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Are Australian Aboriginal Communities Adapting to a Warmer Climate? A Study of Communities Living in Semi-Arid Australia

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Abstract

Communities around the world adapt to warming climates in a number of ways. Adaptations can often be energy intensive or dependent on expensive infrastructure to cope with harsh weather, so the use of renewable energy and energy efficient housing is becoming an increasing feature in conversations about climate change adaptation. The cost of energy for households continues to increase, with this cost adding considerable financial pressure on low-income households in both developed and developing countries. The concept of 'energy poverty' is gaining utility around the world to highlight the prevalent dilemma faced by low-income households that they cannot afford the level of energy use to maintain their desired livelihood. In regions of the world with extended periods of extreme weather, households can allocate as much as 20 per cent of their budget on energy consumption to maintain comfortable housing. Research by the authors indicates that effective adaptation must not add to the financial burden on low-income households, if the liveability of Australia's semi-arid region is to be sustained.

Keywords: household energy use, energy cost, energy poverty, desert Australia

1. Introduction

Communities around the world follow different approaches to when pursuing adaptation to warmer climates. Climate interventions were initially considered unsustainable if they contributed to more greenhouse gas (GHG) emissions (Markandya & Halsnaes, 2002) which also categorises fossil fuel based energy intensive adaptation actions as unsustainable. Recent adaptation research increasingly signifies the importance of responses that also consider context-specific non-climate related stressors (Brown, 2011), especially when designing responses for vulnerable communities in developing countries (e.g. Mathew et al., 2012), thus broadening the goals of sustainable adaptation. Sustainable adaptation now focuses on ensuring inter- and intra-generational social and environmental integrity as well as addressing poverty and the causes of vulnerability (see Eriksen & Brown, 2011). Sustainable adaptation is not easy to attain even with respect to GHG emission reductions, as under half of the world's primary energy is used for power generation (BP, 2014), which also accounts for almost half of the energy-related GHG – making it the largest sectoral contributor to GHG emissions (IPCC, 2014). This challenge may be particularly evident in countries such as Australia where the country's energy consumption per capita is much higher than most other countries (257 million Btu per person), including more than 10 times that of some rapidly developing countries, such as India (19 million Btu per person) (EIA (US Energy Information Agency), 2011). Also, Australia's average residential electricity prices have recently been higher than in many other developed countries such as Japan, United States of America, Canada and others in the European Union (European Commission, 2014). High electricity prices coupled with a high level of energy use by Australian households can exert more pressure on low income households, raising concerns about whether Australia's high standard of living can be sustained. Despite having a high Human Development Index, Australia's heterogeneous population consisting of socio-economically disadvantaged Indigenous communities are at risk from many adaptation interventions that may not be sustainable for them in the long-term. In this article, we examine if adaptation interventions practised by and implemented for Aboriginal households in central Australia are at risk of unsustainable adaptation, and the implications of this with a warmer climate projected in the future. In particular, we examine sustainable adaptation to hot weather using energy poverty and energy efficient housing as indicators for two central Australian Aboriginal community camps and settlements (Alice Springs Town Camps and Lajamanu).

1.1 The Context of Central Australia and Key Vulnerabilities to Warmer Climates

Central Australia has a semi-arid climate with vast areas of remote lands and a sparsely settled population. Inland Australia is likely to experience more extreme events and a temperature rise in the range of 3 to 7°C by 2100. The changing climate in the form of increasing temperatures and extreme weather events, such as floods and storms, can adversely affect the transport systems of remote locations (Green et al., 2009). Also, rising temperatures and intense solar radiation can reduce the functional life of buildings and other infrastructure (e.g. electricity, tele-communication) (Maru et al., 2012), thereby compounding the already limited access to remote locations. A number of studies have also established a correlation between rising temperatures and poor health of people especially the elderly, children and Aboriginal people more generally in central Australia (e.g. Webb, 2014; McMichael et al., 2002). Expensive and limited availability of goods and services due to remoteness, coupled with more extreme weather projected under climate change, are likely to affect the liveability of central Australia, particularly in remote desert settlements.

Implementation of adaptation plans for coping with extreme weather events will be challenged because of people's isolation from major service centres, inadequate and commonly overburdened local health care facilities, fragile infrastructure for tele-communication and energy provision, and the sparsely settled population (van Iersel & Bi, 2009; Maru et al., 2012; Campbell et al., 2008). In addition to the many climate-induced risks, many remote Aboriginal communities do not have affordable housing that adequately insulates them from harsh weather (SCRGSP, 2015). Understanding the vulnerability of remote Aboriginal communities to climate change is likely to require a different mindset to that when exploring other populations (e.g. urban communities), as remote Aboriginal communities typically have strong social networks (McAllister et al., 2008), a close relationship with their country, and considerable family and kinship responsibilities (ABS, 2014) and so may be less likely to relocate to places with a temperate climate. While the long-term projection of rainfall patterns is uncertain for central Australia (Whetton, 2011), the rising temperatures suggest there will be an increasing demand for water – raising the issue of water scarcity in the large semi-arid region. Even if some remote communities have access to plentiful supplies, as most communities depend on groundwater (Barron et al., 2010) their health could be compromised if the potable quality of groundwater deteriorates as usage increases. Some analysts have argued that water shortages will be a critical national issue for Australia by 2030 (Hennessy and Overton, 2011).

Another major threat that households in central Australia are likely to face due to climate change is an increased demand for energy, with projections indicating greater energy requirements for cooling than heating (Wang et al., 2010). Remote dwellings can also be inefficient in terms of energy usage due to out-dated or poor quality household appliances, variable housing quality, restrictions on the extent tenants are allowed to modify rented houses, and a fluctuating number of residents that sometimes leads to lengthy periods of overcrowding (Lea & Pholeros, 2010; AIHW, 2014). Summer months in central Australia are characterised by high usage of conventional air-conditioners and refrigerators (powered by electricity) for cooling, which is likely to be exacerbated under the climate change projected for this region. To counter the effects of warming temperatures, more energy is expected to be used to keep existing buildings at the same level of comfort. Most Aboriginal households in central Australia use pre-payment meters to purchase power. Pre-payment meters remain popular among Aboriginal households in central Australia as they enable different people in the household (e.g. short and long-term visitors, long-term residents) to directly contribute to the cost of electricity utilised within an individual house, but has disadvantages in remote locations as the purchase of power cards can be restricted to when the local shop is open (e.g. absence of afterhours shops in remote locations) (McKenzie, 2013) resulting in power interruptions.

In short, the excessive reliance on appliances powered by non-renewable energy sources during extended periods of hot weather may create a dependence on an adaptation pathway that contradicts mitigation objectives. This 'mitigation-adaptation disconnect', as termed by Thornton and Comberti (2013), can result from an unplanned, reactive and opportunistic response to climate change. The vulnerabilities of remote Aboriginal communities may lead to path dependency or create 'lock-in' effects that can severely constrain the choice of adaptation options (see Wilson, 2014), with this likely to be a risk for communities in 'very remote' locations in the absence of thoughtful planning. In the following section, we focus on the experiences of people in two locations in central Australia:

Alice Springs and the smaller settlement of Lajamanu, about 680 kilometres north-west of Alice Springs (see Figure 1).

1.1.1 The Central Australian Case Study Locations

Alice Springs is the major town in the central Australia region with a population of about 28,000 (ABS, 2013). This town acts as a service hub for the many small communities and settlements within about a 500 kilometre radius. Most of the area in the region is classified as 'very remote' (ABS, 2013), with Alice Springs classified as a 'remote' location. Central Australia has a generally semi-arid climate with a low and variable rainfall (Alice Springs has a long-term average annual rainfall of about 280 mm). Lajamanu on the other hand has a small community (resident population of about 750) and is situated about 680 kilometres north-west of Alice Springs. Figure 1 shows the average daily maximum temperature during a typical summer month for these two locations in central Australia, where the majority of days in January have a daily maximum temperature exceeding 40°C. Climate projections indicate a rise in temperature for central Australia by at least 1.6°C by 2050 (Whetton, 2011), and an increase in the number of hot days and a decrease in the number of cold nights. For example, the annual average number of days over 35°C in Alice Springs is likely to increase from the current 89 days to 96-125 days by 2030 (Hennessy et al., 2007). While climate models indicate a decline in rainfall for southern and eastern parts of Australia, changes in rainfall for other parts are uncertain (CSIRO & BoM, 2007).

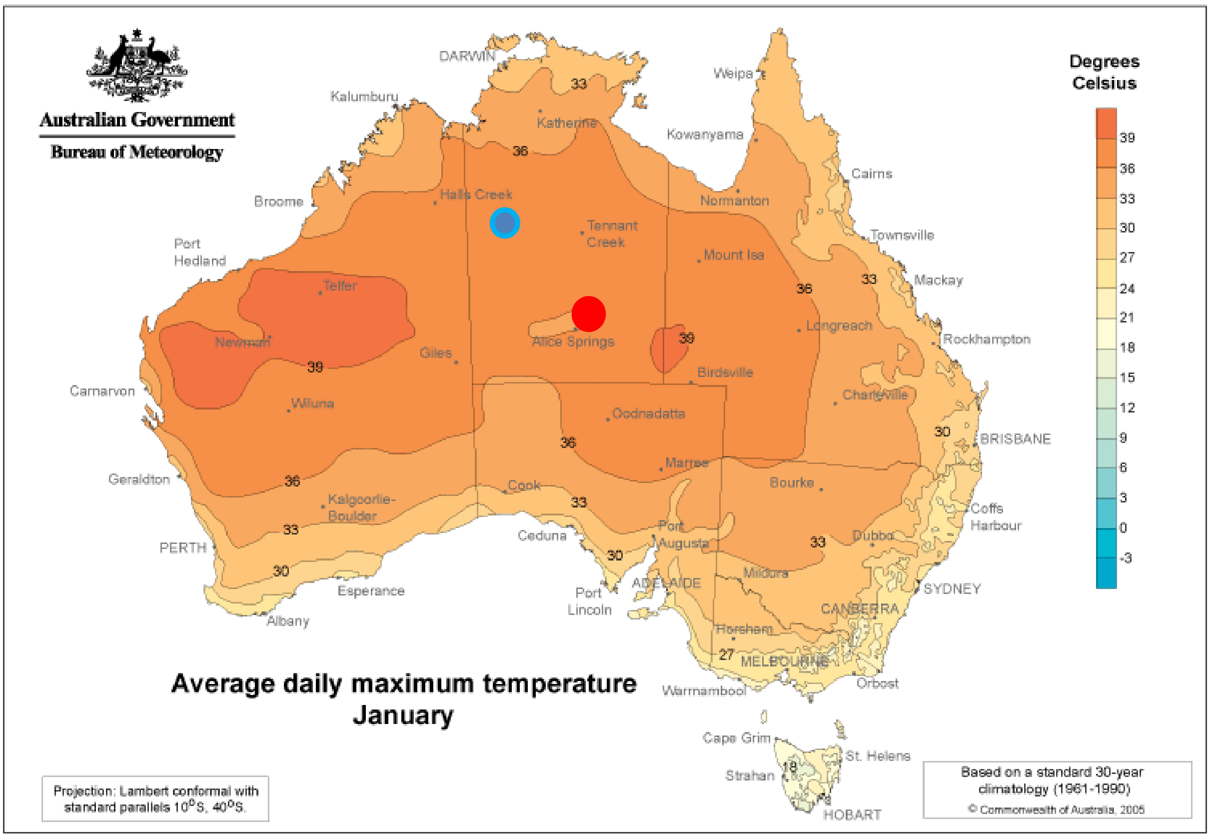

Figure 1. Mean daily temperature maxima for the month of January (summer) at the case study locations: Alice Springs (red circle) and Lajamanu (blue circle)

Source: BoM climate data online, http://www.bom.gov.au/jsp/ncc/climate_averages/temperature/index.jsp?maptype=1&period=jan

Alice Springs ('remote' ABS classification) has a population with about 20 per cent comprised of Indigenous people. Lajamanu ('very remote' ABS classification) has a much smaller resident population of about 750 people, but a higher proportion (~90 per cent) of Indigenous people (ABS, 2011). A minority of the Alice Springs community speak non-English languages at home, while a majority of the Lajamanu community speak Aboriginal languages at home (mainly Warlpiri). The socio-economic contexts of the two locations also differ markedly. For instance, the Index of Socio-economic Advantage and Disadvantage (IRSAD, created using ABS 2011 census data) shows that the area of 'Tanami' (ABS SA2 area code: 702011053), which includes the township of Lajamanu, has a low score of 654, ranking it among the lowest percentiles (in the lowest 1st percentile) nationally in terms of socio-economic advantage. By contrast, the area of 'Larapinta' (ABS SA2 code: 702011048), which includes the western part of Alice Springs has a score of 1021, ranking it in the 59th percentile nationally.

The main sources of electrical power for remote settlements in the wider central Australia region are through localised diesel, or hybrid diesel-solar powered generators (McKenzie, 2013). The electrical power in Alice Springs is largely derived from local generators powered by natural gas (58.7 MW), with a small amount from solar (1 MW), while in Lajamanu it is mainly from diesel (1.9 MW), with an additional input from solar (0.3 MW) (BREE, 2013). The solar radiation potential has been assessed as 22 MJ/m^2 per day for Alice Springs and 24MJ/m^2 per day in Lajamanu (ARENA, 2013). The supply of electrical power to households in both locations is by a single government agency – Power and Water Corporation (www.powerwater.com.au). A high proportion of electricity is used to power air-conditioners, refrigeration and supply fresh water to maintain the liveability of central Australia due to the hot summer season and semi-arid climate.

2. Research: Exploring Sustainability of Adaptation Practices in Two Communities in Central Australia

Our approach for this research was to adopt a method of convergent triangulation, where various data sources are integrated to obtain a better understanding of a research issue, rather than relying on a single limited data source (Olsen, 2004). This method is particularly important as data for central Australia is scarce, with many national level surveys using only data for the coastal urban centres of Australia. Our research thus included analysis of existing secondary data collected by independent organisations (e.g. Australian Bureau of Statistics) which was then linked with qualitative data collected via semi-structured interviews with a sample of residents living in Alice Springs and Lajamanu.

Firstly, we discuss the issue of energy poverty. Energy poverty has been defined by international energy agencies and energy researchers in a number of ways, depending on the aim and context of the study (Pachauri & Spreng, 2004; Nussbaumer et al., 2011). Some definitions use a relative measure, such as the International Network for Sustainable Energy (INFORSE) which states that 'energy poverty occurs if household energy costs are above 10 per cent of disposable incomes, transport fuels not included' (INFORSE, 2009, p.1). The INFORSE definition has been applied in this research at a preliminary stage to examine the likely prevalence of energy poverty among households in central Australia, and the extent their energy use will be affected by the changing climate.

2.1 Analysis of Energy Poverty Using Existing Data

Energy poverty has already been discussed as an emerging issue for non-remote households in Australia. Simhauser et al. (2010) explained energy poverty to be caused by the 'Boomerang' paradox, where the rising wealth of Australian households and the availability of historically cheap electricity led to an increase in household floor size, inefficient housing orientation and increased dependence on electrical appliances. These factors combined to result in high per capita electricity consumption, in turn exerting pressure on electricity supply networks and increasing electricity prices (Simhauser et al., 2010).

Firstly, we focus our analysis on existing energy consumption data drawn from a national level survey on household energy consumption conducted by the Australian Bureau of Statistics (ABS) during the period 2012-2013. We draw on the ABS data because many Aboriginal households in remote locations use prepayment meters which do not record energy consumption (usage rate or total) and different household members, including visitors, purchase power cards of different values (e.g. Au$20 or Au$50 cards) as needed, making it difficult to track a household's total energy consumption. The ABS data indicated that the cost associated with household energy consumption varied with household income, ownership of house, household types and climate zones (ABS, 2013). The ABS data also indicated that although the average total household energy expenditure (cost of energy for households and fuel for vehicles) was more for 'high income' households, the 'low income' households were more affected financially by energy costs. The 'low income' households spent around 10 per cent of their gross household income (before tax, so more than 10 per cent of their disposable income) on energy costs, with about 20 per cent of 'low income' households reporting difficulty paying their energy bills on time. According to the energy poverty definition adopted for this paper and the ABS (2013) national survey, 'low income' households are already experiencing energy poverty. Further investigation of climate zone-specific data in the ABS data shows that the expenditure on household energy varied from Au$30 to 47 per week (excluding fuel for vehicle costs) across the designated climate zones, with most regions in central Australia spending around Au$37 to 40 per week.

Table 1. ABS 2011 data for Alice Springs (Urban Centre & Localities) and Lajamanu

Location	Median weekly incomes (Au$)	Weekly electricity costs per HH (Au$)	Electricity costs as a proportion of weekly income (%)
Alice Springs UCL	1676	109[1]	6.5%
Alice Springs (Aboriginal & Torres Strait Islander)	1073	152[2]	14.2%
Lajamanu	1166	61[3]	5.2%

Notes:

[1] Around 38 per cent of the power generated in Alice Springs is used for residential purposes (Alice Solar Facts: http://www.alicesolarcity.com.au/facts/solar). The average per capita consumption of energy by households in Alice Springs is 8500 kWh (Alice Solar Facts), which is much higher than the national average of 2500 kWh. The average annual electricity cost for a household with 2.6 residents in Alice Springs is Au$5,657 (based on a charge of 25.6 cents/kWh for standard meters) (see ABS, 2011).

[2] Assuming the same per capita a consumption throughout Alice Springs, the average electricity cost (28.15 cents/kWh for prepayment meters) for a household with 3.3 residents is Au$7,896.

[3] About 60% of the total power generated at Lajamanu (3.1 GW) is delivered for household use (pers. comm. Catherine Joyce, Charles Darwin University, 25/11/2014). The per capita energy consumption is 2487 kWh (748 people) and with an average household comprised of 4.5 residents (see ABS, 2011), they will spend around Au$3,150/year for electricity (prepayment meters charged at the rate of 28.15 cents for 1 kWh).

Secondly, we use location specific average electricity consumption data for the two case study locations. The electricity costs shown in Table 1 for Aboriginal households may vary considerably over a year, as household composition can vary for extended periods, sometimes to a point of overcrowding – likely to lead to periods of higher household energy use. The calculations for electricity costs in Table 1 are based on a number of assumptions (e.g. fixed daily charges for standard meters not included; electricity consumption is an estimate), but this data can still provide an indication of the prevalence of energy poverty. Our analysis indicates that many Aboriginal households in Alice Springs spend more than 10 per cent of their income on electricity costs, and so can be categorised as ‘energy poor’ households. Although the energy expenditure shown in Table 1 is considerably different from the ABS national household energy consumption survey, this difference is mainly attributed to the ABS survey not including data from ‘remote’ towns (e.g. Alice Springs) or ‘very remote’ settlements (e.g. Lajamanu, where around a quarter of the population have a gross income less than Au$600 a week, see ABS, 2011), thus skewing the energy expenditure data towards urban centres.

As a third source of data, a total of 23 Aboriginal people from four Alice Springs Town Camps and eight people from Lajamanu were interviewed with the help of Aboriginal researchers (N = 31). The interviews were conducted with a cross-section of the community to understand if people had observed any changes in the local climate during their lifetime. We acknowledge the small sample, with the interview data used to provide a deeper understanding of the local community context, household dynamics and energy use, not for any statistical analysis.

Most interviewees reported that they were not sure how much they were spending on electricity, as different people purchased power cards within a household, and power cards were of different values (although the Au$20 power card was the most commonly purchased). Many people expressed concern at the amount of money they were spending on power cards (electricity), with some people reporting their households were regularly spending Au$50 to 100 per week. Households using power cards have little capacity to track their energy consumption from week to week, or year to year; hence receiving little empirical feedback about energy use or efficiency measures. Most people in the interviews reported that they were using a lot of power to stay comfortable (n = 15), yet there is considerable uncertainty about exactly how much households were using with some illustrative quotes being:

> *“Sometimes it’s hard to know how much we’re using as we all use a lot of power”* (woman, 18-25 years)
>
> *“Yes, I think I use a lot of power and I do get worried all the time* (about excessive power use)*”* (woman, 36-45 years)
>
> *“I buy power cards weekly and yes I would like to know how much I'm using”* (man, 36-45 years)

> *"I don't know how much is spent* (on household power), *but I would like to know"* (man, 36-45 years)

The most common power card purchased by people interviewed was that valued at Au$20 (*n* = 19), with a small number of people purchasing power cards valued at Au$50 and Au$100. The variable, although often uncertain, household energy costs are illustrated with the following quotes:

> *"We use a lot, $60 to $70 a fortnight"* (woman, 26-35 years)
>
> *"Maybe $80 a week"* (woman, 36-45 years)
>
> *"$20 to $100 a week"* (man, 36-45 years)

Summarising results from the three data sets, it appears that many Aboriginal households spent about 5-15% of their household income on electricity. Thus we conclude that a sizeable percentage of Aboriginal households in the two locations regularly experience energy poverty (as defined as >10% household income allocated to energy costs), although the exact proportion is unknown.

2.2 Assessing Sustainability of Housing Infrastructure as a Means to Moderate Hot Weather

Housing is the most important infrastructure for people living in remote Australia in terms of moderating the impacts of extreme weather (Race et al., 2014), with the design and quality of housing being critical components. During hot weather, most people in the interviews reported staying inside and turning on air-conditioners and fans (*n* = 16) and a few others reported sitting in the shade on grass, or ground recently watered, as other common practices (*n* = 7). Some illustrative comments from interviewees about these practices are provided below:

> *"When it's hot, I clean the yard and hose the ground and sit under a tree outside, or stay inside and put the fan and air-con on"* (woman, 36-45 years)
>
> *"Turn the air-con on and stay inside"* (woman, 26-35 years)
>
> *"Watering garden and sitting under the tree"* (man, 36-45 years)
>
> *"Air-con, fan, having a cold shower"* (woman, 18-25 years)
>
> *"Watering garden, wetting the ground"* (woman, 36-45 years)

People interviewed at Lajamanu reported that when the weather is extremely hot (e.g. shade temperature greater than 35^{o}C), they preferred to stay inside their home (*n* = 14) and turn on the air-conditioner (*n* = 11). The combination of housing and using electrical appliances was important for maintaining a comfortable temperature, particularly during periods of very hot weather (e.g. air-conditioners, fans, fridges), or cold weather (e.g. heaters, ovens/stoves). Some of the interviewees reported that a Au$100 power card was likely to last for a week, but they could not recall if that happened during summer or winter.

As for most people, housing is a key aspect to moderating extreme weather for the residents in Alice Springs and Lajamanu. Most houses constructed in Australia during 1990 was of just a 1-star rating on the energy efficiency scale developed by NatHERS (Note 1) (Nationwide House Energy Rating Scheme developed in 2006 to rate the potential thermal comfort of Australian homes on a scale of 0 to 10-stars). Less than one per cent of all houses in Australia rated 5-stars or higher before the energy efficiency regulations were introduced in 2003 (see Zero Carbon Compendium (Note 2)). The ABS (1999) Australian housing survey assessed housing characteristics (physical conditions, tenures and quality of housing) and found that more than half of Australian houses were 20 years or older (see ABS, 1999). Although the Northern Territory (which includes Alice Springs and Lajamanu) reported the highest proportion of housing stock which was less than 5 years old (13 per cent), the Northern Territory data was skewed towards the major urban areas and remote locations and sparse settlements were excluded (ABS, 1999). This again makes it difficult to get an estimate of the average energy rating of housing in Alice Springs and Lajamanu.

Australia now has a National Construction Code which includes mandatory requirements for energy efficiency and thermal comfort of new residential housing, with new houses required to meet the minimum standard of a 6-star rating (e.g. in the states of Western Australia and Queensland), with the exception being the Northern Territory which has a minimum 5-star rating. However, achieving a minimum 5-star rating may not be an adequate long term energy management strategy in the Northern Territory as climate change may reduce the energy efficiency of housing to an equivalent rating of 3.4-stars in 2050, and 1.5-stars by 2100 (under an AIF1 fossil fuel-intensive scenario, Wang et al., 2010). A comparison of results in Table 1 (current average electricity costs) and Table 2 (electricity cost for a 5-star rated house) indicate that houses in Alice Springs and Lajamanu could save around Au$1000 to Au$4500 per year on electricity bills by improving their housing energy efficiency to five stars.

Table 2. Electricity costs to maintain comfortable temperatures in a standard house with 5-star rating (Source: ABCB 2006)

Location (see ABCB 2006 for climate regions)	Energy loads for a 5-star rated house (1 kWh = 3.6 MJ)	Cost of maintaining a comfortable air temperature for a standard 3-br house of 110 m^2 (internal) with a 5-star rating
Alice Springs (climate region 6)	148 MJ/m^2/year	Au$1157/year
Lajamanu (climate region 37)	259 MJ/m^2/year	Au$2227/year

Constructive Concepts (2009) reported greater energy savings in extreme climates when improving the star rating of housing, than in more moderate (temperate) climates. For example, improving the star rating of a house in Alice Springs or Darwin will lead to greater energy saving than a similar improvement in star rating for housing in Brisbane or Sydney.

Housing in Lajamanu, as in most other remote communities, is of variable age, size and quality. Housing in the Alice Springs Town Camps is similarly variable with a mix of new houses, rebuilt and refurbished houses, and a larger pool of older housing (CAT, 2013). An evaluation of post-occupancy experiences of houses built or upgraded via the Strategic Indigenous Housing and Infrastructure Program (SIHIP) in the Alice Springs Town Camps indicated that the newly constructed houses were of a 7-star energy rating (see CAT, 2013), and so would generally consume far less energy for heating and cooling compared to 2-star and 5-star rated houses, as seen in Figure 2 (i.e. energy use by a 7-star house in Alice Springs equates to 84 MJ/m^2/year). The importance of cultural considerations in the design of housing is argued by Fien et al. (2011, p.346), who described some Indigenous households as '… a complex, multigenerational, extended family with several family sub-units, each living in their own bedroom', thus requiring housing design to suit their lifestyle and culture (Martel & Horne, 2012). This highlights the importance of housing designs that are not only energy efficient, but also designed to suit the specific lifestyles of current and likely future residents (e.g. to minimise seasonal overcrowding). This also indicates that the same adaptation measures for different populations (e.g. public housing for Indigenous and non-Indigenous Australians) can result in different adaptation outcomes depending on differing values and interests (also see Eriksen et al., 2011).

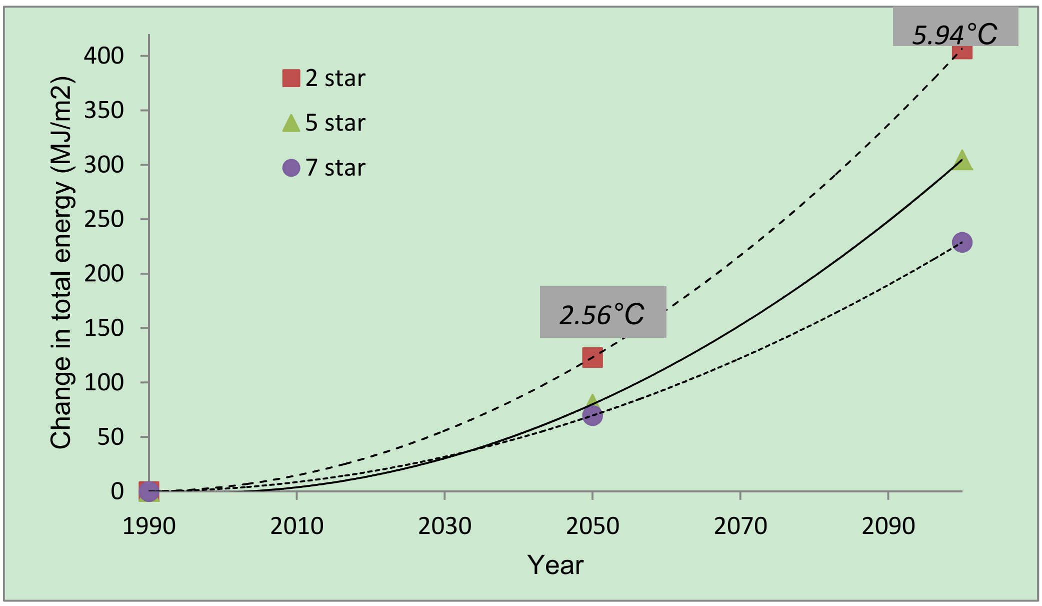

Figure 2. Change in annual energy consumption for heating and cooling in Alice Springs; Temperature increase projections indicated in shaded boxes (Source: Wang et al., 2010; Ozclim temperature data)

2.3 Factors Causing Additional Stress on Household Budgets

Fuel costs are also a significant expense for households in remote central Australia. Australian households that received most of their gross weekly income from a government pension (e.g. Au$530 per week for a *Newstart* allowance with 2 children & Family Tax Benefit A and B, see Centrelink, 2014) spent close to 10 per cent of their income on total energy (household energy (Au$30 per week) and vehicle fuel (Au$31 per week) costs (total = Au$61 per week). Adding to household energy consumption is that few houses occupied by 'low income' families had insulation, window treatments, solar electricity or solar hot water installed compared to households with higher incomes (ABS, 2013). Many households in central Australia are likely to fall into the 'low income' category (ABS, 2011). Travel costs from remote locations, such as Lajamanu, are expensive. For instance, a one way trip from Lajamanu to Katherine (closest regional town) by bus over a distance of around 1100 kilometres can cost Au$140 (see *Bodhi* bus fares (Note 3)). Also petrol prices are around 30 per cent higher in Lajamanu than in Alice Springs (Spandonide, 2014). Around 43 per cent of the Alice Springs UCL households live in rented homes with a median rent of Au$300 per week, and while the majority of Lajamanu residents live in rented homes the median rent is just Au$20 per week (see ABS 2011). The maximum rent in the Alice Springs Town Camps is in the range of Au$290-$334 per week for a 2-4 bedroom house (Territory Housing, 2010), which likely to be a considerable expense for families in the 'low income' category. Water supply in remote locations is also energy intensive with around 1100 kWh required per ML for Alice Springs (see *Alice Solar Facts*). As the average house uses around 740 kL each year, that adds 814 kWh of electricity consumption for water supply per household – equating to about an additional Au$200 per year. The cost of living in remote communities is generally higher. For example, the cost of a standard basket of goods (basket sufficient to provide food for a family of 6 people, including children and elderly for a fortnight) in 2012 in Alice Springs supermarkets was around Au$500, while a similar standard basket was estimated to cost around Au$800 in remote community stores (see Dept. of Health, 2013).

In summary, many 'low income' households in the study locations – Alice Springs and Lajamanu – are likely to already be experiencing energy poverty on a regular or sustained basis. Electricity, fuel, rent and water costs combine to make the liveability in central Australia expensive, perhaps even unaffordable for many 'low income' households. Changes including rising electricity prices and climate change are likely to exacerbate energy poverty in remote desert Australia, making adaptation interventions unsustainable if based on high electricity usage and poor housing design.

3. Discussion: Sustainable Adaptation to Hot Periods in Central Australia

While many characteristics of remote Australia are unique, lessons for sustainable adaptation to warmer climates from both developed and developing countries may be informative. One main strategy pursued in the UK to eradicate energy poverty is to improve the energy efficiency standards of social housing stock and rented homes (Bird et al., 2010). This strategy appears to be highly relevant for central Australia, where a high proportion of Aboriginal families reside in public housing, rather than privately owned housing. In central Australia, electrical appliances are commonly used to maintain housing comfort (e.g. air-conditioners), and thereby are making up for deficiencies in the housing infrastructure (design, quality). The cost of appliances – either the initial purchase and/or operating – is borne by residents. As such, poor quality housing, or housing with a low energy 'star' rating, is likely to be adding to 'cost of living' pressures for residents, as many rely on electrical appliances to maintain the comfort of their housing. This issue may be felt more acutely by long-term residents of public housing with low incomes, who typically have little control over the housing infrastructure yet must meet the operating costs to achieve an acceptable level of thermal comfort. Unless housing is upgraded to meet a high level of energy efficiency (e.g. '7-star' rating), climate change will compound 'cost of living' pressures – risking 'unsustainable adaptation' becoming a contagious phenomenon in central Australia.

Given the high value of housing and the projections for climate change, there is a need to increase the baseline data for 'star' rating software (e.g. *AccuRate*) so that all climate zones are equally supported with reliable data and housing design is optimised for the diverse climate zones across Australia. Integrated analysis of ABS and Bureau of Meteorology (BoM) data is needed, so that models can analyse household composition and income, cost of living, housing infrastructure and climate (current and projected), and have the results spatially referenced and culturally interpreted. Energy poverty may not in itself appear to be a critical issue, however it compounds already stressed households by adding to the cost of living pressure, which in turn leads to social and economic stress – undermining health and wellbeing, and subsequent participation in employment, education and the wider community. It may also be an underlying 'push' factor, causing people to move temporarily and then permanently to larger population centres where living costs are perceived to be more affordable (a source of overcrowding in housing). This may already be evident in Lajamanu, where the community population has declined by about 35 per cent during the period 2010-13 (a loss of 412 people, to 748 residents), making it difficult to plan for the future needs for infrastructure (e.g. housing, power and water supplies) and services (e.g. education and health), and also creating more accommodation pressure on larger service towns such as Alice Springs.

The movement of people, both temporarily and permanently, also has implications for improving the wider community's awareness and knowledge about appropriate energy efficiency strategies. When people move between houses with different designs and appliances, and to different climate zones – effective strategies for energy efficient behaviour may be markedly different. For example, the recommended use of natural ventilation in one climate zone may be contrary to the advice to increase the sealing of a house and use of air-conditioners in another climate zone. That is, housing behaviour and design may need to be very different in Darwin compared to Brisbane, even if similar houses have the same energy 'star' rating (e.g. varying energy loads and efficiency strategies for housing in different climate zones). As such, education programs and incentives seeking to improve household energy efficiency will need to be culturally appropriate, household focused (e.g. age, number and behaviour of residents) and tailored for specific climate zones. The energy 'literacy' of residents across Australia is typically low, with an apparent potential to greatly improve household energy efficiency – and thereby reduce the incidence of 'energy poverty' and ease 'cost of living' pressures. Improved 'in house' displays linked with an education program and incentives may be key elements of a short- to medium-term 'package' to lift households out of 'energy poverty'. Medium-term strategies will need to invest in upgrading the energy 'star' rating of housing, from the current '5-star' requirement for new housing to '7-star' (by 2050) and probably '10-star' (by 2100). A '5-star' energy rated house in Alice Springs may need to adopt an integrated strategy that includes using energy efficient appliances, retrofitting to a '7-star' rating and installing photovoltaic technology to restrict household energy consumption to current levels as the climate warms by 2 to 6◦C (Ren et al., 2011).

In a developing country context, many authors advocate integrating 'energy poverty' programs with efforts to achieve the Millennium Development Goals (e.g. poverty alleviation) (see Mehta et al., 2009; Sirohi, 2007; Cunha et al., 2007; UNDP, 2007; Laufer & Scaufer, 2011). This approach may also be appropriate for remote central Australia where strategies to 'close the gap' between Indigenous disadvantage and mainstream Australians could complement strategies for improved energy affordability and efficiency. While access to an adequate supply of energy has been identified as a requirement to alleviate poverty and foster development for developing countries (UNDP, 2007), some authors also argue the need to synchronise adaptation, mitigation and development strategies to ensure sustainable 'green' growth (Thornton & Comberti, 2013). Understanding the demographic heterogeneity of communities living in remote towns and small settlements of central Australia is important (e.g. Aboriginal population, presence of elderly residents, household behaviour) if to effectively re-design housing, enhance energy use and to adapt to future climates. Others have raised concerns about the energy trilemma – energy poverty, energy security and climate change mitigation – faced by millions across the world (Gunningham, 2013), that could be tackled by moving towards a renewable energy-based economy (Urge-Vorsatz et al., 2012). For instance, in India with its rapidly developing economy, government has focussed on implementing renewable energy policies and projects over the past decade as a strategy to decentralise energy generation and overcome energy poverty in rural communities (Agrawal, 2014). The Renewable Energy Rural Livelihood (RERL) program implemented in remote villages in Indian states such as Rajasthan, Uttarakhand and Jharkhand, provide examples where the use of renewable energy has improved the livelihood prospects for people previously living in poverty (Mehta, 2009). Rural communities in these states of India appear to share many characteristics with remote central Australia, including a semi-arid warm desert climate, resident indigenous (tribal) people, limited access to central energy grids, limited commercial opportunities, and communities with marginal political influence. While Australia is generally considered to have a developed economy, lessons from developing countries, such as India, may be informative given the challenging socio-economic conditions faced by many residents living in remote communities. The RERL program suggests linking the benefits of renewable energy closely to community priorities such as poverty reduction, improved quality of life and increased livelihood opportunities, for its successful deployment and acceptance. The effects of climate change in the form of more intense storms, high rainfall events (not necessarily an increase in annual rainfall) and flooding are likely to result in road closures to remote communities, restricting the transportation of fuel to generate local electricity. Given likely disruption to transportation and damage to infrastructure (bridges, roads), it appears advantageous for remote communities to increase their energy self-reliance, such as from solar energy. Also, the marginal cost of generation from diesel power (Au$250 to Au$400 per MWh) in remote or regional areas is higher than the cost of installing photovoltaic systems (Au$200 to Au$240 per MWh) (Frearson, 2014).

Specifically for Australian remote locations, Frearson (2014) identified structural barriers to the widespread uptake of renewable energy, which is centred on governance (legislative/regulatory regime, management of revenue stream, management of liability), finance (capital constraints, risk and ownership) and logistics (intellectual property, materials and labour). Also, policies that focus on encouraging technological advancements remain important if they lead to low cost options (see Groba & Breitschopf, 2013). Besides making energy affordable, available and reliable for households, consideration should also be given to the economic, social, cultural and political dimensions of each location (Sovacool, 2012; Laufer & Schaufer, 2011). A degree of vulnerability (e.g. low socio-economic conditions, remote settlements) and resilience (e.g. past experience of living in extreme and variable weather) to climate change may be exhibited by Aboriginal communities in central Australia (Maru et al., 2014). Current reliance on electrical appliances (old appliances using non-renewable energy sources) to adapt to extreme weather has a short-term focus on reducing vulnerability. However, this approach is unsustainable in terms of its GHG emissions and in terms of its increasing cost for using electricity generated from conventional sources (e.g. diesel generators), both likely to erode the long-term resilience of Aboriginal communities. Transforming the local economy to one that is largely powered by renewable energy (solar) would likely assist in terms of enabling affordable use of existing electrical appliances. However, the design and construction of energy efficient housing has a longer term focus in terms of its contribution to reduce vulnerability and increase resilience. Apart from constructing energy efficient buildings (e.g. use of building materials with high insulation characteristics, orientation of windows to allow cooling breezes, provision of shade in summer), sustainable adaptation will require extensive community consultation to fully understand important cultural needs (e.g. flexible/movable walls to cater for seasonal overcrowding) of the house occupants. Thus, an approach that brings potential residents, design engineers and builders together well before construction of new housing should be encouraged.

There has been a transition from the historical nature-based adaptation to the prevailing weather to a growing dependence on public housing and electrical appliances by many in remote Aboriginal communities (see Figure 3). If this current approach to climate change adaptation continues, Aboriginal communities are also likely to contribute towards the 'Boomerang' paradox (see Simhauser et al., 2010), due to the compounding nature of increased energy use and rising levels of GHG emissions. Transitioning to using renewable energy and upgrading energy efficiency standards of housing will make an important contribution to building more resilient and sustainable communities in remote central Australia.

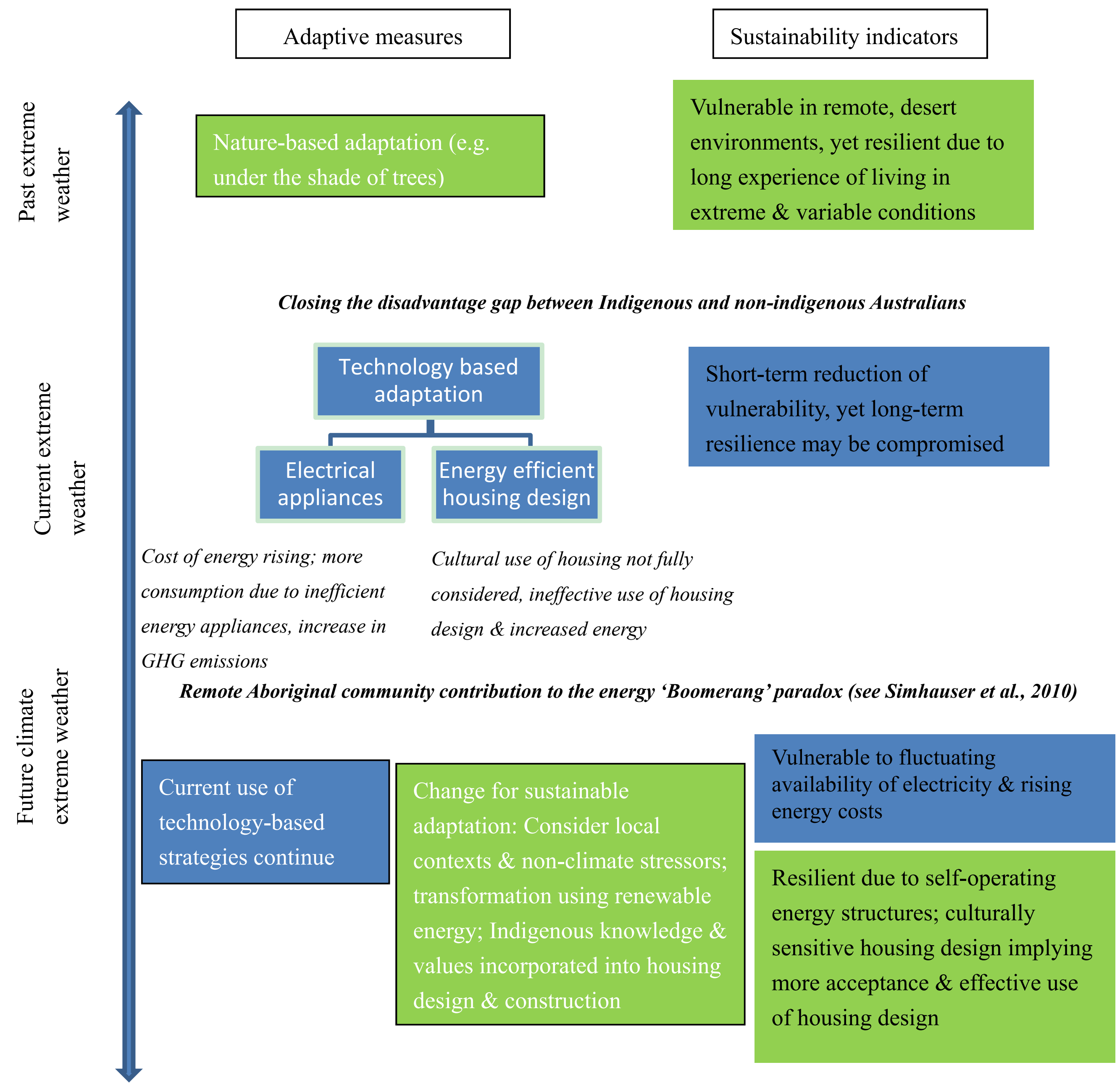

Figure 3. Sustainability of adaptation measures to extreme weather by remote Aboriginal communities

4. Conclusions and Policy Implications

Contemporary development has created an inextricable link between climate adaptation and energy use, particularly in terms of moderating extreme weather. A high proportion of electricity is used to power air-conditioners and supply fresh water to maintain the liveability of central Australia. While 'best practice' and lessons from international experiences are informative for understanding what may be possible in central Australia (e.g. pathways for transitioning to renewable energy), it is important to fully appreciate the context and characteristics of the local setting.

This research reveals that energy poverty is likely to be a common experience in many 'low income' households in central Australia, both within the regional town of Alice Springs and the remote settlement of Lajamanu – a situation that will be exacerbated with climate change. In terms of designing effective adaptation policies, uniform national-level programs may not easily account for local characteristics. Community participation will be a crucial component of such a program if to engage 'low income' households comprising diverse socio-economic and cultural attributes. Local wisdom and traditional knowledge should contribute to the design, and subsequent acceptance, of adaptation interventions.

Sustainable adaptation by households and community-based enterprises will be vital if the liveability of remote central Australia is to be maintained. While general ideas are emerging, there remains a need to invest in understanding a range of sustainable adaptation options that cater for the demographic heterogeneity across the vast area of central Australia, with a focus on:

- community participation and inclusion of local experience and knowledge in the design of socially acceptable options. This can shed light on potential responses (as individuals and social norms, institutional arrangements) to the most feasible options;
- quality, scale and cultural acceptance of high-cost investments (e.g. housing, community buildings and major infrastructure);
- extent, quality and usage of electrical appliances (e.g. for cooling and heating); and
- systems for data monitoring in remote settlements (e.g. energy consumption data, expenditure data).

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Notes

Note 1. http://www.nathers.gov.au/

Note 2. http://www.lowcarbonhomesworldwide.com/case-studies/countries/australia.html#ref:02

Note 3. http://thebodhibus.com.au/route-service/

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