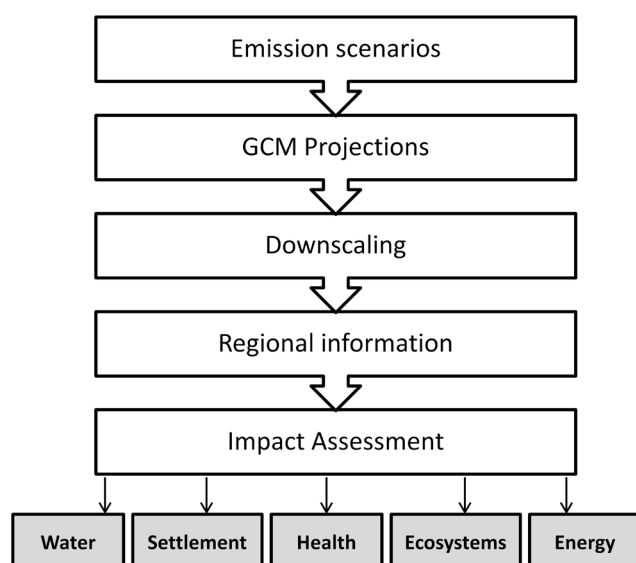


Figure 10: Links between broad categories of models and scenarios involved in producing local climate change information

Source: modified from Giorgi 2008.

Current understanding

Currently General Circulation Models, which are sometimes called Global Climate Models (GCMs), are the primary tools available to simulate climate change (Giorgi 2008). They are mathematical models developed to study the Earth's climate system (see Section 1). There are multiple GCMs used for projecting climate change. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) used aggregated results from an ensemble of 23 GCMs, although recently the underlying assumption of independence and equal weighting of outputs from each model has been questioned by some authors (e.g. Knutti 2010, Masson & Knutti 2011, Pirtle et al. 2010), with implications for the AR4 claims of robustness based on convergence of model results. Some authors have evaluated the performance of the different models and suggested criteria for culling worst performing models (e.g. Perkins et al. 2007) or selecting best ones (e.g. Smith & Chandler 2009).

Quantifying uncertainty requires more models that entail a larger spread of forecasts unless data can constrain the likely range and eliminate outliers. On the other hand, decision making may require reducing uncertainty on projections based on a few models, which can quickly lead to overconfidence, particularly if the models chosen are based on similar assumptions (Knutti 2010). It may be less controversial to down-weight or eliminate a few very poor models that are clearly unable to mimic important processes, or are even physically implausible (e.g. violation of conservation of momentum or mass) than to agree on the best model (Giorgi 2008).

While there have been significant improvements in spatial resolution, climate information from GCMs is still at a relatively large scale (resolutions of ~100–300 km grid size), which may not be suitable for regional climate change assessment (Giorgi 2008, Jacob 2009). For this reason, different regionalisation techniques are used to produce climate information at finer scale.

Giorgi (2008) identifies four regionalisation tools, which are commonly categorised into two broad regionalisation methods used to refine or downscale the information produced by GCMs and provide regional-scale climate data for various purposes (Giorgi 2008, Jacob 2009):

1. Dynamical downscaling (DD), which encompasses high-resolution 'time-slice' Atmospheric General Circulation Models (AGCMs) and Variable Resolution Atmospheric-Ocean GCMs (VarGCMs)
2. Statistical downscaling (SD).

A summary of these four regionalisation tools, including their strengths and weaknesses, is provided in Table 8.

Table 8: Weaknesses and strengths of regionalisation tools

Regionalisation tools	Description	Strengths	Weaknesses
DD	Nested RCM Uses high resolution three-dimensional regional climate models (RCMs). The RCMs account for regional and small-scale processes with the simulation domain and are connected to the GCM using nesting techniques. Basic assumption is that the Atmospheric-Ocean General Circulation Model (AOGCM) simulates the response to global circulation responses to large-scale forcings (e.g. GHG radiative forcing) and the nested RCM simulates the effect of sub-GCM scale regional forcings (e.g. topography).	Substantially improves the simulation of climatic spatial details, for example, as forced by complex topography and coastlines and extreme events compared to outputs from the driving GCMs.	Assumptions need to hold true. Expensive to run.
	AGCM-based RCM Uses a high-resolution atmosphere-only global model (AGCM) to attain relatively high resolution for some given time period. The sea-surface temperature (SST) necessary for the simulation is obtained from the AOGCM with the main underlying assumption that the SST forcing provided by AOGCM is consistent with the climatology of the high resolution AGCM.	Global coverage and ability to simulate teleconnection patterns across remote regions. Regional to global feedback included.	The main assumption may not always hold. Expensive to run, requiring large computing platforms.
	VarGCM-based RCM Same as in AGCM but using AOGCM with gradually increasing horizontal resolution towards a given region of interest, but computational grid left sparser elsewhere.	Regional to global feedback partially included.	Computationally intensive and relatively expensive.
SD	Develops statistical relationship between predicants of interest, for example temperature, at a certain location and predictors that can be obtained from GCMs. The relationships are developed using observations and applied to the outputs of AOGCM simulations of future climate to obtain local climate change information. Basic assumption is that the statistical relationships developed using present day climate information are valid under different climate conditions.	Computationally inexpensive thus readily applicable to outputs of different GCMs. Can provide tailored local information for impact studies which may not be available from numerical models. Regional to global feedback can be included.	Fundamental assumption may not hold under increased GHG forcing. Require observational datasets of sufficient quality and length to develop robust statistical relationships.

Source: Giorgi 2008, Jacob 2009

Green et al. (2010) noted a further difficulty for both GCMs and RCMs. Even the state-of-the-art models have not simulated some complex interacting mechanisms (Lin 2007), such as the inter-decadal variability and associated teleconnections of the El Niño Southern Oscillation (ENSO) that is a major influence on tropical cyclone frequency, winds and rainfall in the Australian region (Nicholls 1992).

There is also a requirement for high quality observational data for model validation and for regional climate projections to be useful for change assessment and adaptation. However, such high quality data may not exist for remote communities. For example, (Green et al. 2010) noted the inadequacy of both quality and spatio-temporal coverage of meteorological data in the Torres Strait for regional climate change projections.

Gaps

- Collation of sets of historical weather data of sufficient resolution in time and space that they can be used to parameterise dynamical and statistical regionalisation models in remote Australia.
- Implementation of regionalisation models at sufficiently local scales that they can provide climate change projections to support community and enterprise adaptation planning in remote Australia.

Conclusion

There are two broad categories of downscaling to produce regional climate change information, dynamical and statistical, which require different skills and have different costs. Although costly, a combination of those two is noted as best practice (Wilby et al. 2004). To date, the application of regionalisation models has been limited in remote Australia, due to data limitations and a focus on more densely populated parts of Australia.

Methods: Climate change adaptation

The methodologies for analysis of climate change adaptation relate to how it is assessed. The IPCC Third Assessment Report lists what is included in adaptation assessment: ‘identifying options to adapt to climate change and evaluating them in terms of criteria such as availability, benefits, costs, effectiveness, efficiency and feasibility’ (McCarthy et al. 2001). A host of analyses and attendant methodologies can be added to this list by conceptualising adaptation not as a one-off activity, but as an iterative process (Stafford Smith et al. 2011). Figure 11 shows four major phases of the adaptation cycle: 1) problem framing (adaptation of what to what?); 2) planning and decision making (options and barriers identification; prioritisation and resource allocation); 3) implementation; and 4) monitoring and evaluation.

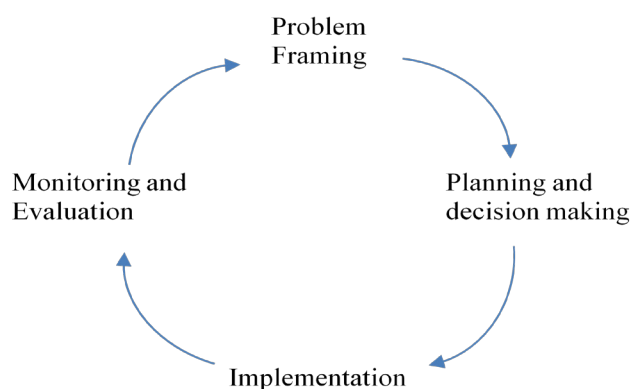


Figure 11: Four major phases of the adaptation cycle

So far, the focus of methodologies has been on impact, vulnerability, and to a limited extent, adaptive capacity assessments, which are all useful for framing and analysing problems. There has been little or no focus on the other phases in the cycle: planning and decision making; implementation; and monitoring and evaluation. There is now a recognition of the limitations of current methodologies in providing relevant information for these phases; these challenges are faced by many governments, sectors and communities (Eakin & Patt 2011, Fussel 2007).

There are three broad approaches to climate change assessment commonly applied to framing the problem or analysing the ‘adaptation of what to what?’ question (Maru et al. 2011, Preston & Stafford Smith 2009). A summary of these approaches and their weaknesses and strengths is compiled in Table 9, below.

Table 9: Approaches to climate change assessment

Approach	Description	Weaknesses	Strengths
Impact or hazard based	Assessment starts from model-based climate change projections	Focuses on consequences of climate change, often ignoring current risk associated with climate variability and non-climatic biophysical and socio-economic factors. Usually top-down process dependent on model-based climate projections. Expert-driven, often with little or no participation from stakeholders. Not generally immediately useful for the purposes of adaptation policy design.	Has been crucial for identifying research priorities, raising awareness of climate change risk.
Vulnerability based	Assessment does not necessarily start with models-based climate change projections. Often interprets vulnerability as inherent to social or social-ecological system of interest. Can proceed with assessment with little detail on the nature and intensity of climate change. Strong focus on the social-ecological determinants of susceptibility and those that determine the ability to cope with climatic hazards.	Mainly actor-based approach that lacks systems perspective. Has potential to be participatory but the conceptual complexity surrounding vulnerability assessment makes it rely heavily on experts. Tends to be qualitative with diverse methodologies, thus limited comparability across regions. Largely limited to providing information on relative extent of vulnerability of entities of concern, often not adequate for decision-making on specific adaptation measures.	Better captures societal and ecological responses to climate change. Tends to be bottom up and can involve stakeholders from the outset, potentially leading to adaptation planning. If participatory, this approach can produce useful information for climate change adaptation even in the absence of reliable impact projections.
Integrated	Considers vulnerability as an emergent property from the interactions of climatic perturbations, biophysical and socio-economic determinants. Employs a system-oriented approach. Can integrate information from climate change projections, emission scenarios and socio-economic scenarios with dynamics of socio-ecological system. Can account for cross-scale effects.	Mainly system-based approach requiring significant integrative expertise. Simplicity and relevance and stakeholder participation can be lost seeking integration.	Better integrates and captures climate change social-ecological dynamics for robust decision making.

Some vulnerability assessments, particularly those that consider vulnerability as inherent to a social system, may not require precise climate change projections in order to recommend adaptation pathways.

Gaps

- Accounting for persistent and deep uncertainty about future changes in climate conditions is still a major challenge for methodologies in translating climate change assessments into adaptation policies and actions.
- Another challenge for translating assessment into policy and action is the less participatory nature of some assessment approaches, particularly those that depend heavily on climate change projections and more integrated approaches because of the complexities of the techniques used.
- These result in a loose connection between projections of climate change assessment and adaptation policy and decision-making.
- While climate change projections are well considered, assessments often report the impact or vulnerability of current socio-economic conditions. There is little work on or consideration of the corresponding changes to socio-economic and demographic situations in the future.

Conclusions

The hazard or impact-based, vulnerability-based and integrated assessment approaches have contributed to significant awareness about potential impact on and vulnerability of different groups to climate change, but these assessment approaches are still not well connected, and are insufficient for exploring effective adaptation pathways. Given a propagation of high levels of uncertainty along the assessment process, starting from climate change projections to potential impacts to interactions with other biophysical, socio-economic, and political changes, there are those who note the futility of detailed and precise assessments and instead prefer approaches that assist in exploring robust adaptation options.

Methods: Energy scenarios

Current understanding

We have included three modeling exercises in this section: future energy projections to 2030 by ABARE, transport and energy scenarios by CSIRO, and modeling of the electricity market under a national carbon pricing mechanism by SKM MMA.

Energy projections

- Energy projections for Australia by state and sector have been developed for 2030 by ABARE (Syed et al. 2010). ABARE's E₄cast model (2009 version) is a dynamic partial equilibrium model of the Australian energy sector. The model uses 24 sectors, 19 fuel types and 17 generation technologies.
- Demand for fuel is modelled in the ABARE projections as a function of income or activity, fuel prices and efficiency improvements. Key government policy measures are modelled explicitly, including proposed carbon reduction targets, renewable energy targets, and clean energy initiatives. The base year used is 2007–08. Energy statistics are based on ABARE's fuel and electricity survey of 1400 large energy users and producers.
- Assumptions: The model uses population data and projections from the Australian Bureau of Statistics. The population of Australia was 21.6m in 2008, and is projected to be 26.3m in 2020 and

28.5m in 2030 (ABS 2008b, 2009). For economic growth, GDP growth is used as the main driver of energy demand, and gross state product is used for non-energy intensive sectors. Long-term energy prices are expected to recover from the downslide in 2008. New oil projects are estimated to be uneconomic at a world price of less than US \$70 barrel. For electricity generation technologies, ranking is more important than absolute cost. End-use energy technologies are assumed to become more efficient with technological improvements. Government policies modelled explicitly include the Renewable Energy Target, the proposed emission target, and clean energy initiatives. An international emissions trade is assumed to expand gradually. Scenarios are given for 5% and 15% reductions in emissions by 2020.

- Limitations: The authors note that the projections are intended to indicate potential changes in Australian energy consumption, production and trade patterns given the assumptions used. There was significant uncertainty around technology, investment and government policies at the time the work was done.

Transport sector

- The modelling of future needs in the transport sector used CSIRO's Energy Sector Model (CSIRO 2008, Graham et al. 2008). This is a partial equilibrium model of the Australian energy sector, and includes a detailed transport sector representation.
- Model assumptions about fuels included declining oil scenarios, electricity and transport services, vehicles and plant capacities.
- The authors note that the main limitation of a partial equilibrium model is that it seeks to model one sector of the economy, while keeping the remaining sectors constant. As well, some parameters are uncertain and evolving rapidly, especially in biofuel production technologies and costs of partially electrified vehicles. Community acceptance is not included, so the rate of uptake of new energy sources may be overestimated.
- One of the strengths of a partial equilibrium model is that it allows more detailed modeling of the transport sector than would be possible with a general equilibrium model. It is possible to interface partial and general equilibrium modelling approaches, but this is a resource- and time-intensive process (Graham et al. 2008).

Costs and benefits to the electricity market of a national carbon pricing mechanism

- The third example of energy modelling was done for the Australian Treasury (SKM MMA 2011).
- Given demand forecasts supplied by Treasury, the modeling included the impact of different options in the electricity sector. Outputs from SKA MM models were fed into Treasury's MMRF (Monash Multi-Regional Forecasting) model of the Australian economy. The process was iterative until there was convergence between demand and supply. The Strategist market modeling software package was used to simulate the electricity market and contains a database of the major electricity systems.
- The scenarios contained assumptions for atmospheric CO₂ concentration targets for the world and/or Australia ranging from 450 to 550ppm, with initial carbon prices of \$0–\$18.5/t CO₂-e.
- Some of the high-level assumptions were that the market was assumed to operate to maximum efficiency; the study period was 2005–2050 with carbon pricing assumed to commence in 2012; any price changes flow through to retail prices; and heat rates and capacity factors for all plants were based on historical trends and other published data. Other electricity policies and schemes from Queensland, New South Wales and ACT were included.

- The NT Government commissioned further modeling from SKM MMA to provide information on options for renewable energy markets (Green Energy Taskforce 2011) .

Gaps

- We were unable to locate references for projections of energy consumption for remote Australia for the times specified in the terms of reference, 2050 and 2100. Results of the national modelling are not assessed by remoteness.
- All of the models use assumptions about fuel prices, government policies and efficiency improvements that are not likely to be robust in this period of rapidly changing prices, technologies and policies. There are uncertainties around when peak oil is likely to occur in different regions around the world and subsequent effects on Australia.
- Partial equilibrium models used model only parts of the energy system at a time.

Conclusion

The available energy scenario models were developed for the national and state level, and lack any regionalisation that would make them directly relevant to remote Australia. It is not apparent how these models could be applied productively at a regional scale. However, systemic characteristics of remote regions such as sparse and low population density, harsh and highly variable climate will interact with climate change and extreme events and continue to generate unique energy needs. Lack of consideration of these unique needs in the national- and state-level models and limited involvement of remote communities in national and state policy-decision process can adversely impact remote regions (Stafford Smith & Huigen 2009). The caveat for such a use is the sensitivities of the models to assumptions of prices, technologies and policies that are each changing rapidly at present.

Methods: Carbon scenarios

Current understanding

Methodologies to measure carbon sequestration and greenhouse gas emission reductions through land management are provided for in the *Carbon Credits (Carbon Farming Initiative) Act 2011*. The Act specifies criteria that methodologies must meet in order to be valid for establishing carbon credits under the Carbon Farming Initiative and thereby be acceptable in Australia's carbon credit market. The Act established the Domestic Offsets Integrity Committee (DOIC), an independent expert committee supporting the environmental integrity of carbon offsets generated under the Carbon Farming Initiative. Its role is to assess draft methodologies proposed for use under the scheme and advise the Minister for Climate Change and Energy Efficiency, who makes a decision whether to approve the methodologies.

The Interim DOIC has approved four methodologies to date:

- Capture and combustion of landfill gas
- Destruction of methane generated from manure in piggeries
- Environmental plantings
- Savanna burning (for mean annual rainfall > 1000 mm)

Two other methodologies are under consideration:

- Avoided emissions from diverting waste from landfill to process-engineered fuel manufacture
- Management of large feral herbivores (camels) in the Australian rangelands (DCCEE 2011f)

The environmental plantings, savanna burning and camel management methodologies are all of particular relevance to remote Australia.

There are, as yet, no methodologies for other carbon farming activities relevant to remote Australia including:

- savanna burning (mean annual rainfall < 1000 mm), although this is currently under development, with support from the Department of Climate Change and Energy Efficiency
- managed burning in more southern, fire-prone ecosystems other than savanna, for example, spinifex- and mulga-dominated ecosystems
- restoration of historically degraded rangelands, especially net sequestration opportunity through revegetation and soil rehabilitation
- reduced methane emissions from improved diet or altered rumen microbial flora in rangeland cattle.

Under the Act, one of the criteria for approval of methodologies is that estimations of emissions reduction, sequestration and emissions are measurable and capable of being verified. This criterion is an oxymoron, since it specifies that *estimates* are *measurable*. All the methodologies approved or under consideration are models, based on previous research and using mean values for parameters in calculations, in order to calculate estimates of baseline emissions and reductions due to management. Indeed it is some proxy, usually an intermediate in the model calculations, which must be measurable and verifiable. For example, in the case of the savanna burning methodology, it is the areas of burning in the early dry season and late dry season that are measurable and can be used to verify that a carbon project is meeting targets, rather than the greenhouse gas emissions in the strict sense.

Acceptance of proxy measurements for verification purposes is a reality of any potential methodology under the Carbon Farming Initiative, given the time and expense required to measure actual carbon flows in an ecosystem. For example, carbon pools stored in vegetation and soils are highly patchy in all ecosystems and the number of samples required to obtain a precise measurement of change may be so large that the cost of the measurement exceeds the value of the carbon credit. Allen et al. (2010) review the challenges of estimating soil carbon.

As discussed in Section 8, principles for Aboriginal and Torres Strait Islander co-benefit schemes are now established (Robinson 2011b), but methodologies to demonstrate and calculate co-benefits are not available.

Gaps

The obvious gap in carbon methodologies is the absence of DOIC-approved methodologies for many greenhouse gas emissions reduction or carbon sequestration activities that might be undertaken through land management in remote Australia. Four examples are given above. In each case, the drafting of such a methodology is hampered by a serious scientific knowledge gap about the biophysical principles and biogeochemical cycling rates that underpin the management activity. For example, there has been little

analysis done on the long-term mean rates of carbon sequestration in soils during rehabilitation of the many types of rangelands in Australia.

For existing and future approved methodologies, formal analysis is required of the magnitude of uncertainty associated with use of measurable proxies for difficult-to-measure sequestration or emission rates. The relative magnitude of uncertainty is most likely to be significant in the more arid parts of remote Australia, where long-term sequestration or emission rates are low (due to low mean ecosystem productivity) and thus difficult to estimate by any means. Such uncertainty may reduce the price that a carbon credit attracts in a floating-price emissions trading scheme.

Methodologies currently all assume mean rates of sequestration or emission without considering temporal variation, especially that due to disturbance or natural disaster. In the case of natural disaster eliminating sequestration, risk analysis is required to underpin an ‘insurance’ model for carbon farming activities, without which the price of a carbon credit in a free market may be reduced.

There is a need for methodologies for Aboriginal and Torres Strait Islander co-benefit determination.

Conclusions

The methodology for developing methodologies under Australia’s Carbon Farming Initiative is well-developed, but the number of methodologies approved to date is small and only half of them describe real opportunities for carbon farming in remote Australia. Other potential opportunities for carbon farming activities in remote Australia will require considerable research before a methodology could be developed. Determination of Aboriginal and Torres Strait Islander co-benefits also requires additional research. All methodologies would be enhanced by analysis of uncertainties and risks in delivery of sequestration or emissions reduction outcomes. In the absence of measured uncertainty and risk, a free carbon market may prove to avoid risk and thus perceived risky carbon credits may devalue, especially under the expanded market that will occur when international carbon credits are available to Australia emitters seeking to buy offsets.

Conclusions

The literature on climate change adaptation, future energy options and carbon economies as it describes or relates to remote Australia is large, but variable in terms of its relevance, depth of analysis, and reliability. The literature also contains significant gaps, which present both challenges for individuals, businesses, communities and governments planning for the future, and opportunities to focus further research work in the immediate future.

To assist easy reading, the concluding remarks below are organised around the original Terms of Reference that shaped the topics discussed in detail in preceding sections.

The vulnerability and adaptive capacity of individuals and communities under the climate scenarios for remote Australia, especially Aboriginal and Torres Strait Islander people.

- The literature on vulnerability and adaptability is primarily of a general nature and lacks formal assessment for remote peoples. The individuals and communities of remote Australia are expected to be more vulnerable to climate change scenarios because of their remoteness and the ensuing cascade of consequences encapsulated by the ‘desert syndrome/desert systems’ concept that has also been found to apply in Australia’s tropical north.

- Most Aboriginal and Torres Strait Islanders are understood to be especially vulnerable because of their current positions of social and economic disadvantage, but this needs investigation at local level on a case-by-case basis. Because Aboriginal and Torres Strait Islander people are diverse, a typology of vulnerability and adaptive capacity is required to facilitate future development of adaptation pathways.
- Concerns about climate change risks and adaptation are not often ranked highly among the priorities of Aboriginal and Torres Strait Islander communities because of other social and economic needs that are perceived as more urgent, and this may reduce capacity to develop adaptation pathways.

The vulnerability and adaptive capacity of industries and businesses under the climate scenarios for remote Australia

- Vulnerability and adaptive capacity of the pastoral industry has been assessed in some detail. For other industries and businesses, including mining, vulnerability has largely been assessed in terms of problems of infrastructure (see below) and consequent access to services, especially transport of inputs and outputs. Despite its importance to remote Australia, the vulnerability and adaptive capacity of the tourism industry has received scant attention.
- Some studies identify potentially increasing difficulty in filling staff positions by businesses due to declining liveability of remote environments and communities (see below).

The liveability of remote Aboriginal and Torres Strait Islander settlements under the climate scenarios for remote Australia, including impacts on health and education.

- There have been no detailed case studies of remote settlement liveability under climate change scenarios.
- Increasing temperature and more frequent heat waves have been identified as the most significant influence on future liveability of remote communities. Higher demand for air-conditioning and thus high energy demand is anticipated. Where air-conditioning supply cannot keep up with demands due to changing temperature, provision of safe health-care facilities and effective schools will decline.
- Existing extensive and chronic health issues are generally expected to worsen and require additional services, especially for socio-economically disadvantaged individuals and communities. Vector-borne disease are likely to increase in incidence and prevalence, or appear in remote Australia from overseas sources for the first time, but different studies identify different pathogens as most likely to increase or appear anew.

The impacts of increasing energy costs on the individuals, communities and businesses of remote Australia.

- General increases in all goods and services, due to increasing energy costs, will be particularly hard on the many low-income households and disadvantaged communities in remote Australia.
- Mobility and transport is critical to all social and economic activity in remote Australia, and proposed mass-transit and alternative fuel options for urban and regional Australia are not necessarily applicable to remote Australia. Thus increasing transport energy costs will be experienced disproportionately by remote Australians, but there are no studies on the impacts and opportunities arising from this.

The social and economic benefits of harnessing alternative sources of energy in remote Australia.

- There has been extensive research and development activity about renewable energy generation – solar and wind – in remote Australia. Appropriate technologies for small-scale installations are well understood, and consequent employment opportunities and health benefits have been identified.
- Business models for viable renewable energy generation facilities to service remote communities are not well developed. Many community facilities require subsidies, suffer from inability to ensure ongoing, on-site maintenance personnel for guaranteed continuity of supply, and lack depreciation plans for future capital replacement.
- Many studies report the enterprise potential for large-scale renewable energy production in remote Australia, with transmission to larger markets in Australian cities or Southeast Asia. The limited economic analyses, however, identify the high costs of transmission as likely to limit viable large-scale generation to the fringes of remote Australia, where transmission distances are minimised. There is a need to test whether inclusion of broader social and indirect economic benefits to remote Australia resolves the conflict in current assessment of industry viability.

The social and economic benefits of carbon storage and emission abatement enterprises in remote Australia, especially those relating to employment in Aboriginal and Torres Strait Islander traditional land management practices.

- As many remote Australians make a living from the land and/or are culturally closely attached to the land, carbon-based enterprises under the Australian Government's Carbon Farming Initiative offer a significant opportunity for wellbeing of remote Australians. However, uncertainty about carbon price from mid-2015 makes economic modelling highly speculative at this time.
- Especially in higher rainfall zones, and assuming that future carbon prices do not devalue dramatically, carbon farming has potential to be the most valuable economic activity on lands that have low potential for forestry or pastoral grazing, as demonstrated by the WALFA savanna burning project in western Arnhem Land. On pastoral land, management options exist for concurrent animal production and carbon farming.
- Fire management in higher rainfall (annual >1000 mm) savanna, as exemplified by the WALFA project, remains the only fully articulated economic model for carbon farming. There is a clear need for business models of all other biophysically possible combinations of carbon farming activities and ecosystem types.
- Carbon farming generates significant health, social and cultural benefits for Aboriginal and Torres Strait Islander people because of the close alignment of traditional Law and land management practice with carbon farming activities. These 'co-benefits' also have an economic value as a price premium on carbon offsets – recently up to \$2 per tonne CO₂-e.

The effects of government policies on climate change adaptation ability, energy cost and potential for carbon storage and emission abatement enterprises in remote Australia.

- There is strong government policy for climate change adaptation action plans at national and state levels, but impacts at local level are variable. There has been no reporting of adaptation at community and local-government levels in remote Australia.
- There are many national and state/territory-level policies relating to energy. These policies do not form a coherent body and are often contradictory, for example, simultaneous promotion and subsidies of fossil fuels and renewable energy technologies.

- Carbon policy is relatively integrated at the national level through the Clean Energy Future plan, but is not yet fully implemented and thus remains untested. The international context for future carbon prices adds additional uncertainty to the potential outcomes of the new policy package.

The previous and current methodologies used in analysing climate change adaptation, energy scenarios and carbon economy participation, including the strengths and weaknesses of the different approaches.

- Climate change adaptation methodologies are developed for national and state/territory use, but not for local use. There are no methods as yet for linking climate change impact to adaptation.
- A wide range of models has been developed for assessing future energy needs and supply options, but their varying assumptions (especially concerning important pricing elements) lead to varying predictions from which there are no clear preferred scenarios.
- The only fully tested methodology of carbon economy participation in remote Australia is the WALFA savanna burning project. Attempts to develop business models elsewhere remain incomplete. The principles that are required for a co-benefit assessment method have been identified, but a suitable method is still under development.

The most likely climate scenarios for remote Australia over the next 50–100 years, including gaps in data or analysis for this region.

- There has been extensive work by the Bureau of Meteorology, CSIRO and others to develop national-scale forecasts of climate change. These models indicate increasing temperatures, especially in western and central Australia, but uncertainty in changing rainfall.
- Downscaling models for regional and local forecasts exist and have been used for places other than remote Australia, but these models have high requirements for historical data. Application of these models in remote Australia is hampered by lack of suitable input data.

The vulnerability and adaptive capacity of remote infrastructure, ecosystems and primary industries under these climate scenarios.

- Infrastructure is expected to deteriorate more rapidly and suffer more frequent major damage due to extreme events, leading to higher replacement, depreciation and insurance costs, which are likely to be costed through higher service charges and higher taxation.
- Coastal ecosystems are expected to be sensitive to sea-level rise and there is already evidence of such changes in northern Australia. There are projections about range shifts for terrestrial biodiversity, and different species are likely to shift at different rates, but there have been no detailed studies in remote Australia. Habitat corridors for ecosystem connectivity have been found in other parts of the world to facilitate range shifts, but again there are no data from remote Australian ecosystems.
- Southern pastoral areas have been identified as most vulnerable to increasing temperature and likely decreasing rainfall, leading to declining plant and animal production. Northern pastoral areas are more likely to experience higher rainfall and thus higher potential productivity, but this may be offset by forecast higher impacts of pests and diseases.

Within predicted climate and population scenarios, the energy needs of remote Australia, from household through to regional scale.

- In remote Australia, energy needs will be driven by the interaction of increased population, increased per capita energy consumption through poverty alleviation, increased temperature driving air-conditioning demands, increased telecommunications infrastructure, and increased heavy industry, especially mining.
- Net projections have been calculated for the mining industry and at state/territory level, but there has no local or community-scale assessment that links to opportunities for harnessing alternative energy sources (other sections).

The opportunities for carbon storage and emission abatement in remote Australia, including scale of the biophysical capacities and any gaps in data for this region.

- The magnitude of emissions abatement through fire management in higher rainfall savannas is well understood as a result of the former Tropical Savannas CRC and the WALFA project in western Arnhem Land, and is now formalised as a model-based methodology for the Carbon Farming Initiative. There is potential for analogous land management in lower rainfall savanna and spinifex vegetation types, with the magnitude of the emissions abatement likely to decline with decreasing rainfall more rapidly than does ecosystem primary production. At low rainfall, rates of effect may be marginal compared with management and monitoring costs, despite the options for extensive management of large areas.
- The magnitude of carbon storage potential in savanna and rangeland soils across much of remote Australia is currently being scoped using the CENTURY model of soil carbon by a CSIRO research team.

Commentary on the previous and current methodologies used in measuring and analysing climate change, energy and carbon in remote regions, including the strengths and weaknesses of the different approaches.

- Methodologies for measuring climate and detecting climate change are well-developed nationally and internationally, through IPCC and participating research organisations, but data are relatively sparse for much of remote Australia because of the low population density. Data for assessment of change in rainfall is more readily available than data for assessing change in temperature, which counterbalances the relative uncertainty of rainfall projections compared with temperature projections.
- Measurement of ecosystem carbon pools and fluxes is highly underdeveloped, due to limited past research and the very high spatial variability (patchiness) of carbon in most ecosystem types, which necessitates large numbers of analysed samples to achieve confidence in any one measurement. Model-based methodologies (based on extensive research histories) exist for savanna burning (annual > 1000 mm rainfall zone). Extensive current research activity, initiated by the Department of Climate Change and Energy Efficiency and by a number of industry and land-management interest groups, is addressing the need for carbon farming methodologies application to other carbon farming activities and in other ecosystems, in readiness for the start of the formal carbon market in July 2012. Due to the need to achieve sequestration or emission reductions over large areas, most methodologies will require satellite data inputs and need thorough validation.

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Appendix 1: Search methods

The first part of the literature search involved preparing search terms from the Terms of Reference (ToR). We used the ISI Web of Science database for peer-reviewed journal, books and conference articles. Google and Google Advanced Scholar were used to search for reports, grey literature, and conference materials and published materials that were not found through the ISI Web of Science search. We filtered the energy results by discipline to exclude references related to the biological meaning of energy. Reference databases were created for relevant articles using EndNote software.

The ISI web of Sciences searches were conducted between 6 July 2011 and 6 November 2011. The bounding terms for the climate-change related search were *climate change or climatic change or extreme event** in the title with a variety of terms related to *remote* in the Topic = (*remote not remot* sens* or desert or peripher* or margin* or aboriginal or indigenous or arid or semi arid or dryland* or rangeland* or savannah**). The bounding terms for energy-related searches were *energy or power generation or power supply* in the title with a variety of terms related to *remote* in the Topic = (*remote not remot* sens* or desert or peripher* or margin* or aboriginal or indigenous or arid or semi arid or dryland* or rangeland* or savannah**). We then searched the results of these searches for themes from the ToR including *projections, impacts, vulnerability, adaptation, methods, industry, government, community* or variations or details of these terms.

The ISI Web of Science relevance ordering tool was used to select relevant articles from each set of search results returned using the Web of Science database, then these articles were checked for relevance by reading their title and abstracts. Criteria were 1) whether the search term was a significant focus of the article and 2) whether the context and content of the article was relevant to climate change and energy research in remote Australia. The Web of Science search results for search terms including *climate change* and *energy* are shown in Table A10 and Table A11.

Google Advanced Scholar was used to complement the ISI Web of Science searches as these did not find relevant grey literature on Australian studies of climate change and energy. As Google Advanced Scholar does not have a facility to restrict by topic, the search terms needed to be more targeted.

We also circulated an e-mail to a few experts in the field of climate change adaptation and energy working in different organisations for reference materials for the review, which provided several additional references.

We found that the database searches were not sufficient (see Table A10 for climate change and Table A11 for energy futures). Most of searches turned up few relevant articles and only a few were rated as having a high percentage of relevant articles. For example, only one article was found for search terms with Australia and industry, which was relevant. Furthermore, the database searches failed to capture some general but important current topics. For example, a recent review by Preston et al. (2011) of adaptation plans, including plans from Australia, was not picked up by our database searches. Therefore, we also selected current research articles and used 'snow balling' to find additional relevant articles by manually checking their reference list and electronically checking articles that cited them. Most of the material cited in this report was located using these 'snowballing' methods.

Table A10: Summary of searches conducted through Web of Science database with search criteria which included literature related to *climate adaptation* in remote communities (date of search 13 July 2011).

No.	Search	Results 13 July 2011	Relevant literature			
			Abstracts	Papers	Total	% Relevant
1*	General	701 (1122)	Not separated		(120)	(11)
2**	General Australia	43 (103)			(26)	(25)
3	Adaptation	144	19	0	19	13
4	Adaptation Aus	10	2	0	2	20
5	Scenario	157	2	1	3	1.9
6	Scenario Aus	11	1	1	2	18
7	Vulnerability	77	14	3	17	22
8	Vulnerability Aus	6	1	0	1	17
9	Method	176	28	3	31	18
10	Method Aus	11	2	1	3	27
11	Policy	90	9	1	10	11
12	Policy Aus	9	1	3	4	44
13	Community	127	15	1	16	13
14	Community Aus	10	3	3	6	60
15	Industry	14	2	0	2	14
16	Industry Aus	1	1	0	1	100
17	Sectors	95	11	0	11	12
18	Sectors Aus	6	0	0	0	0
19	Impacts	242	11	0	11	5
20	Impacts Aus	39	7	0	7	18

*. ** In each of these two rows, there are two totals. The first is the actual number of articles. The second total (inside a bracket) includes articles that have been repeatedly returned using different ToR terms.

Table A11: Summary of searches conducted using the Web of Science database with search criteria which included literature related to *energy* in Australian remote communities (date of search 13 July 2011)

No.	Search	Results 13 July 2011	Relevant literature			
			Abstracts	Papers	Total	% Relevant
1	Australia	62 (82)	(2)	(17)	(19)	(23)
2	Built environment	12	1	0	1	8
3	Community	13	0	2	2	15
4	Policy	7	0	2	2	29
5	Renewable	31	0	11	11	35
6	Scenario	1	0	0	0	0
7	Specific remote sectors	8	1	0	1	13
8	Industry, business, enterprise	10	0	2	2	20

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