DESERT KNOWLEDGE CRC

Scoping study of design and thermal performance in the desert built environment

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The Desert Knowledge Cooperative Research Centre is an unincorporated joint venture with 28 partners whose mission is to develop and disseminate an understanding of sustainable living in remote desert environments, deliver enduring regional economies and livelihoods based on Desert Knowledge, and create the networks to market this knowledge in other desert lands.

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Contents

1. Executive summary

This report examines the internal climates of buildings in desert communities, their design and passive climate control characteristics and the energy used for active heating and cooling.

The primary outputs of this report are:

- A review of the literature on building energy efficiency
- A review of models and their applicability to the desert built environment
- A review of the applicability of the Building Code of Australia for desert communities
- An improved understanding of energy usages and costs associated with active climate control in buildings in remote desert communities
- A greater appreciation and understanding of opportunities for energy conservation through passive climate control and appropriate building design
- A platform for future improved modelling of buildings, improved data on suitable design and improved practical recommendations and guidelines, allowing for more informed decision making when designing and retrofitting
- A greater awareness of Aboriginal cultural and other user issues related to building design
- Identification of knowledge gaps that directly or indirectly influence thermal performance of the remote desert built environment.

The methodology adopted within this scoping study is to investigate each of the key areas: Desert design, the Building Code of Australia, modelling methodologies and cultural sensitivity in a direct manner to identify the scope of knowledge currently in the public domain. Based on this information, knowledge gaps have then been identified and in some instances, including the modelling methodologies section, were further pursued in the report.

1.1 Desert design

There are two broad methods for the regulation of the internal climate within a house. Active climate control refers to the conversion of electricity into energy to regulate the internal climate, while passive design relies on ambient energy sources, such as wind and solar energy to regulate the internal climate.

There is a shift towards passive climate control for a number of reasons: reduced energy consumption, potentially lower maintenance, and reduced impact on the environment. Active climate control can consume large amounts of electricity resulting in the generation of greenhouse gases. The use of electricity also places greater pressure on the community's infrastructure, which has many follow-on effects including the increase of maintenance requirements. Passive climate control relies on material properties, placement and the external environment to influence the internal climate.

The majority of buildings in most remote desert communities are houses. A number of building designs have been identified throughout these regions. House designs include standardised designs, temporary housing such as transportable buildings and shelter accommodation. There is also a variety of buildings from previous generations available for post–life cycle analysis. Two houses in particular have been analysed in detail. These appear later in the report in Section 4: Modelling methodologies.

1.2 Building Code of Australia assessment

The Building Code of Australia is a comprehensive set of requirements and standards for the design and construction of buildings and similar structures in Australia. Produced, maintained and annually updated by the Australian Building Code Board, the Building Code of Australia can be applied across Australia as a nationally uniform code that allows for variations in climatic, geological and other geographic conditions. While the Building Code of Australia sets the minimum building standard in order to eliminate poor or worst practice, the builders or consumers may choose better performing systems as part of the building design and construction process. The Building Code of Australia makes no allowance for variable social issues. However, there are a number of complementary documents to the Building Code of Australia that specifically deal with Aboriginal culture and housing.

There are two avenues to BCA compliance: Energy Rating Schemes (ERS) or Deemed to Satisfy (DTS) check lists. Energy Rating Schemes evaluate the energy consumption of a house based on the interaction of all the components as a system, taking into account characteristics such as orientation, floor materials, insulation, and glazing. Deemed to Satisfy provides a check list of requirements that ensure a minimum level of energy efficiency is achieved regardless of component interaction. The Energy Rating Schemes provide an invaluable tool for improving the thermal performance of housing as it takes into account the specific climate. However, there are questions regarding the level at which the minimum standards should be set.

Energy efficiency amendments are being proposed for the Building Code of Australia to reduce domestic energy demand. The amendments aim to bring all new houses to a level of 5 stars based on National House Energy Rating Scheme (Kennedy 2004) that essentially represents buildings of very good energy efficiency. Some states such as Victoria have already implemented these changes. In order to determine its relative merits in desert climates, two Central Remote Model standardised house designs used by the Indigenous Housing Authority of the Northern Territory were analysed for life cycles, embodied energy, the efficiency of energy saving measures and the resulting active energy consumption. The standardised houses, like others in the Northern Territory, are designed for retrofitting within 10 years. This limits the time available for savings in operational energy to exceed energy invested in installing these measures. It was found that adopting the proposed Building Code of Australia energy efficiency measures would increase the embodied energy within the houses without markedly reducing the energy requirements of evaporative air conditioners that are the primary source of active climate control. The short lifespan of these houses did not permit sufficient time to pay back the energy investment through operational energy savings. Therefore, for these desert housing designs, implementation of the Building Code of Australia's proposed energy efficiency measures was found to be out of balance.

1.3 Modelling methodologies

There are three main forms of modelling tools available: numerical simulation, theoretical calculation and experimental modelling. Numerical simulation is a popular form of modelling due to the ease of rapid evaluation of housing design. A combination of numerical simulation and full-scale experimental modelling techniques have been employed to analyse the effect of changes and to test the comfort parameters. A Central Remote Model standardised design has been numerically simulated subject to a number of variations in design, and a Wongatha Wonganarra Aboriginal Corporation house has been data logged representing a full scale model. Variations to the orientation, insulation, external wall composition, window framing and veranda depth have been examined in detail.

A standardised IHANT design, CRRC3K – a compact, concrete block 3-bedroom house with deep verandas on the north and south sides of the building – has been studied in detail by numerical simulation. There is a large variation in energy rating requirements due to the orientation of the house. The most significant improvement occurs at an orientation of 270º where a 6.7% improvement is achieved. An optimised variation is achieved through compounding the improvements based on the orientation, external wall composition and glazing variations. A clockwise rotation of 270º from the north, 200mm Autoclaved Aerated Concrete block work with 10mm of plasterboard and a change to clear double glazed windows produces a dramatically improved rated energy requirement from the base rating of over 65%.

Through project partners Murdoch University, and links with the Wongatha Wonganarra Aboriginal Corporation, a resident's house was data logged April to July 2005 in Laverton Western Australia (James 2005). The house was a novel design that incorporated a range of sustainable design concepts, including thermal performance, community development aspects and sustainable materials through the use of rammed earth (Anda 2005). The limited data logging analysis correlates well with the numerical analysis.

The CRRC3K design and the Laverton house design are performing well during the summer period but have been designed to insulate the house too much during the winter and as such require a heating load which is greater than the cooling load. This in turn leads to a greater electricity requirement during the winter, impacting on the infrastructure.

1.4 Cultural sensitivity

'To competently design appropriate residential accommodation for Aboriginal people who have traditionally orientated lifestyles, architects must understand the nature of those lifestyles' (Memmott & Go-Sam 2003). Cultural considerations must be included in Aboriginal housing design, to ensure basic needs are catered for and housing designs satisfy their main objective of providing a suitable, healthy environment in which to live. Behavioural and social sensitivity also have a significant impact on the way that a house should be designed.

Memmott (2003) states that the key premise for appropriate residential accommodation for Aboriginal people is to understand the nature of those lifestyles, particularly in the domiciliary context. As an example Fantin (2003) states that many of the Yolngu householders from north-east Arnhem land were interested in ways of incorporating particular cultural aspects into their housing designs. The issues of avoidance laws and their associated behaviours and sorcery were investigated with relation to visual surveillance, access to houses and yards, landscaping, lighting, ablutions design and security. Keys (2003) specifically investigates the social and physical properties of a single women's camp in Yuendumu, Central Australia. In particular the ability to visually survey social and environmental conditions was highly valued by the Warlpiri women. A numerical simulation analysis of variable window height allowing for visual surveillance while sitting on the ground found that there was little impact on the overall thermal performance of the house.

There is a direct link between the temperature of the environment and the health impacts of individuals, particularly groups that are at risk such as children, the elderly and the sick. The effects of extreme temperatures are generally referred to as heat stress and can include heat stroke, exhaustion and cramps (New South Wales Government 2002) but can also induce irritation, anger and other emotions that can lead to rash actions (Leveritt 2004). It can be seen in Housing for Health data presented in Table 16 that there are a significant number of houses that exceed 30°C. This is beyond comfort levels and is impinging on health. It can also be seen that 25% of houses did not have any form of cooling climate control.

1.5 Knowledge gaps

There have been a number of knowledge gaps identified by the project. These range from specific technical design issues to issues that are design considerations before and after the thermal performance consideration. The purpose of a house is to be functional to the resident. This means not only providing protection from the elements but also a design that is culturally sensitive. The effects of altering housing design to incorporate cultural sensitivity or shifts will have an overriding impact on the thermal performance of the housing.

Thermal performance of buildings has a large influence on the settlement's ability to provide power. The settlement energy use depends on two factors: base energy consumption and peak energy demand. The settlement's power supply must be able to handle the base load of the infrastructure, community buildings and housing. The peak loads come from fluctuations in these components. Based on simple analysis as well as anecdotal evidence it would appear that the peak loads are driven by active climate control, both heating and cooling in the settlements.

Passive design concepts can greatly reduce the energy demands of active climate control. There are two aspects to passive design: passive cooling and passive heating. It was found in the modelling analysis that the CRRC3K and Laverton designs have been over-engineered towards passive cooling for the summer period rather than passive heating for the winter period.

The Northern Territory Government has stated that one of the most urgent issues is addressing the massive shortage of housing. In addition to the issues discussed above, labour shortages for construction and maintenance in remote areas and longer term requirements, both cultural and social, also need to be considered.

2. Desert design

The hot arid regions of Australia are characterised as a harsh environment that is difficult for humans to exist in, yet 'most of the early urban civilisations of the world emerged in the arid or semi-arid zones' (Golany 1983:2). This demonstrates that desert housing design has been an evolving process for many generations. While the Australian deserts are not uncommon from other deserts around the world, the spatial distances, population distribution and cultural sensitivities of Aboriginal communities make the Australian desert region a unique place.

There are two broad methods for the regulation of the internal climate within a house. Active climate control refers to the conversion of electricity into energy to regulate the internal climate, while passive design relies on ambient energy sources, such as wind and solar energy to regulate the internal climate. Examples of active and passive climate control devices are listed in Table 1.

Table 1: Forms of climate control – active and passive

Active climate control	Passive climate control
Refrigerative air conditioning	Thermal mass
Evaporative air conditioning	Shading
Ceiling fans	Natural ventilation
Pedestal fans	Insulation
Central heating	Glazing
Radiant heating (bar heaters)	Radiation
Gas heating	

There is a shift towards passive climate control for a number of reasons: reduced energy consumption, potentially lower maintenance, and reduced impact on the environment. Active climate control can consume large amounts of electricity resulting in the generation of greenhouse gases. The use of electricity also places greater pressure on the community's infrastructure, which has many follow-on effects including the increase of maintenance requirements. Passive climate control relies on material properties, placement and the external environment to influence the internal climate.

The *Your Home* guide (Reardon 2001) is an Australia-specific guide to housing design throughout all the climate zones. It is a result of the collaboration between Australian Government departments, the Building Commission and industry partners. It refers to both the construction and renovation of houses. The guide suggests a number of specific design principles for hot arid climates: high thermal mass, shading and ventilation. High thermal mass refers to materials such as concrete, rock or rammed earth that are particularly dense or heavy and have the ability to store heat energy. As the thermal mass absorbs large amounts of heat energy it can reduce the fluctuations of the external climate by minimising the peak temperatures during the day. Optimally, thermal mass would absorb the excess heat during the day and release it during the cooler night period, creating a temperature stable environment. Shading reduces the incident solar radiation, assisting in decreasing the absorbance of energy into the building envelope, while ventilation allows the house to capture transient breezes, assisting convective cooling.

3. Building Code of Australia assessment

The BCA is a comprehensive set of requirements and standards for the design and construction of buildings and similar structures in Australia. Produced and maintained by the Australian Building Code Board (Berry 2005), the BCA can be applied across Australia as a nationally uniform code allowing for variations in climatic, geological and other geographic conditions. The BCA sets the minimum building standard in order to eliminate poor or worst practice. The builders or consumers may choose better performing systems, however, as part of the building design and construction process (Williamson 2002).

3.1 Building Code of Australia documentation

The BCA has several sections in two volumes. Volume Two deals expressly with Class 1 (Houses) and Class 10a buildings (Non-habitable connected, e.g. garage). All other classes are included in Volume One. Within the volumes there are general outlining sections:

- Section 1 (General requirements): provides general information about the scope and use of the BCA
- Section 2 (Performance provisions): details the performance levels expected of buildings in terms of the structure, safety and health aspects, and energy efficiency requirements. Section 2.6 (of the BCA) deals with the energy efficiency of buildings
- Section 3 (Acceptable construction): provides minimum construction standards that if applied in a building, will achieve BCA compliance. Section 3.12 provides the acceptable construction methods for energy efficiency in buildings.

There are two avenues to BCA compliance: (1) to prove that a house satisfies the requirements through an Energy Rating Scheme (ERS), such as Nationwide House Energy Rating Scheme (NatHERS), or (2) to meet Deemed to Satisfy (DTS) criteria. ERS rate the energy consumption of a house based on the interaction of all the components as a system, taking into account characteristics such as orientation, floor materials, insulation, and glazing. DTS criteria provide a check list of requirements that ensure a minimum level of energy efficiency regardless of component interaction. There is a general movement to ERS with DTS criteria to be abolished in the near future.

The BCA makes no allowance for variable social issues. Issues such as population distribution, services availability, maintenance, and transport limitations are not addressed by the BCA because the impact on a building is beyond the normal operation conditions. Regionally specific documents such as Basic Specification – Aboriginal Housing should be applied in conjunction with the BCA to achieve a site specific standard for housing that respects the relevant social issues.

3.2 Complementary BCA documents

There are a number of complementary documents to the BCA that specifically deal with Aboriginal culture and housing.

3.2.1 Environmental Health Standards for Remote Communities in the Northern Territory

The *Environmental Health Standards for Remote Communities in the Northern Territory* (EHSRCNT) recognise the cultural differences and subsequent requirements of the Aboriginal built environment. It has been designed for ease of use when integrating relevant sections with the BCA. The EHSRCNT was written by Aboriginal and non-Aboriginal building, health and medical professionals in conjunction with government departments. The cultural issues associated with building design are further discussed with relation to thermal performance in Section 5.2: Cultural sensitivity design modifications.

3.2.2 National Indigenous Housing Guide

The *National Indigenous Housing Guide* (NIHG) provides methods of improving the living conditions for Aboriginal people throughout the country. In particular it incorporates the nine Healthy Living Practices for Aboriginal people to improve their environmental and living conditions. In order of priority, the Healthy Living Practices (Nganampa Health Council 1987) are:

1. Washing people
2. Washing clothes and bedding
3. Removing waste safely
4. Improving nutrition: the ability to store, prepare and cook food
5. Reducing crowding
6. Reducing negative contact between people and animals, insects and vermin
7. Reducing dust
8. Controlling the temperature of the living environment
9. Reducing trauma

Number eight of the healthy living practices, controlling the temperature of the living environment, highlights the importance of maintaining comfortable internal temperatures as a method of providing healthy living conditions.

3.2.3 Basic Specification – Aboriginal Housing

The *Basic Specification – Aboriginal Housing* document specifically relates to the Anangu Pitjantjatjara people of South Australia. It is intended to specify basic workmanship standards and material selections for the construction of various types of dwellings. It was developed to provide an appropriate building solution for the social and environmental needs of Aboriginal residents.

The sections relevant to increasing energy efficiency are:

- Section 2.2b (Protection of trees): indicates that trees that are to remain on site need to be marked on plans and their preservation is the responsibility of the builder. External shading of buildings using vegetation is an important passive solar design feature, especially in hot arid regions of Australia.

4. Modelling methodologies

There are three main forms of modelling tool available for analysis of residential housing: numerical simulation, theoretical calculation and experimental modelling.

Numerical simulation is a popular form of modelling due to the ease of rapid evaluation of housing design. The numerical simulations are generally based on theoretical calculations derived from empirical data. Numerical and theoretical modelling are cost-effective methods of analysing houses before construction. There is also a multitude of houses available in the community for experimental modelling to provide 'real' data.

A combination of numerical simulation and full-scale experimental modelling techniques have been employed to analyse the effect of changes and to test the comfort parameters. A CRM standardised design has been numerically simulated subject to a number of variations in design, and a Wongatha Wonganarra Aboriginal Corporation (WWAC) house has been data logged representing a full scale model.

4.1 Energy rating schemes

A software calculation engine to analyse residential housing was developed by the Australian Federal Government and Commonwealth Scientific and Industry Research Organisation (CSIRO) in the 1990s. The software calculates hourly temperatures and heating and cooling loads, based on the building design and regional weather data. The simulation engine is called Cheetah and is the basis for a range of state and territory ERSs but was primarily developed for use with NatHERS (Housing Industry Association 2003). From this base there have been variations incorporated that suit individual regions' requirements. For example, the Building Sustainability Index (BASIX) incorporates local planning requirements for the NSW region while the National Australian Built Environment Rating Scheme (NABERS) not only measures thermal performance but refrigerant use, occupant satisfaction, waste, etc.

The NatHERS software is now considered limited due to a number of modelling simplifications and graphical user interface constraints that restrict the applicability of NatHERS to the wide range of climate zones in Australia (Australian Government Productivity Commission 2004). Through funding from Commonwealth, State and Territory governments CSIRO has developed a new version of NatHERS called AccuRATE. There are a number of improvements to the software but the primary improvements have been made to comfort and ventilation models (Delsante 2003). As of July 2005 there was a national pilot program designed to both test and implement the software into the national built environment industry. The range of acceptable ERSs available within Australia is detailed in Table 5.

5. Cultural sensitivities

To competently design appropriate residential accommodation for Aboriginal people who have traditionally orientated lifestyles, architects must understand the nature of those lifestyles.

Memmott & Go-Sam 2003

Cultural considerations must be included in Aboriginal housing design, to ensure basic needs are catered for and housing designs satisfy their main objective of providing a suitable, healthy environment in which to live. However, behavioural and social sensitivity also have a significant impact on the way that a house should be designed. This section incorporates all three levels of sensitivity into the analysis.

5.1 Aboriginal housing

It is stated by Hughes (2005:1) that traditional Aboriginal housing was primarily used for the protection of residents from the weather, namely wind and rain. In response to a push for better Aboriginal housing, the Commonwealth, State and Territory Housing Ministers in 2001 developed the policy *Building a Better Future: Aboriginal Housing to 2010*. One of the principal outcomes of this policy was the development of better housing: 'Housing that meets agreed standards, is appropriate to the needs of Aboriginal and Torres Strait Islander people, and contributes to their health and well being' (Family and Community Services 2001:2). In response to the increasing costs of delivering houses on an individual basis the governing Aboriginal bodies in the NT developed standardised housing (Jardine-Orr 2004) known as the Central Remote Model (CRM).

The CRM was developed by the CRRC, in association with ATSIC and IHANT, in response to the increasing costs associated with the prevailing community-by-community approach to the provision of housing under IHANT's Construction Program and the lack of opportunities for Aboriginal youth in remote communities.

Jardine-Orr 2004:25

There are three main advantages of the CRM: a single project manager, standardised designs and the training employment program, all designed to improve the delivery of housing to remote communities. The CRM was first developed around the Papunya, Laramba, Urapuntja, Santa Teresa, Ntaria, Pipalyatjara and Willara settlements. The training program centred on a three-year program that would eventually develop building teams in each of the communities. The aim of the standardised designs was the 'development of a range of standard, high quality designs with standard, robust and interchangeable fixtures and fittings to make maintenance easier in future' (Jardine-Orr et al 2004:25). However, the designs are claimed to have lost cultural sensitivity during the design process (Z Hughes, pers. comm., 2004).

Lee and Morris (2005) investigated the best practice model for effective consultation focusing on the built environment, with their research seeking 'to identify where endurable best practice methods for cross-cultural and cross-disciplinary consultation have been employed'. While the BCA does not take into account the cultural sensitivities of the Aboriginal population, the EHSRCNT states that as part of the performance requirements 'designs must address cultural requirements including high and fluctuating occupancy levels' (NTG Environmental Health Task Group 2001:B40). Other requirements stated as necessary are indicated in Table 14.

It can be seen from the results of the variable window height analysis that there was little impact on the overall performance of the house based on varying the window heights. That was primarily due to the fact that the windows were designed to retain their shading characteristics as they were lowered. On the north and south sides this does not vary much as the depth of the verandas is substantial enough to provide continuous shading. As such the windows could be extended from the ground to the roof without affecting the thermal performance of the house. On the east and west sides the windows are protected by permanent eaves. While the variable height of windows does not make a difference, the visibility out of the windows will be affected for anyone not sitting on the ground. This can be corrected by extending the eaves or other variations.

5.3 Health

There is a direct link between the temperature of the environment and the health impact on individuals, particularly groups that are at risk such as children, the elderly and the sick. The effects of extreme temperatures are generally referred to as heat stress and can include heat stroke, exhaustion and cramps (New South Wales Government 2002). The human body can only function well when its temperature is maintained within a narrow temperature range. When heat gain exceeds heat loss, the body's core temperature rises and heat related disorders may occur. The consequences of heat stress can be severe. It is estimated that 35,000 people lost their lives as a consequence of the European heat wave of 2003. In France alone, 14,802 people died – more than 19 times the death toll from the SARS epidemic worldwide (Canada 2004). In Australia, heat waves kill more people than any other weather-related disaster and are projected to increase in severity and frequency with climate change (Isted 2004). It was found that in the Murdi Paaki region of NSW the primary cause of hospitalisation was dehydration during the summer period (New South Wales Government 2002). Heat stress can also induce irritation, anger and other emotions that can lead to rash actions (Leveritt 2004).

The housing for health program developed in the late 1980s is a methodology that is designed to improve the living conditions for Aboriginal Australians. The program in part consists of two surveys that have been used by FaCS to produce the NIHG as discussed in Section 3.2.2: *National Indigenous Housing Guide*. The data presented in Table 16 is from the NIHG. It demonstrates that there are a significant number of houses in which temperatures exceed 30ºC. This is beyond the comfort levels and is impinging on the health of the occupants. It can also be seen that 25% of houses did not have any form of cooling climate control.

Table 16: Housing for Health survey data showing the number of houses that exceed extreme temperatures that have direct links to health impacts

	Total number of houses surveyed	Number of houses	Percentage of houses
House temperature less than 30°C, when outside temperature was greater than 30°C	311	83	27%
Maximum summer temperature regularly greater than 40°C	787	561	71%
Cooling system (ceiling fans or air conditioning)	787	594	75%
Ducted air conditioning	594	17	3%
Air conditioning not ducted	594	101	17%
Ducted evaporative cooling	594	63	11%
Evaporative cooling not ducted	594	21	4%
Ceiling fans	594	392	66%
No cooling system	787	193	25%

Source: Family and Community Services 2005

6. Stakeholder engagement

Two meetings were held to inform, reorganise and focus the research project with relevant stakeholders. The first meeting was held on the 20th of December 2004 and the second was held on 23rd of September 2005.

6.1 Stakeholder meeting 1 – December 2004

Date: 20-12-04
Time: 1500
Location: Charles Darwin University, Engineering Conference Room
Present: Friso De Boer (CDU), Michael Duell (CDU), Gary Boyle (NTG), Zane Hughes (BIITE)
Audio conference: Martin Anda (Murdoch), Rachel Gibson (FaCS), Robert Letheby (FaCS)
Minutes: Asma Akram (CDU)

The stakeholder meeting was organised to bring together all the interested to discuss the direction of the project. The meeting used a PowerPoint presentation to direct conversation around a range of issues including each of the 5 milestones – existing knowledge, the BCA, modelling methodologies, cultural sensitivities and potential knowledge gaps – as well as the BIITE project proposals and future research of the project.

There is a new development in the BCA that it will potentially be applied to desert regions in the NT. Currently the BCA only applies to metropolitan centres and 500m off the Stuart Highway. The effect of imposing the BCA on desert regions would require all buildings to adhere to the strict BCA regulations. Current standardised designs do not adhere to these regulations. The standardised designs would have to be further redesigned and brought up to scratch. The NT government is interested in the development of this issue as currently under IHANT there are approximately 20 standardised designs built every year as well as through the National Aboriginal Housing Scheme (NAHS) program. Gary Boyle floated the figure that it could cost upwards of 20%–30% of the cost of a house to satisfy the current DTS criteria. There are still questions arising as to how long the BCA amendment process might take. The issue of what level the designs are brought up to was also raised. If it were going to cost a considerable amount for the DTS criteria to be met what effect would using the energy rating schemes have? Would a lifecycle analysis further influence the decision? It was decided that Gary and Martin Anda would discuss this issue further and inform the group of the details. There was potential for future work investigating these issues.

The stringency increases to the BCA were investigated by CDU and have been reported in this document. The summary of the main analysis is in Section3.3 Energy efficiency stringency with the corresponding submitted conference paper available in Appendix F – Embodied Energy Analysis.

It was also mentioned that through Zane Hughes' work of educating Aboriginal people with regards to the thermal performance of their homes, a basic design guide could be produced to help in the decision process.

7. Knowledge gaps

There have been a number of knowledge gaps identified by the project. These range from specific technical design issues to issues that are design considerations before and after the thermal performance consideration. The energy use from active climate control has direct impacts on the settlement's ability to provide power. However, the effects of altering housing design to incorporate cultural sensitivity or shifts will have an over-riding impact on the thermal performance of the housing. This is seen as an issue of great significance.

7.1 Settlement energy use

Thermal performance of buildings has a large influence on the settlement's ability to provide power. The settlement energy use depends on two factors: base energy consumption and peak energy demand. The settlement's power supply must be able to handle the base load of the infrastructure, community buildings and housing. The peak loads come from intensive energy consumption by one or more components. Based on simple analysis as well as anecdotal evidence it would appear that the peak loads are driven by active climate control, both heating and cooling in the settlements.

Passive design concepts can greatly reduce the energy demands of active climate control. Passive cooling and passive heating for the CRRC3K and Laverton designs have been studied in detail. It was found in the modelling analysis of the CRRC3K design and the data logging of the Laverton design that they have both been over engineered towards passive cooling for the summer period rather than passive heating for the winter period.

7.1.1 Active cooling

There are two major forms of active cooling prevalent in desert regions of Australia, evaporative and refrigerative cooling. Typically evaporative air conditioners use a substantial amount of water but are low on electricity consumption while refrigerative air conditioners use little water but substantial amounts of electricity. In Section 2.1 Active energy consumption, Glenn Marshall states that there is a growing move towards refrigerative air conditioning in settlements, both small and large.

A DKCRC project has been set up that will form a network of associated researchers and will analyse the effects of the shift to refrigerative air conditioners using the Areyonga community as a case study. Power loads, maintenance requirements and external effects on the air conditioners will be analysed and detailed. Local Environmental Health Workers will be closely involved with installation of monitoring equipment, downloading and interpretation of data and collection of usage pattern data from householders.

Table 33: Housing for Health survey data indicating the number of houses that exceed minimum comfort levels and the type of active heating devices present in the house

	Total number of houses surveyed	Number of houses	Percentage of houses
Air temperature less than or equal to 20°C at survey	787	140	18%
House temperature greater than 20°C, when outside temperature was less than 20°C	140	37	26%
	Total number of houses surveyed	**Number of houses**	**Percentage of houses**
Minimum winter temperatures regularly less than 10°C	786	256	33%
Ducted reverse cycle heating	274	4	1%
Reverse cycle heating not ducted	274	44	16%
Open fire	274	37	14%
Combustion heater (wood or solid fuel)	274	139	51%
Ducted gas heating	274	2	1%
Gas heating not ducted	274	9	3%
Plug-in electric heaters	274	39	14%
No heaters	787	513	65%

Source: Family and Community Services 2005

A project examining the impacts and the use of reverse cycle air conditioners to heat houses could reveal a potential cost saving and improved standard of living scenario for desert communities. If reverse cycle air conditioners are used for heating purposes during the winter period and consume less power than bar heaters or other forms of smaller but more energy intensive heating devices then the peak power demands of remote communities could be reduced over the year while providing a higher standard of living through improved active climate control.

7.2 Behavioural/Social/Cultural sensitivity

The purpose of a house is to be functional to the resident. This means not only providing protection from the elements but also a design that is culturally sensitive. The effects of altering housing design to incorporate cultural sensitivity or shifts will have an over-riding impact on the thermal performance of the housing. It was found in the limited workshop held by BIITE in late September that the majority of the participants would prefer to see more cultural sensitivity built into the house designs, primarily in the form of gender- or age-separation zones.

7.2.1 Cultural design

The aim of the CRM designs was the development of a range of quality designs that took into consideration general cultural sensitivities (Jardine-Orr 2004), however the designs are claimed to have lost cultural sensitivity during the design process (Z Hughes, pers. comm., 2004). The issue of the way or the extent to which a house is being used by the resident is fundamental to the purpose of the house. Memmott (2003), in his review of books on Aboriginal housing, states that there are no books produced from an architectural perspective that incorporate specific design principles. Memmott highlights studies from the 1970s that have raised the issue but still not addressed it.