THE APPLICATION OF NatHERS SOFTWARE IN NORTHERN AUSTRALIAN CLIMATES

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GLOSSARY

Chenath – is the NatHERS benchmark software engine that has been developed and maintained by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The Chenath engine is approved by the NatHERS Administrator and is the underlying software used by all three currently accredited NatHERS software tools – AccuRate, BERS Pro and FirstRate5.

Computational Fluid Dynamics (CFD) – In relation to this project, CFD refers to highly accurate computer calculation methods of predicting air flow through a building. Such methods are significantly more complex than the method used in the Chenath engine to predict the internal room air speed when windows are opened. While this may be the gold standard for calculation of wind induced air flows the computational power needed to run such simulations would lead to such long run times with conventional personal computers that the house energy rating process would be significantly slower.

Free running mode – is a software mode where no artificial cooling or heating (via air conditioning systems) is used in assessing the house design. This is a non-regulatory mode, where the software simply predicts the dwelling's internal temperatures. It can provide useful diagnostic information of the design that the star rating (regulatory mode) cannot. The results from the free running mode cannot be used for compliance purposes.

Lightweight construction – are lighter building materials, such as timber, weather-board products and steel. These materials do not gain and store heat for long periods, and are typically used to assist with providing a cooler internal temperature.

National Construction Code (NCC) – is the national building code that includes regulatory standards for energy efficiency (thermal performance) of house design. The NCC provides different assessment methods that can be used to demonstrate compliance, including the use of accredited NatHERS software tools and the more prescriptive elemental (deemed-to-satisfy (DTS)) requirements. The current energy efficiency standard for houses (class 1 buildings) under the NCC is 6-stars (out of 10), however States and Territories may vary this minimum standard.

NatHERS – is the Nationwide House Energy Rating Scheme. It accredits software tools that can be used to assess the energy efficiency (thermal performance) of house designs under the NCC. It provides a star rating of between 0 stars (lowest) to 10 stars (highest). NatHERS software tools model the predicted annual heating and cooling loads of a house's building shell (i.e. roof, walls, windows and floor) to determine an overall energy load for the design (based on megajoules per square metre, per year (MJ/m².annum)) relative to a reference file location.

Outdoor living area – is a covered outdoor design feature, such as a verandah, balcony, deck or patio, attached to a dwelling. It has the ability to access prevailing breezes or air movement (e.g. it may contain a ceiling fan) and promotes lifestyle benefits of living in tropical and hot climates.

Queensland Development Code (QDC) – is subordinate legislation under Queensland's *Building Act 1975*. It provides specific regulatory standards for building design and construction. The QDC Mandatory Part 4.1– Sustainable buildings (QDC 4.1) has varied some of the NCC energy efficiency requirements, such as insulation requirements for suspended flooring in climate zones 1 (Tropical) and 2 (Subtropical). The QDC also provides optional credits where a house includes a covered outdoor living area (up to 1 star subject to minimum specifications) and a photovoltaic (solar) energy system that has a minimum capacity of 1 kilowatt (1 star). These optional credits can be used towards the 6-star energy efficiency requirement in Queensland.

Standard house design – for the purposes of this study, are mass-market designs typically referred to as 'spec homes', 'volume builder homes' or 'project homes'. Typically these houses obtain compliance with minimum regulations using few traditional hot climate design strategies (defined below).

Thermal mass – refers to building materials which have a high density, such as concrete, blockwork, bricks, tiles and other masonry. These materials absorb and store heat, and correct use of thermal mass can delay heat flow through the building envelope, producing a warmer house at night in winter and a cooler house during the day in summer.

Traditional hot climate design, sometimes referred to as passive design– for the purposes of this study, is housing design provides comfort in hot weather by being well-orientated, using light colours, extensive shade, low thermal mass materials so that the house can cool down quickly and cross flow ventilation which provides air movement. Air movement increases heat loss from the body by evaporation making conditions inside the house comfortable at higher air temperatures than would be considered comfortable in an air-conditioned house. The 'Queenslander' house design is one example of traditional hot climate design.

REPORT FORMAT

This study is broken into the following parts:

- Main report
- Appendices
- A: Tools used in the preparation of this report
- B: How the Chenath engine models thermal comfort
- C: Wind speed and direction analysis for climates covered by this report
- D: House selection & aspects of methodology
- E: Comparison of free running temperatures

This report is a summary of a more detailed report. A copy of the full detailed report is available on request from the NatHERS Administrator.

1 KEY FINDINGS AND RECOMMENDATIONS

1.1 OVERVIEW

This study has been undertaken in response to concerns that the software accredited under the Nationwide House Energy Rating Scheme (NatHERS) does not appropriately value traditional hot climate house design in tropical and hot climates. NatHERS software is used by the housing industry as an assessment method to demonstrate compliance with the energy efficiency provisions of the NCC.

The main concern has been that NatHERS tools do not satisfactorily reward the comfort benefits of cross ventilation from opening windows. Instead, it has been suggested for some time that NatHERS software rewards a 'sealed box' design i.e. smaller windows and heavily insulated, and therefore reinforces inappropriate dwelling design in hot climates.

This is the first study of its type, and extensive software modelling was undertaken to identify and analyse if there is any systemic evidence to support these concerns. A special version of the Chenath engine was developed for this project by the CSIRO which showed the number of hours windows were opened and the calculated reduction in perceived temperature due to internal air movement when windows were open.

This study compares the performance of two standard housing designs and four traditional hot climate designs in a variety of climates from warm temperate (e.g. Toowoomba) to hot humid climates (e.g. Darwin) with NatHERS software. This modelling shows that NatHERS software makes extensive use of natural ventilation to provide comfort. Windows are opened far more frequently to provide comfort than air conditioning in all climates and for all types of house designs. NatHERS software also predict that the additional level of comfort provided by cross ventilation in traditional hot climate designs is much higher than for standard designs. The results of this study show that NatHERS software does not simulate a 'sealed box' design in these climates.

This study found that the NatHERS software does give higher star ratings when traditional hot climate design techniques are used with standard designs. Despite the significantly higher star ratings that can be obtained using traditional design strategies these techniques are not being used widely by practitioners in the housing market. This is because, at the current level of energy efficiency required in most northern climates i.e. 5 stars plus an outdoor living area, alternative design modifications can provide an equivalent improvement in the star rating at a much lower price e.g. with higher levels of insulation or smaller sized windows to reduce solar heat gain. More widespread adoption of traditional hot climate design strategies would therefore only be taken up by the market at higher rating levels.

While NatHERS software does not simulate 'sealed box' designs and can provide significant reward for traditional hot climate design elements, the anecdotal experience of skilled designers is that traditional hot climate designs still receive inappropriately low star ratings. This study supports this anecdotal experience to some degree. It found that the benefits of traditional hot climate design in bedrooms may not be adequately rewarded by NatHERS software. Traditional designs would potentially receive up to a star higher rating if the thermostat setting in bedrooms was reduced to

better reflect the limits of human comfort for sleeping in these climates. However, while this change may be desirable it would not be able to be made immediately. Proposed major changes to NatHERS scheme would require recalibration of the star bands across all 69 NatHERS climate files and would then need further evaluation to ensure that the benefits of achieving minimum compliance outweigh the cost through a Regulatory Impact Statement.

Another concern of skilled designers in northern Australian climates is that windows sizes in new housing estates are much smaller than is needed for good cross ventilation. As mentioned above, this study has found that the minimum energy performance requirements of the NCC are too low to force widespread adoption of traditional hot climate design techniques. One of the outcomes of this is that designers have two broad approaches they can take to meeting NCC requirements: a low heat gain design with smaller windows and high insulation levels or a traditional well ventilated design with large openable window areas and extensive shade. Because traditional design strategies are more expensive the low heat gain approach is more frequently used. It is important to remember that the NCC sets a minimum performance requirement, not an optimal performance requirement. Low heat gain designs will have lower demands for air-conditioning than they would have without regulation.

Most of the findings were consistent for 'tropical' and 'hot climate' (sub-tropical and hot arid) areas, but may be different in 'warm temperate' climates where heating loads required for comfort are relatively higher. Findings related to warm temperate climates are specifically identified in this study.

1.2 FINDINGS AND RECOMMENDATIONS

The report's key findings are:

1. Based on the modelling results of this study, it is considered that the NatHERS software does provide significant reward for traditional hot climate design techniques.

The rating improvements due to several typical design strategies are shown in section 4.3.

2. The NatHERS software takes into account the ability of a house design to promote air movement though the house when calculating the design's star rating. It <u>does not</u> simulate a 'sealed box' house design.

For example, in Darwin, the software opens windows for around 65 per cent of the time, which is around 4 times more than it uses air conditioning. In Brisbane, the software opens windows around 45 per cent of the time, which is 20-40 times more than it uses air conditioning (depending on the design).

3. Designs that focus on cross ventilation showed significant improvements to comfort as a result of being able to promote more air movement through windows.

In the best traditional hot climate design, the effective cooling impact of cross ventilation when windows are opened was 40-60 per cent higher than in standard housing designs.

RECOMMENDATION: While this project shows that traditional hot climate design strategies lead to significant improvements in star ratings, this does not mean that there is no scope for improvement with the NatHERS scheme. Further testing and validation of the NatHERS simulation engine (Chenath) through monitoring internal air speeds in real houses or comparison to 'Computational Fluid Dynamics' simulation may significantly improve predictions. Market research and monitoring could also be undertaken to better understand occupant's use of windows to see if it is consistent with software assumptions for homes in northern Australia.

4. Traditional hot climate designs have greater design flexibility in terms of their window size due to the benefits the simulation software gives to traditional hot climate design techniques.

Window areas at minimum NCC compliance for traditional hot climate design were 50-100 per cent higher than in standard housing designs and used windows with much greater openable areas. This is due to higher internal air speeds when windows are opened in traditional designs which provides greater comfort.

5. Traditional hot climate designs showed much better comfort in bedrooms, however, this may not be appropriately reflected by the NatHERS rating.

NatHERS software cools bedrooms at from 4.00 pm to 9.00 am. Outdoor temperatures at these times are significantly lower than in the middle of the day (e.g. on average 4°C lower in Darwin) and there is no solar radiation at night. Consequently, cooling loads in bedrooms are too small to make a significant difference to the star rating. Lower thermostat temperatures in bedrooms would increase energy loads in bedrooms and increase the impact of their performance on the star rating, and human comfort theory says we need lower temperatures when sleeping. This project examined the impact of a 3°C lower overnight thermostat setting in bedrooms. In the climates studied the change to the bedroom thermostat would improve the rating of the traditional hot climate designs by between 0.5 and 1.0 star.

RECOMMENDATION: Review whether the thermostat setting for bedrooms at night time should be altered for tropical and hot climate zones. Overnight thermostats settings should be based on further research into the appropriate adaptive comfort temperatures to be used for houses in these climate zones.

6. Based on the modelling results of this study, the current energy efficiency standards are considered too low to encourage the widespread adoption of traditional hot climate design techniques in standard housing designs.

Traditional hot climate design techniques, such as good orientation and room configuration, wider eaves and verandahs and highly openable windows, can lead to substantial star rating improvements. The availability of cheaper options used to meet the current **minimum** energy efficiency standards mean that traditional hot climate design techniques do not need to be adopted in order to comply with regulations.

RECOMMENDATION: Review the appropriateness of current minimum energy efficiency standards for dwellings in tropical and hot climates. A higher level of stringency, particularly in climates with a

high cooling load requirement, may improve the take up of traditional hot climate design strategies and consequently improve the cost effectiveness of minimum regulatory requirements.

7. Other adjustments could be made to the NatHERS Scheme to encourage better performance in hot conditions.

Subtropical, warm temperate and hot arid climates can require significant heating loads to provide warming in winter (e.g. Brisbane, Alice Springs and Toowoomba). Standard housing design often achieves compliance in these climates by implementing design approaches which have a greater effect on heating performance. Setting separate heating and cooling targets within the NatHERS scheme would see less trade-off with cooling performance in calculating the design's total energy load to achieve compliance.

Concern has also been expressed about the cooling needs of larger houses. This could be addressed by adjusting the floor area correction factor to effectively increase the efficiency standard applied to larger houses.

RECOMMENDATION: Separate heating and cooling load targets could be set for dwellings in tropical and hot climates. Action on this recommendation would need significant further research.

8. The benefits of outdoor living areas could be assessed by the software tools.

The Chenath engine could be modified to assess the comfort conditions in outdoor living areas. The Chenath engine could switch off cooling in rooms adjacent to an outdoor living area when the conditions in the outdoor living area are comfortable.

RECOMMENDATION: Further research into the use of outdoor living area and the cooling energy savings these deliver would allow the impact of this design feature to be integrated into the NatHERS energy rating. The inclusion of outdoor living areas for dwellings in tropical and hot climates are typically a common-sense strategy, however policy decisions and outcomes would be better informed with more accurate quantification.

9. This study shows that NatHERS software assessments do not show a benefit for timber floor construction in northern climates when compared to concrete slab floor construction. This is contrary to traditional hot climate design theory, but appears to be justified by building physics.

Thermal mass in floors acts differently to thermal mass in walls. Concrete slab-on-ground floors have a very different temperature underneath them compared to timber floors. The ground temperature is typically cooler than the subfloor temperature during the day in hot conditions. This therefore reduces the cooling energy load required when demands are highest. It is this temperature difference, and not so much the thermal mass of the concrete, which is responsible for the performance advantage of slab-on-ground floors over timber floors.

Note that houses with slab floors do not perform as well houses with timber floors at night in tropical climate zones. This is due to two factors. Firstly, the temperature of the ground under the slab can be higher than the temperature of the air under a timber floor. Secondly, the heat stored during the day in the concrete is released into the dwelling at night. In point 5 above it

was explained that if bedroom thermostats were lowered the rating of traditional hot climate designs would potentially improve. A lower overnight thermostat setting in bedrooms would therefore reduce the benefit of timber floors over slab floors in tropical climate zones.

2 INTRODUCTION & BACKGROUND

The purpose of this study is to identify the extent to which the Nationwide House Energy Rating Scheme (NatHERS) software appropriately reflects and rewards climate appropriate housing designs for tropical and hot climates in Australia. NatHERS software is used by the housing industry as an assessment method to demonstrate compliance with the energy efficiency provisions of the NCC.

The project arose from ongoing concerns expressed by some sections of the design and building industry over the validity and outcomes of the NatHERS software for housing design in hot northern climate zones. These concerns have also been expressed for designs in sub-tropical, hot arid and warm temperate climate zones¹. These areas are collectively referred to as 'tropical and hot climates' throughout this report. Where results relate to a specific climate zone(s), these are identified individually.

These concerns remain despite significant improvements made to 2nd generation NatHERS software in 2006 which included the modelling of air flow through the house and the impact of this air flow on physiological comfort for occupants.

This study was undertaken to investigate these concerns by assessing the results of six (6) sample house designs, including four (4) traditional hot climate designs and two (2) standard house designs. These designs were modelled and evaluated across the broad range of Australia's warmer climates from Brisbane to Darwin.

To more thoroughly assess these results, the CSIRO provided a modified version of the Chenath engine. This revised engine reported how often windows were opened and ceiling fans were used, and reported the calculated impact of air movement on occupant comfort.

Subsequent parts of this section describe:

- industry concerns with NatHERS software assessments in tropical and hot climates
- background on distinctions between NatHERS software tools and NatHERS as a Scheme
- traditional hot climate design techniques which were applied to standard house designs in this study, and
- explains what is meant by testing and validating the NatHERS software in the context of this study.

Note that this report is a summary of a far more extensive report which provides an in-depth analysis. A copy of this report is available from the NatHERS Administrator upon request.

2.1 INDUSTRY CONCERNS ABOUT SOFTWARE OUTCOMES FOR HOUSING DESIGNS IN TROPICAL AND HOT CLIMATES

1st generation NatHERS software was introduced in the early 2000's. Practitioners of traditional hot climate design raised concerns at the time that the software rating method was not suitable for hot climates. They argued that the software favoured designs for southern, cooler climates which

¹ <u>http://www.abcb.gov.au/Resources/Tools-Calculators/Climate-Zone-Map-Australia-Wide</u>

resulted in 'sealed box' housing when the most appropriate housing for hot and warm climates with high humidity provided comfort though promoting air movement. The NatHERS administrator responded to these concerns by developing 2nd generation NatHERS simulation software which specifically focussed on evaluating the benefits of cross ventilation, and the impact of humidity on occupant comfort. NatHERS software is now the only residential energy rating tool in the world to predict the air speed through the house resulting from ventilation and its impact on occupant comfort levels. While some simulation tools are available which calculate air flows using Computational Fluid Dynamics these tools require far more computational power and user expertise than is available to most house energy assessors that use NatHERS software.

Despite these improvements, some practitioners are still dissatisfied with the software results e.g. submissions to the Queensland Government's Parliamentary Inquiry into Energy Efficiency in 2010. There is an ongoing concern that southern Australia's cool climate project homes seem to be filling the new suburbs in tropical and hot climates with little incorporation of traditional hot climate design techniques. There is a perception that this must be due to the inadequacies of the NatHERS scheme and software. Furthermore, when experienced practitioners in tropical and hot climates submit their house designs for a software assessment, they find that the modifications required to comply with energy efficiency requirements seem to be at odds with design practices they have used in the past.

The major concerns from the building and design industry with the NatHERS software include:

- rating results seem to favour high thermal mass materials and smaller windows
- insufficient reward for traditional hot climate design techniques
- an over reliance on air conditioning to provide comfort instead of air movement (from cross ventilation promoted through open windows)
- the additional cost of insulating elevated floors, and
- a lack of emphasis on bedroom performance when research has shown that people in hot climates use air conditioning in bedrooms more often than living rooms².

In response to these concerns this study:

- compares the window areas for NCC compliant standard housing designs and traditional hot climate designs to examine concerns that the application of NatHERS software leads to house designs with minimal window area, despite the fact that larger window sizes would promote better cross ventilation
- compares the number of hours NatHERS software opens windows to provide comfort compared to the number of hours mechanical cooling is applied to test the 'sealed box' theory

² The National Energy Efficient House Assessment (NEEHA) project, which pre-dates NatHERS (released in 1991) showed bedroom comfort on hot nights was a key concern for Australians.

- reports the reduction in perceived temperatures that the NatHERS simulation calculates due to air movement in standard house designs compared to traditional hot climate house designs
- examines how building construction elements with thermal mass affect the NatHERS star rating, and
- examines how applying a number of traditional hot climate design techniques affects the star rating of standard housing designs.

2.2 DISTINGUISHING BETWEEN THE SOFTWARE AND NatHERS AS A SCHEME

In assessing star rating outcomes it is very important to distinguish between the software modelling tools and NatHERS as a Scheme. The software's benchmark engine (Chenath) has passed international tests (e.g. BESTEST in 2004) and has reproduced monitored temperatures in Australian houses for several decades, including in monitored houses in Darwin, Brisbane and Longreach³. However, just because the calculation engine can correctly predict the physics of buildings, it does not mean the star ratings produced from the rating reflect appropriate outcomes. The amount of energy a house needs to provide comfort is influenced by assumptions about how occupants use the house. If the scheme is producing unacceptable star ratings it may be possible to fix these star ratings by adjusting occupant behaviour setting, for example:

- if the NatHERS software does favour 'sealed box' house design, then the engine's settings may be able to be amended to open windows more often
- if bedroom performance has little impact on the house's star rating, then bedroom performance can be weighted differently, separately assessed or thermostats lowered to increase the impact of bedrooms on the house's overall rating, or
- if standard house designs are meeting minimum energy efficiency requirements with minimal modification, it may be that the scheme's star bands need further refinement.

Changing occupant settings may not be all that is required, for example, if the impact of air movement on human comfort is found to be too small then these algorithms would need to be changed in the simulation tool itself.

The occupancy settings are determined by the states and territories who make up the NatHERS Steering Committee, with advice from the NatHERS Technical Advisory Committee. These settings are embedded as part of the software's calculations. If occupant settings are found to lead to inappropriate outcomes, then these can be changed. In this case it is the 'Scheme' settings and not the 'Software' that is the issue.

³ Temperature comparisons with real houses have always shown a good correlation with on-site monitored conditions since testing began in the 1970's, including 3 houses located in Darwin and houses in Brisbane and Longreach. Recent testing in a mud brick building in Melbourne, two houses with identical plans (one with a slab floor and the other with a timber floor) in Tasmania and test cells in Newcastle all confirmed this correlation. These reports are available at <u>www.nathers.gov.au</u>.

The Chenath engine is required to make certain assumptions about how occupants use the house. For example, the following factors are prescribed for the software:

- Hours of use for cooling and heating separately in living areas and in sleeping areas
- Thermostat settings and the comfort conditions that initiate the use of heating and cooling,
- The conditions under which windows (and other openings) are opened to ventilate the house
- The use of standard internal curtains (Holland Blinds) to reduce heat gains through windows, and
- The amount of heat (and moisture) generated by human activity within the house, such as cooking, heat gains from appliances like fridges and TVs and the heat generated by people.

Refer to the NatHERS Software Accreditation Protocol for the full list of software assumptions.

If star ratings for traditional hot climate design delivered by NatHERS software are considered inappropriate, this may not reflect a flaw in the benchmark engine (Chenath), but an unintended consequence of the scheme's settings. It may be that tropical and hot designs could be more appropriately rewarded through modifying either the user behaviour settings or star band widths used to scale the ratings from 0 to 10 stars. This study therefore evaluated alternative user behaviour patterns. It also separately evaluated the performance of bedrooms to investigate whether changing thermostat settings under NatHERS as a Scheme could produce different outcomes.

Refer to the Appendix B and C for how the software works for the differing climates in 'tropical' conditions.

2.3 TESTING TRADITIONAL HOT CLIMATE DESIGN TECHNIQUES FOR STANDARD HOUSE DESIGNS

This study aimed to evaluate how NatHERS software performs for housing design in tropical and hot climates. Part of this task was to see whether traditional hot climate design techniques (passive design) can lead to improved star ratings for standard housing design, and to describe the extent of possible improvements.

A number of design changes were made to the standard house designs to test the impact of individual traditional hot climate design techniques, these being:

- 1. Room placement and opening design (including window orientation) to limit solar radiation gains and promote cross ventilation by evaluating performance at 4 orientations (north, east, south and west)
- 2. Highly openable windows using louvres for all windows
- 3. Use of light coloured roof and walls with solar absorptance of 0.30 (light cream)
- 4. Use of heavily shaded design, with 1.8 m deep verandahs
- 5. Use of lightweight floors and walls that allow the house to cool down rapidly at night
- 6. Elevated house design to better capture breezes and allow underfloor ventilation
- 7. Use of ceiling fans to provide air movement when there is little breeze (1 x 1200 mm diameter fan to each habitable room, with up to 3 in the main living room), and

8. Use of high thermal mass walls and floors – only in hot inland climates which are better suited to these climates because minimum temperatures are much lower at night in these climates, particularly in winter i.e. a large diurnal temperature range.

It can be difficult to apply some of these techniques to an existing design e.g.

- it can be hard to apply an elevated house design strategy to a 2-storey house because raising the ground floor above ground level would be impractical, and
- re-designing for good cross ventilation, which in some cases would have required a complete re-working of the house's design.

However, where possible, each of these techniques were applied to the standard house designs. The 8 design strategies listed above are referred to in this report as **traditional hot climate design** strategies.

In contrast to the traditional hot climate housing design techniques, the typical market response to dealing with energy efficiency regulations in tropical and hot climates has focussed on three main design approaches, these being:

- 1. Reducing heat flows through walls and ceilings by using high levels of insulation, rather than using shading (e.g. wider eaves and external blinds),
- 2. Providing air movement with ceiling fans, rather than focusing on cross ventilation from good window design, and
- 3. Reducing solar heat gains from windows by using smaller windows with tinted glazing (with lower solar heat gain coefficients), rather than using shading from wider eaves, external blinds, verandahs and screens.

These design strategies are referred to in this report as **standard housing design** strategies.

It should be noted that concrete block construction is now prevalent for new housing across much of northern Australia because it is cheaper than other forms of construction and also for ease of meeting NCC building requirements for high wind speeds in cyclonic areas.

2.4 TESTING SOFTWARE OUTCOMES

Testing software outcomes for the climates zones covered in this report could entail a range of measures. At its most detailed, this would involve monitoring a range of real houses and measuring their internal temperatures and air flows through each room. This data would be compared with the benchmark engine's algorithms.

Researching these issues would require significant resources and time. For the purposes of this study, testing and validating of the Chenath is taken to mean that software:

- Opens windows when appropriate to achieve comfort for occupants for a reasonable amount of time
- Shows that the additional 'internal comfort' provided by air movement when windows are open is greater in traditional hot climate designs than in standard housing designs

- Demonstrates that inclusion of traditional hot climate design techniques can potentially provide an increase in the star rating, and
- Rewards designers using tropical and hot climate design techniques with greater design flexibility for achieving a desired energy rating.

If rating software demonstrates the outcomes above, then it will go a long way to addressing industry concerns mentioned in section 2.1.

There are some houses which this study simply does not consider. Houses which are essentially no more than a set of permeable screens used to enclose spaces for living will never achieve a good NatHERS rating. Predicted cooling loads from NatHERS software will always be high in such dwellings, because they let too much hot and moist air in. But these houses were never designed to be air conditioned. They are designed to match the comfort needs of the occupants for the prevailing climate. If these houses never use cooling appliances, regardless of their star rating, then they are meeting the policy objectives of the regulations.

NatHERS software can accurately simulate the temperatures in such dwellings. In fact, it is relatively easy to predict the temperature: it should be the same as outdoor air less a few degrees for air movement. Temperatures in these dwellings will often exceed the traditional comfort zone⁴, but the experience of tropical design experts suggests that this discomfort does not lead to air conditioning. In this sense NatHERS software cannot be applied to lightly enclosed dwellings because the software assumes that if comfort conditions are exceeded, then heat needs to be extracted from the house. In the NCC an 'Alternate' method already exists to assess this form of tropical design (sometimes called 'free-running' houses) to achieve compliance with the energy efficiency provisions and the use of the NatHERS software is not required, nor does the software need to change to accommodate this form of housing. A different pathway to achieve compliance already exists for these types of designs.

2.5 HOW THE CHENATH ENGINE CONTROLS COOLING

To properly understand the results obtained from NatHERS simulation it is important to appreciate the way in which the Chenath engine accounts for cooling use and how this is related to human comfort. The following information is a summary of a more extensive description of how the Chenath engine models for thermal comfort as presented in Appendix B.

The Chenath engine was developed in response to industry concerns regarding the inability of 1st generation NatHERS software to model the impact of air movement on thermal comfort. It is therefore important that the way Chenath models thermal comfort is explained.

Houses are heated and cooled to maintain occupant comfort. It is therefore important that the software tools used to assess energy use can calculate all the major influences on comfort. Table 1 describes the various factors that influence comfort and how Chenath models these factors:

⁴ Soebarto, V. et al, The performance of award winning houses, PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture, Geneva, Switzerland, 6-8 September 2006

Table 1 Effect of various factors on thermal comfort and how Chenath models these factors

Factor	Effect on Comfort	Modelled in Chenath
Air temperature	Our bodies lose heat by contact with the air	The Chenath engine predicts internal air temperature
Temperature of surrounding objects, or radiant temperature	If objects are warmer than us they make us feel warmer	Chenath engine combines air temperature and radiant temperature into the 'environmental temperature' to better reflect human perception of comfort
Amount of moisture in the air or humidity	We lose heat by sweating. At higher humidity levels the amount of heat we can lose through the evaporation of sweat is reduced. However, a large range of humidity levels provides adequate heat loss and discomfort is generally only felt at high humidity when combined with higher air temperatures.	Chenath engine will turn on cooling if the air becomes too humid, typically at a humidity over 50% if the air temperature is at 30 degrees. If there is air movement provided by opening windows or ceiling fans Chenath will not cool to reduce humidity until the humidity exceeds 90%.
Air movement	With higher air speeds the body's ability to lose heat by evaporation of sweat is increased	Chenath engine calculates the wind speed through each room of the house if windows are opened. It then calculates the additional comfort this air movement provides as a reduction in perceived temperature. Effects of ceiling fans are also allowed for.
Activity and clothing	As the body is more active it generates heat and the amount of clothes affect the body's ability to lose heat by providing insulation e.g. with appropriate clothing it can feel hot while skiing at subzero temperatures.	Thermostat temperatures are set with household activity levels and clothing in mind. Bedroom heating temperatures overnight are set to lower levels because bedding provides insulation and the lower metabolic rate during sleep means a lower temperature is comfortable.
Personal preference	Each body's ability to lose or gain heat from the environment is different, and each person has a preference for the rate of heat loss to the environment they consider comfortable. The ranges of conditions which will keep most people comfortable have been evaluated in many studies.	Those temperatures which satisfy the greatest proportion of people have been used as thermostat settings. These take into account Australian and international research into adaptation to climate. Note that cooling is switched on when it is 2.5 degrees above the thermostat setting i.e. when it becomes uncomfortable.
Acclimatisation	Simply put, if you live in a hot place you will feel comfortable at higher temperatures than a person who lives in a cold place. This is thought to be in part because people wear lighter clothes in warmer climates and in part human adaptation.	Cooling thermostat temperatures are set according to the comfort conditions relevant to the climate. This is based on Australian studies of acclimatisation.

3 METHODOLOGY

This study evaluated house performance in six locations in four of the NCC climate zones. These climates were selected to be representative of the broad range of climate zones where traditional hot climate design strategies may be beneficial. They are:

- Tropical (NCC climate zone 1) using Darwin (Northern Territory) and Townsville (Queensland) as reference locations,
- (ii) Sub-Tropical (NCC climate zone 2) using Brisbane (Queensland) as a reference location,
- (iii) Hot Arid (NCC climate zone 3) using Alice Springs (Northern Territory) and Emerald (Queensland) as reference locations, and
- (iv) Warm Temperate (NCC climate zone 5) using Toowoomba (Queensland) as a reference location.

Six (6) detached house designs (class 1 buildings) including four (4) traditional hot climate designs and two (2) standard house designs were used for this project.

To more thoroughly assess these results the CSIRO provided a modified version of the Chenath engine with the AccuRate front-end. This enabled extensive analysis of how often windows were opened, ceiling fans were used and the comfort impact of promoting internal air movement.

This section describes the climate zones that were evaluated, the selection of standard and traditional hot climate design sample houses. It also presents the modelling used to evaluate the ability of NatHERS software to assess a range of house designs in tropical and hot climates.

3.1 CLIMATE ZONES EVALUATED

This study investigated how the Chenath engine modelled ventilation and traditional hot climate design strategies across a wide variety of climates in six (6) locations. The locations were selected to cover a broad range of climates where traditional hot climate designs may be beneficial ranging from Darwin (with 413 megajoules/m²/annum at 5 stars) to Brisbane (at 55 megajoules/m²/annum at 5 stars).

Table 2 Climate zones and relative energy efficiency compliance levels for houses Table 2 provides an overview of the climate zones modelled in this project.

Climate Zone	Location	NCC Climate Zone	NatHERS reference file	Postcode	Compliance level used for sample houses (class 1 buildings)
Tropical	Darwin (NT)	1	1. Darwin	800	5 stars*
(CZ 1)	Townsville (QLD)	1	5. Townsville	4810	5 stars (6 – 1 for outdoor living area)**
Sub-Tropical (CZ 2)	Brisbane (QLD)	2	10. Brisbane	4000	5 stars (6 – 1 for outdoor living area)**
Warm Temperate (CZ 5)	Toowoomba (QLD)	5	50. Oakey	4350	5 stars (6 – 1 for outdoor living area)**
Hot Arid	Alice Springs (NT)	3	6. Alice Springs	870	5 stars*
(CZ 3)	Emerald (QLD)	3	19. Charleville	4720	5 stars (6 – 1 for outdoor living area)**

Table 2 Climate zones and relative energy efficiency compliance levels for houses

* Northern Territory Government, Building Advisory Services, Building note 68 issued 5/5/2010 requires a minimum of 5 stars for class 1 dwellings in Northern Territory (by using the provisions of the BCA 2009). Refer www.nt.gov.au, and use the search term 'Building notes'.

^{**} Queensland Development Code, MP 4.1 Sustainable Buildings (QDC 4.1) (using version 1.12 dated 15 January 2013) for energy efficient houses requires 6-stars. QDC 4.1 offers optional credits where the design includes a complaint outdoor living area (1 star) and/or photovoltaic (solar) energy system (1 star). Where these are included, a minimum building shell rating of at least 4.5 stars in climate zones 1 (tropical), 2 (subtropical) and 5 (warm temperate) is required , thereby allowing optional credits of up to 1.5 stars. For climate zone 3 (hot arid), the minimum building shell rating is 5-stars. Where only an outdoor living area is included, a rating of 5 stars is allowed where it is directly connected to an internal living area, has a floor area of at least 12 m² with a minimum dimension of 2.5 m in all directions, has two or more sides open or capable of being readily opened, has an insulated roof of at least R-1.5 (0.5 star credit) and a ceiling fan with a blade rotation of at least 900 mm (0.5 star credit). All designs modelled in Queensland climates for this study had a compliant outdoor living area. Refer <u>www.hpw.qld.gov.au</u>.

3.2 STANDARD HOUSE DESIGN SELECTION

Two houses were selected to be typical of standard housing designs in tropical and hot climates. These houses were selected to:

- Be typical of new project home designs prevalent in the climate zones evaluated. Both standard house designs are built in reasonable volume by the builders who provided the designs. Similar house designs can be seen in use by many of the volume builders who work in these climates.
- Provide two typical house sizes. A smaller single-storey 4 bedroom house ('Luna 4' around 150 m² excl. garage) and a larger 2-storey 4 bedroom house ('IV27' around 200 m² excl. garage). The use of the 2-storey house design is particularly important to evaluate how upper floor bedrooms perform (as they are usually much less comfortable than bedrooms on ground floors in tropical and hot climates) and 2-storey houses are being constructed in increasing numbers.
- Be as different to the traditional hot climate designs as possible. The houses that use slab floors are considered not to pay particular focus on cross ventilation, provide minimal fixed shading and use standard sliding or awning windows with clear glazing (untreated).

Floor plans and detailed descriptions of these two standard house designs are contained in Appendix D.

3.3 TRADITIONAL HOT CLIMATE DESIGN HOUSE SELECTION

To demonstrate the benefits of how traditional hot climate design techniques may benefit standard house designs, it is important to show the potential benefits of their inclusion, emphasising design features particular to its climate zone. For instance, these techniques may provide benefit in houses which promote cross ventilation with more focus on good window design and room placement. To investigate this, traditional hot climate designs were selected for each of the four climate zones.

During the course of this study a fourth house design was also added as an example of hybrid design ('Redlynch House'), which uses louvre windows, has an outdoor living area and has reasonable cross ventilation.

The four traditional hot climate designs are described below:

• Tropical climate – 'updated C19 style design':

- The C19 is a public housing design which has been praised by exponents of good tropical design. This house has often been held up as a model of good tropical design; each room has windows on two sides to facilitate cross ventilation and the design uses deep eaves, verandahs and screens to provide shade and the house is elevated to expose it to higher wind speeds. For this study, the design was updated to reflect trends in contemporary housing e.g. inclusion of an ensuite bathroom to the main bedroom, skillion roof with clerestory windows and a second living area downstairs. This design was assessed in Darwin and Townsville.
- Subtropical/Warm Temperate 'Innovation House':

- Innovation House was constructed on the Gold Coast as a display home which was promoted by the developer and Gold Coast City Council to support the benefits of subtropical design and technological innovation. This design was used in Brisbane (climate zone 2) and Toowoomba (climate zone 5) to test the benefits of traditional hot climate design strategies. The differences in how the design operates in the two climate zones is covered in the Appendix.
- Hot Arid 'Shayne's House':
 - Shayne's House was designed by Build-Up Designs in the Northern Territory and was used by the Northern Territory Government as an example of good hot arid housing for a research project in 2006. It has a classic passive solar plan form and uses deep verandahs to provide shade. This design was assessed in Alice Springs and Emerald.
- Hybrid design 'Redlynch House':
 - The 'Redlynch House' is typical of the emerging hybrid designs found in tropical regions, which seek to be both energy efficient and provide good free running performance as well. While this design is not strictly a traditional hot climate design, it is closer to this style than most standard house designs, except that it uses high thermal mass materials in both floor and walls. It provides an interesting contrast to both the traditional and standard housing. This design was evaluated in Darwin and Townsville.

Floor plans and detailed descriptions of these house designs are shown in Appendix A.

3.4 COMPARISON OF HOUSE DESIGN FEATURES

The most striking differences between the designs which use traditional hot climate design techniques and the standard house designs are window and wall areas. The standard house designs had, on average, around half the window area per square metre of floor area of the traditional hot climate designs. Total wall areas (including windows) of the traditional houses were on average 50 – 100 per cent higher than the standard designs. Traditional designs used at least a 2700 mm (instead of 2400 mm) wall height and used courtyards and/or clerestory windows to provide better cross ventilation which increased the wall area relative to the standard designs.

There were two other significant differences. The traditional designs concentrated windows on the north and south side of the house while the standard designs had an even distribution of windows on all sides. Eave depth in the traditional designs was also much greater than in the standard designs.

Appendix D provides a detailed comparison of the features of all 6 designs.

3.5 EVALUATING HOW NATHERS MODELS VENTILATION IN HOT CLIMATES

The following sections outline the modelling techniques that were undertaken to assess the performance of NatHERS software for the sample house designs.

3.5.1 Evaluation of the extent of air movement from window openings and ceiling fans

A modified version of the Chenath benchmark engine was developed by the CSIRO for this study. This engine had a number of special features not found in the regulatory version:

- It counted the number of hours per year that windows were opened in each room in the house,
- It counted the number of hours per year that ceiling fans were used in each zone of the house to provide air movement, and
- It calculated the extent of any additional comfort provided by air movement i.e. the effective reduction in temperature that the air movement provides.

These data sets were output to the software's hourly temperature file that were used for detailed analysis.

By evaluating the use of window openings and ceiling fans it was possible to measure the number of hours the software models the design as a 'sealed box'. By comparing the traditional hot climate designs and the standard house designs, it was possible to also test whether the comfort provided by air movement is greater in houses which have been specifically designed to enhance cross ventilation in tropical and hot climates.

3.5.2 Evaluation of bedroom performance

Keeping cool at night in bedrooms has been shown to be a key concern of Australians e.g. the National Evaluation of Energy Efficient Houses project (Ballinger et al, 1991). A variety of research projects have found that bedrooms use air conditioning for a greater number of hours than living rooms despite the fact that night time temperatures are cooler than daytime. This makes intuitive sense, as occupants may tolerate some discomfort from hot conditions during the day, but have less tolerance for discomfort during the night as this may prevent them from sleeping. The energy loads for bedrooms and living rooms were therefore assessed separately.

The current user behaviour assumptions in the NatHERS settings assume that cooling in bedrooms will only be applied between 4.00 pm and 9.00 am. Temperatures are typically cooler at these times of day e.g. in Darwin the average temperature over the year is 4 degrees higher between 9.00 am to 4.00 pm than between 4.00 pm and 9.00 am, and there is no solar heat gain at night. Consequently, the predicted cooling loads in bedrooms are much lower than in living rooms and their performance therefore has less impact on the star rating than living areas.

Research by Isaacs in 2006 showed that bedroom cooling loads only represented between 18 to 23 per cent of the total predicted cooling loads for house designs in Darwin. Furthermore, this research showed that free running temperatures in houses with concrete block walls remained at higher temperatures overnight, even when they had higher star ratings than houses with lightweight

construction. This suggests that the better performance of bedrooms in traditional hot climate designed houses may not be appropriately reflected by the NatHERS settings in warmer climate zone.

NatHERS also assumes that the thermostat setting for cooling in bedrooms is the same as in living rooms. However, human beings require lower temperatures to sleep, in part because heat loss is limited by the mattress which insulates the body. If bedroom thermostat temperatures were lowered during sleeping hours, this would be consistent with the theory of human thermal comfort. It would also increase the cooling loads in bedrooms so that their overnight performance had a greater impact on the star rating. This project also therefore examined the impact of lower overnight thermostat in bedrooms to see whether this would potentially improve the star rating of traditional hot climate house designs relative to standard house designs.

While lowering the thermostat setting in bedrooms may assist to address practitioner's concerns, making this change is not as simple as just releasing an updated version of NatHERS software. For instance, the higher loads in bedrooms would mean that the current energy loads for the star rating are no longer valid. New star bands would also have to be developed for NatHERS in these climates, and this is resource intensive. Further, because NatHERS is a method for demonstrating compliance with the NCC the impact of the potential change to the settings would be subject to a cost-benefit assessment.

If traditional hot climate design receives a higher star rating, standard house designs may receive a lower star rating. Concrete block construction is now prevalent for new homes across much of northern Australia. If the star rating of houses with concrete block walls in warm to hot climates was lowered by the thermostat setting change (due to higher overnight temperatures), then these houses would be expected to face additional compliance costs.

This issue may be able to be addressed through careful readjustment of the star bands so that traditional designs could improve their star rating and standard designs maintain their star rating.

3.5.3 Comparison of designs using free running mode

The 'free running' mode describes the operation of the software without any artificial cooling or heating. In this mode, the software predicts the dwelling's internal temperatures. However, it is important to note that this mode cannot be used to demonstrate compliance with regulatory standards. Notwithstanding, an assessment of the design using the free running mode can provide useful diagnostic information that the star rating alone cannot e.g. it can identify a particular problem room. Showing free running performance comparisons between traditional and standard house designs can also assist practitioners who are familiar with houses designed to achieve good free running performance to see whether the software result is consistent with their experience.

The free running temperatures in the traditional hot climate designs and standard housing designs were compared to see whether the temperature reduction due to air movement calculated by NatHERS software (i.e. improved comfort due to air movement) was better in the traditional design than in standard designs, particularly in bedrooms.

3.6 MODELLING OF STANDARD HOUSE DESIGNS

The following sections describe additional modification and modelling of the standard house designs that informed this study. Each house in the study was modified to achieve minimum compliance in the six locations selected. Sections 3.6.1 to 3.6.3 describe how the standard house designs were modified to achieve compliance. Section 3.6.4 explains the traditional hot climate design techniques that were applied to these houses to test the impact of these design strategies on the star rating.

3.6.1 Regulatory compliance – Options assessed

Each standard house design was modified to the minimum compliance at 4 orientations (north, south, east and west) and in each of the 6 climates. The techniques used to achieve minimum regulatory compliance focused on the standard housing design techniques, rather than traditional hot climate design techniques e.g.:

- 1. Using higher levels of insulation which reduce heat flows through walls and ceilings rather than using light coloured roof and walls, and shading,
- 2. Using ceiling fans to provide air movement rather than relying on cross ventilation from openable windows⁵, and
- 3. Using smaller windows/tinted windows for lower potential solar heat gain which reduce solar heat gain from window areas rather than using shading from deep eaves, verandahs and window screens.

3.6.2 Use of outdoor living areas

In NCC climate zones 1 (tropical) and 2 (subtropical), a 5 star rating is allowed for the building fabric if an outdoor living area is included with the house's design (in Queensland, this is an option under QDC 4.1). To obtain a 1 star benefit towards the regulatory standard, the covered outdoor living area must have:

- fully covered by an impervious roof that is insulated with a total R-Value of at least R1.5 (for downward heat flow),
- a permanently installed ceiling fan with a minimum 900mm diameter,
- directly adjoins a general-purpose living area (e.g. lounge, kitchen),
- is at least 12.0 m² floor area, with a minimum dimension of 2.5 m in all directions,
- has openings on at least 2 sides with one of these sides being permanently open.

⁵ Results from the ABS householder survey (2008) found that in Queensland 66.1% of houses had ceiling fans (73.2% outside the mild Brisbane climate) and 86.3% of houses in the Northern Territory had ceiling fans. Ceiling fans can significantly improve the NatHERS star rating. If most houses were installing ceiling fans prior to the introduction of energy efficiency regulations, the extra cost is minimal. It is therefore reasonable to assume that houses in these areas will continue to install ceiling fans.

As all the sample houses included a compliant outdoor living area, the 5-star level for the building fabric permitted under the NCC was used in assessing the designs.

3.6.3 Construction materials

The two standard house designs were assessed with the most common construction materials used in each climate zone, as shown in Table 3. These houses used an attic roof space rather than a skillion or cathedral ceiling type with minimal space for insulation, ratings were completed with single clear glazing or were tinted depending on the ability of the designs to get to 6 stars for comparison purposes, see appendices for more details.

Table 3 Construction materials used for standard housing designs ('Luna 4' and 'IV27') at minimum regulatory compliance level

Location (climate zone)	Floor	Wall	Internal Wall	Roof material	Glazing*
Townsville (CZ 1)	Slab	Concrete Block	Plasterboard	metal	Single clear / tinted
Darwin (CZ 1)	Slab	Concrete Block	Concrete Block	metal	Single clear / tinted
Brisbane (CZ 2)	Slab	Brick Veneer	Plasterboard	tile	Single clear / tinted
Emerald (CZ 3)	Slab	Concrete Block	Plasterboard	metal	Single clear / tinted
Alice Springs (CZ 3)	Slab	Concrete Block	Concrete Block	metal	Single clear / tinted
Toowoomba (CZ 5)	Slab	Brick Veneer	Plasterboard	metal	Single clear / tinted

* a mix of single clear and tinted glazing was used, depending on the climate, house design and orientation of the window.

3.6.4 Impacts of traditional hot climate design techniques on NatHERS assessments

As described in Section 2.3, 8 design changes based on traditional hot climate design techniques were applied to the standard houses designs used in this study.

Each of these techniques were applied to the worst rated orientation with a basic insulation and glazing specification i.e. lower than minimum regulatory compliance, as shown in Table 4.

Design Strategy	Luna 4	IV27	
Openable windows	All windows changed to louvres	All windows changed to louvres	
Room placement for cross ventilation	Not possible without re-design	Not possible without re-design	
Light colours	Roof and walls used 0.3 Solar Absorptance	Roof and walls used 0.3 Solar Absorptance	
Deep verandahs	1.8 m deep verandah added on all sides (except garage)	1.8 m deep verandah added on all sides (except garage) on ground floor, and 900mm eaves used on upper floor	
Lightweight materials	Timber framed fibro-composite sheet clad walls and timber floor over an enclosed sub-floor space	Timber framed fibro-composite sheet clad walls and timber floor over an enclosed sub-floor space	
Elevated design	House increased in floor height by 2.4 m, garage moved under house	Not practical	
Ceiling fans	Remove fans from base rating and compare to 1 x 1200mm to all except living area: 3 x 1200mm*	Remove fans from base and compare to 1 x 1200mm to all except living area: 3 x 1200mm*	
High thermal mass elements in inland climates (including Toowoomba)	Change external walls to insulated reverse Block Veneer, with internal block walls and slab floors having ceramic tiles	Change external walls to insulated reverse Block Veneer, with internal block walls and slab floors having ceramic tiles	

Table 4 Application of traditional hot climate design techniques to standard house designs

* In Tropical climates 1400mm diameter fans may be more common, but because the impact on the rating of ceiling fans is smaller in sub-tropical and hot arid climates the improvement to the star rating obtained through using 1400mm compared to 1200 mm fans is very small. Ceiling fans of 1200mm diameter were used throughout to provide consistency of results.

4 RESULTS: IMPACTS OF SOFTWARE MODELLING FOR REGULATORY COMPLIANCE

Software modelling was undertaken for each house design and location to determine the specifications required to achieve regulatory compliance, as well as the impacts of applying traditional hot climate design techniques to the standard housing designs. Based on assessment of these designs, the results are summarised as follows (NB. Full details of the modelling results are contained in a separate report which is available from the NatHERS Administrator on request):

4.1 SOFTWARE ASSESSMENT COMPLIANCE COSTS COMPARED TO ELEMENTAL (DTS) PROVISIONS

In the climate zones reviewed, the specifications for insulation and glazing for designs which achieved minimum compliance using software, were generally lower than those required for the elemental (DTS) provisions of the NCC. The NatHERS software provides a more flexible approach to meeting the NCC requirements. The software assessment method can therefore be a cheaper form of energy efficiency compliance than the prescriptive elemental (DTS) provisions in the NCC.

4.2 TRADITIONAL HOT CLIMATE DESIGNS CAN USE SIGNIFICANTLY HIGHER WINDOW AREAS THAN STANDARD HOUSES

Traditional hot climate designs for tropical, hot and warm temperate climates can use significantly higher window areas than standard houses at minimum compliance. This is mainly due to the better air movement they provide which reduces the need for artificial cooling. The window areas in the traditional hot climate designs were 50 to 100 per cent larger (relative to floor area) than those used in standard housing designs at minimum compliance. This reflects the improved comfort delivered from promoting air flow through the house in the traditional designs.

Even though windows in the traditional hot climate designs were well-shaded from direct solar radiation, diffuse radiation reflected from the sky, ground and surrounding objects can still lead to significant heat loads e.g. in the design with the largest window areas the total heat gain from diffuse solar radiation can still be as much as 4 kilowatts. Consequently, other measures to reduce heat gains were required such as higher insulation levels in walls and roof space, tinted or low-e glazing and external blinds to the few windows which were not well-shaded.

A key concern of some practitioners about NatHERS software is that its use in the NCC is resulting in inappropriately designed houses for the tropics with small windows which are inadequate for ventilation. This concern does not seem to be justified by the findings of this report which shows traditional tropical house designs can use much higher window areas while still complying with the energy efficiency standard. Indeed, the standard housing designs would not be able to achieve compliance at with the large window areas used in traditional designs without substantial and costly increases in specifications for other elements e.g. very high insulation levels, very low solar heat gain glass (which may unacceptably reduce daylighting levels) and extensive use of external blinds.

Traditional hot climate design houses were able to use significantly larger window areas in tropical climates than in sub-tropical, hot arid or warm temperate climates. This is because locations like Brisbane, Toowoomba and Alice Springs also have a significant demand for heating due to their

cooler winters. Even though the amount of heating needed may be less than cooling in these climates, window areas are more restricted because large areas of shaded glazing will significantly increase the amount of heating required in winter.

4.3 TRADITIONAL HOT CLIMATE DESIGN TECHNIQUES CAN SIGNIFICANTLY IMPROVE THE STAR RATING OF STANDARD HOUSE DESIGN

This study found that using light coloured roof and walls, and verandahs increased the NatHERS rating by between 1 and 2 stars in tropical climates when using the software. Additionally, verandahs are recognised to promote lifestyle benefits of living in tropical and hot climates. The inclusion of louvres and tinted glazing were found to increase the NatHERS rating by between a 0.5 to 1.5 star depending on the climate. Table 5 shows the impact of hot climate design strategies on the rating of the standard house designs:

Improvement	t Change to star rating by climate						
	Darwin	Townsville	Brisbane	Toowoomba	Alice Springs	Emerald	
Louvre windows	0.9	1.1	0.4	0.1	0.3	0.1	
Tinted glass	0.3	0.7	0.3	0.0	0.1	0.1	
Light colours	1.8	2.1	0.2	0.2	0.6	0.2	
Deep verandah	1.1	1.5	0.2	0.0	0.3	0.2	
Lightweight construction	-0.7	-0.5	-1.9	-1.2	2.7*	2.1*	
Elevated construction	-0.8	-0.4	-1.9	-2.1	NA	NA	
Ceiling fans	1.0	1.2	0.5	0.3	0.1	0.2	

Table 5 Impact of using hot climate design techniques on star ratings in all climates

* in these climates, high mass materials are more appropriate so the impact of high mass insulated external walls was evaluated.

Deep verandahs and louvre windows can be more expensive than other design strategies that can be used to reduce heat gains through windows e.g. smaller areas of tinted glazing. It is likely that the comparatively higher cost of these traditional hot climate design techniques has prevented their widespread adoption with standard house designs, rather than any lack of value given to them by the software.

The improvement to the star rating delivered by traditional design techniques is not as great in subtropical, hot arid and warm temperate climate zones. This is because these climates also require some heating. While the traditional design strategies significantly reduced cooling loads in all these climates they can also lead to an increase in heating loads so the overall increase to the star rating is not as great.

While several traditional design strategies did show a significant star rating improvement when applied to standard house designs there were some exceptions. These exceptions are outlined in section 4.4.

4.4 LIGHTWEIGHT CONSTRUCTION MATERIALS

The use of lightweight construction materials is typically associated with good tropical and subtropical design because they allow houses to cool down more quickly in summer (compared to high thermal mass materials which retain and re-radiate heat). This study found that houses with a concrete slab floor and internal block walls (typical of standard housing designs in northern Australia), received higher star ratings than the same house using lightweight materials.

The reason why the slab floor designs performed better than timber floor was not due to their thermal mass, but the difference in the temperature underneath the slab and the timber floor. Figure 1 shows the sub-floor (called 'Light Ground Zone') and slab temperatures on a hot day in Darwin for the Henley Luna. The ground temperature under the slab is much lower than the sub-floor temperature. Because heat flow is proportional to temperature difference, the slab floor has less heat gain and therefore lower cooling loads.



Figure 1 Temperatures under floors: Slab vs timber subfloor (Light Ground Zone) in Darwin (Henley Luna)

The standard house designs modelled with internal concrete block walls also showed lower cooling loads. This is because the thermal mass in the walls absorb heat gains during the middle of the day when cooling loads are highest. Houses with concrete block walls will have higher cooling loads in the evening and at night as the thermal mass is released heat back into the house. However, overall

cooling loads are lower at this time due to the lower external temperatures and absence of solar heat gain at night. The net result is that houses with high mass internal walls have lower overall cooling loads even though they are hotter overnight.

This issue is examined further in the sections about alternative user behaviour profiles (Section 6.2) and free running performance (Section 5.5).

4.5 FURTHER COST EFFECTIVE ENERGY SAVINGS COULD BE OBTAINED IN DARWIN AND TOWNSVILLE

The standard house designs in Townsville and Darwin did not have to insulate the ceilings of all rooms to achieve compliance at the 5 star level when the roof was insulated with reflective foil. This is despite the fact that ceiling insulation is recognised as one of the most cost-effective strategies to improve the energy efficiency of a house in all Australian climates. In addition, the standard house designs in Darwin and Townsville (climate zone 1) did not require the use of treated glazing (e.g. low-e glass or tinting) on any windows to achieve compliance. Further, some specifications for insulation levels, were found to be well below those required for compliance if the elemental (DTS) provisions were used.. While it is expected that the use of NatHERS software allows lower cost compliance as it is more flexible than the DTS clauses, the extent of departure from the elemental provisions is substantial. This may indicate that the star bands for tropical and hot climates should be reviewed to ensure that the level of energy efficiency they set at minimum regulatory compliance is more appropriate for the prevailing climatic conditions.

4.6 CEILING FANS CAN PROVIDE A SUBSTANTIAL BENEFIT TO THE STAR RATING, PARTICULARLY IN TROPICAL AND HOT CLIMATES

Ceiling fans are a common design feature for houses in tropical and hot climates. This study found that the inclusion of ceiling fans can provide around a 1 star benefit to designs in Darwin and Townsville (climate zone 1). A benefit of between 0.2 to 0.5 stars was observed in the other climates. This benefit is already recognised by the market as there was extensive use of ceiling fans in Queensland and the NT prior to the introduction of minimum house energy efficiency regulation (ABS, 2008).

With such a large benefit in tropical climates, however, it may be that this has contributed to the low specifications required to achieve minimum compliance in these climates, particularly if the star bands were set using houses which did not use ceiling fans as extensively as is found in the field in these climates.

4.7 APPLICATION OF TRADITIONAL HOT CLIMATE DESIGN TECHNIQUES IN AREAS OUTSIDE OF TROPICAL CLIMATES

Traditional hot climate design techniques often have large areas of well-shaded glass. However, in both subtropical (climate zone 2) and hot arid (climate zone 3) climates this approach has the potential to significantly increase heating loads, and thereby substantially off-set the cooling load benefits of these designs.

Design strategies for housing in these climate zones need to be fine-tuned to ensure that they can balance cooling for summer and heating for winter. The design strategies could include:

- Adjustable shading that can be retracted in cool conditions to allow the house to more easily warm up in cooler weather using solar heat gains.
- Maximise openable area of windows to improve ventilation, but minimise overall wall surface area. In climates that have relatively more significant heating requirement, such as warm temperate areas, a compact design can minimise the amount of heat loss during cooler conditions. Using highly openable windows with a more compact design will still allow good cross ventilation in summer.
- Higher levels of insulation to significantly reduce heat losses in winter.
- Some thermal mass (e.g. slab floor or some internal walls) to maintain occupant comfort into the evening during cooler conditions.

5 RESULTS: VENTILATION AND SOFTWARE CALCULATIONS

5.1 HOW THE SOFTWARE USES AIR MOVEMENT TO AVOID AIR CONDITIONING

In all climates, air movement is useful for cooling occupants, however it is recognised that it may be less effective during periods of high humidity. The use of air conditioning is not invoked in the software until the internal temperature of the house is 2.5°C above the cooling thermostat. The thermostat is set to the 'thermal neutrality' temperature applicable to unconditioned dwellings in summer for the location. Thermal neutrality is the temperature at which one feels neither too hot nor too cold. Cooling may also be turned on if humidity levels are too high for human comfort even if the air temperature is comfortable.

The software tests whether opening windows or using ceiling fans to promote air movement will provide occupant comfort before it uses air conditioning. It calculates space temperatures with windows open and/or ceiling fans switched on, and will only invoke artificial cooling if this fails to provide comfort. In so doing it assumes that occupants have a good understanding of when to open and close windows. The software will close windows if the internal air speed exceeds 1.5 m/second (e.g. papers start blowing about the house). At this speed air movement will make temperatures feel 5.1°C cooler. Even at lower speeds, there are still significant cooling effects. For instance, an internal air speed of 0.5 m/second equates to a 3°C drop in temperature where relative humidity is 50 per cent.

In addition to opening windows to promote air movement, the software will calculate whether occupant comfort could be achieved by opening windows to let in cooler outside air. This is particularly significant in Emerald and Alice Springs (climate zone 3) and Toowoomba (climate zone 5) where the daily range of temperatures is much larger than tropical and subtropical regions. The software closes windows if the temperature would fall below the heating thermostat to avoid using artificial heating.

The techniques that the Chenath engine uses for air movement and artificial cooling by air conditioning are fully explained in Appendix B and C.

5.2 ANALYSING HOW THE SOFTWARE WORKS IN TROPICAL AND HOT CLIMATES

The following sections report how often artificial cooling is used by the NatHERS software simulation engine relative to how often windows are opened to achieve comfort.

The special version of the Chenath simulation engine used in this project provided additional software outputs which allowed the standard house designs to be compared with traditional hot climate designs to see whether the traditional well ventilated designs:

- Open their windows to achieve comfort more often, and
- Show a greater comfort benefit from this ventilation.

The analysis in section 5.3 and 5.4 show how often windows are opened in each climate to provide comfort. This will naturally vary between climates. For instance, cooler climates have less need for

ventilation because their milder temperatures mean that cooling is not required as often as warmer climates.

To provide some context to assist with understanding whether the proportion of hours where windows are opened is large or small for the climate zones in this study, Table 6 shows the proportion of time that external temperatures fall between the heating thermostat and the cooling thermostat. It is reasonable to assume that, if the software is modelling ventilation behaviour correctly, it would open windows for most of these hours.

	Cliı Zo	mate ne 1	Climate Zone 2	Climate Zone 3		Climate Zone 5
Parameter	Darwin	Townsville	Brisbane	Alice Springs	Emerald (Charleville)	Toowoomba (Oakey)
Hours between thermostats for the year	3225	4818	3274	2284	2730	2137
% time between thermostats for the year	36.8%	55.0%	37.4%	26.1%	31.2%	24.4%
Cooling thermostat (°C)	26.5°C	26.5 °C	25.5 °C	26.5 °C	27.0 °C	25.0°C
Heating thermostat (°C)	20.0°C	20.0°C	20.0 °C	20.0 °C	20.0 °C	20.0°C

Table 6 Proportion of hours annually that external air temperatures fall between heating andcooling thermostats in the software for selected locations

Note: Hours in each location are taken directly from the weather data files. As Darwin is hotter than the other locations it has more hours in the year where it is uncomfortable. Brisbane and Townsville are cooler than Darwin so the number of hours per year that outside is comfortable is less.

5.3 USE OF WINDOWS AND AIR CONDITIONING IN SOFTWARE CALCULATIONS

Concerns have been expressed that the software simulates for a 'sealed box' house design. In doing so, it promotes the use of air conditioning to maintain comfort rather than to open windows for air movement.

Table 7 shows how often windows are opened compared to how often air conditioning is used by the software in each location for standard and traditional house designs. The designs of all houses were adjusted to achieve a 5 star rating, and the results for the standard houses are an average of the 4 orientations assessed.

Location	House Designs						
	Standa	rd 1-story	Standard 2-story		Traditional		
	% windows open*	% hours air conditioning used*	% hours windows open*	% hours air conditioning used*	%hours windows open*	% hours air conditioning used*	
Darwin (CZ 1)	61.1	18.3	62.2	13.5	65.5	15.9	
Townsville (CZ 1)	65.5	8.2	68.3	5.4	66.5	4.6	
Brisbane (CZ 2)	39.6	2.2	40.3	1.8	44.5	1.0	
Alice Springs (CZ 3)	32.3	3.0	30.9	2.7	49.0	6.7	
Emerald (CZ 3)	32.6	1.9	31.8	1.8	49.7	4.3	
Toowoomba (CZ 5)	30.1	2.3	29.5	2.3	29.9	1.4	

Table 7 Proportion of hours with windows open and air conditioning used in selected locations*

* Average for two main living and two main bedrooms in each house

As Table 7 shows, the Chenath engine opens windows for far more hours to achieve comfort than it invokes air conditioning. In Darwin windows are opened around two thirds of the time to provide comfort for each of the designs. This was 3 to 5 times more than air conditioning was used. In Brisbane windows were calculated as being open over forty times more than air conditioning in the traditionally designed house.

These results provide evidence that the software does not simulate a 'sealed box'.

In each case the traditional house opens windows to achieve comfort for more hours than the standard house. In some cases, however, the traditional house uses air conditioning for a greater number of hours than the standard house. This seemed counter-intuitive at first, however, examination of the hourly temperature and energy load files shows that this higher number of hours of use stems from situations where the windows have been opened to provide air movement and the wind speed suddenly drops off or changes direction. In this case the internal air temperature without air movement is well above comfort and therefore cooling is switched on. Because the windows are opened more often in these houses this will occur more frequently in the software assessment.

5.4 IMPACT OF VENTILATION ON OCCUPANT COMFORT

While windows may be opened more extensively than air conditioning is used, if the calculated benefit of opening windows is small, the inappropriate outcomes may still be delivered. Houses which are well-designed for cross ventilation in tropical and hot climates should show significantly greater comfort when windows are open compared to standard designs.

Table 8 shows the predicted reduction in temperatures brought about by air movement as calculated by the software. It shows that houses well-designed for cross ventilation achieved a greater reduction in apparent temperatures due to the promotion of air movement.

Table 8 Predicted reduction in temperatures for selected locations achieved through air movement

Location	House Designs						
	Standar	d 1-story	Standard 2-story		Traditional		
	Average reduction in apparent temperature	Peak reduction in apparent temperature	Average reduction in apparent temperature	Peak reduction in apparent temperature	Average reduction in apparent temperature	Peak reduction in apparent temperature	
	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	
Darwin (CZ 1)	0.7	3.8	0.7	3.8	1.2	4.8	
Townsville (CZ 1)	0.9	3.5	0.8	3.3	1.5	4.5	
Brisbane (CZ 2)	0.9	3.6	0.8	3.4	1.0	4.1	
Alice Springs (CZ 3)	0.9	3.8	0.7	2.8	1.0	4.2	
Emerald (CZ 3)	0.8	2.8	0.6	3.0	1.0	4.4	
Toowoomba (CZ 5)	0.9	3.6	0.8	3.4	1.0	4.1	

The results shown in Table 8 shows that houses designed with good cross ventilation are better rewarded by the software. The traditionally designed houses show greater reductions in temperatures due to air movement than found in the standard houses, particularly in the tropical climates of Darwin and Townsville.

It was beyond the scope of this study to say whether the reduction in apparent temperature brought about by air movement calculated by the Chenath engine is appropriate. Further research would be required to determine whether the reductions in temperature calculated by Chenath are an accurate representation of wind induced air movement through a house, or whether the benefits from good window design and cross ventilation are appropriately reflected in the software. It is nevertheless encouraging to see that the reduction in apparent temperature brought about by air movement is larger in traditional hot climate designs than in standard house design.

5.5 TESTING FOR FREE RUNNING PERFORMANCE

When rating dwellings for the NCC, NatHERS software applies heating and cooling to a specified occupancy pattern. In non-rating mode NatHERS tools can turn off heating and cooling to allow the user to examine the temperatures inside the dwelling. This is known as "free running" mode. Specialist designers of traditional hot climate houses design these houses to maximise comfort without air conditioning. Examining the free running temperature predictions of the Chenath engine helps to understand whether it shows that specialist traditional hot climate designs do provide more comfort and the extent of this improvement.

If inappropriate outcomes are obtained in hot climates by using NatHERS software in rating mode for NCC compliance, a comparison of free running temperatures in traditional and standard designs will help to show whether the issue is with the calculation engine itself. If the predictions of free running comfort generally accord with the experience of specialist designers, then the engine is clearly capable of properly modelling such buildings, and the inappropriate outcomes are more likely to be the result of inappropriate settings.

The full version of this report describes the differences in the free running performance (i.e. internal temperatures without any air-conditioning) of a standard house and a traditional hot climate design house in detail for every climate zone. The example below is typical of this analysis. This free running performance shows how NatHERS tools model the impact of cross ventilation in the two styles of housing.

Some explanation is needed to interpret the graphs in Figures 2 and 3:

- The vertical axis has two different scales. The scale on the left represents temperature in degrees (°C), and the scale on the right represents air speed (m/sec) or the window/ceiling fan state.
- The red line is the critical line to observe as it represents living room air speed affected temperature, and is therefore the best indicator of occupant comfort levels.
- The blue dashed line represents the internal air temperature only. Comparing the red and blue dotted lines shows the effect as calculated by NatHERS for that house.
- The green dots show the use of windows and ceiling fans. A dot at a value of 1 on the right axis indicates windows are open; 2 shows that ceiling fans are being used; and 3 shows that windows are open and ceiling fans are being used.
- The orange line is the on-site wind speed adjusted from the weather station's free stream wind speed to represent the wind speed at the height of the house in a suburban location.



Figure 2 Temperatures in the main living rooms of Henley Luna house 3 day hot period in Darwin



Figure 3 Temperatures in the main living rooms of 'C19 Style' house 3 day hot period in Darwin

The graphs above show that windows are opened extensively to provide comfort in both houses. However, in the C19 style house⁶ the impact of opening windows on comfort is much greater. When wind speeds are highest and the wind direction allows, the C19 style house feels 4-5°C cooler, while the Luna only feels 1°C cooler. Furthermore, the C19 style house is doing what good traditional hot climate designs should do: ensuring that the air temperature inside the house never exceeds the outdoor temperature so that it can take advantage of any drop in outside temperature. The Luna, by contrast, takes several hours to cool down to outdoor temperature overnight. This is not only because it does not ventilate as well, but also it has a slab floor which limits the amount the house can cool down overnight as the concrete has retained heat from the day.

Free running temperature results confirm that the Chenath simulation engine demonstrates that the traditional design is significantly more comfortable without air conditioning than a standard design. These results demonstrate that there are no major flaws in the working of the Chenath engine in the way it models traditional hot climate design in warmer northern climates.

5.6 CONCLUSION

Appropriately reflecting the benefits of cross ventilation was the major focus of improvements made to the Chenath engine when 2nd generation NatHERS tools were introduced in 2006. However, until now, no quantitative assessment has been available to explain how these improvements affect software modelling results and how often windows are opened to take advantage of any available cooling breezes. The additional outputs provided in the modified version of the Chenath engine have allowed the operation of these ventilation routines to be quantified.

This report finds that NatHERS software does not simulate a sealed box and does calculate a greater comfort benefit for houses with well-designed cross ventilation. This report provides evidence of these benefits for those who have expressed concern about the way in which NatHERS software assesses natural ventilation in warm to hot climates. In part these concerns have also arisen from the fact that the NatHERS software allows for air conditioning to be available to be used for 17 hours. However, NatHERS software only air-conditions the house once all options for air movement have been exhausted and again only when the house is uncomfortable (2.5°C above the cooling thermostat). This translates to an average use of air-conditioning for just 0.5 to 4 hours per day depending on the climate.

The major findings of this study have shown that:

 NatHERS software opens windows on average between one to two-thirds of the time in summer to maintain occupant comfort. Tropical regions show the most extensive use of cross ventilation, followed by hot arid and subtropical and warm temperate climates. By contrast, the number of hours the software turns on air conditioning is, depending on the climate zone, between 75 to 95 per cent less than the number of hours windows are opened, and

⁶ Refer to Appendix x for details - C19 Style House Tony Isaacs adjusted design to suit traditional hot climate design

• The extent of comfort improvement achieved by designs that focussed on cross ventilation was between 20 to 60 per cent more than in standard housing designs. This reflects the traditional hot climate houses as being better designed for cross ventilation.

6 RESULTS: IMPACT OF ALTERNATIVE SOFTWARE ASSUMPTIONS FOR BEDROOMS

In addition to examining the house designs using existing NatHERS software with standard assumptions, assessments were also undertaken with alternative thermostat settings for bedrooms.

6.1 RATIONALE FOR SELECTION OF A LOWER THERMOSTAT SETTING FOR BEDROOMS

A 3°C lower setting was used between the hours of 10 pm and 7 am in bedrooms in summer when occupants are sleeping. As explained in section 3.5.2, a lower thermostat setting in bedrooms would be supported by the theory of human comfort. The 3°C reduction applied in this study was simply used to demonstrate the extent of change to cooling loads for a given change in the thermostat setting. It is not intended to prescribe an appropriate bedroom thermostat setting for these climate zones. Should the impact of the lower bedroom thermostat setting be seen as encouraging good design practice in northern climates then the appropriate reduction in the thermostat in each climate zone should be assessed by further detailed research. For example, this could be based on reference to adaptive comfort principles for climate, such as Peeters, deDear et al, 2009.

The 3°C lower thermostat setting for bedrooms in summer was selected because:

- Calculation of comfort using the Predicted Mean Vote technique⁷ showed that this reduction was in an appropriate range,
- The reported average thermostat temperatures used by a range of occupants in Darwin were 3°C lower than used by NatHERS software, and
- Overnight temperatures in bedrooms are assumed to be 3°C lower in winter in NatHERS software in all climate zones.

Traditional hot climate designs all have lower bedroom cooling loads than the standard house designs. A lower thermostat setting in bedrooms will increase their cooling loads required in bedrooms in summer and amplify the differences between the two types of houses. Lowering the thermostat in bedrooms could therefore improve the rating of traditional designs and ensure that night time comfort in bedrooms – critical to sleep -has a greater impact on the star rating.

The upgrades required to house specifications in bedrooms to achieve NCC compliance were found to be much lower than expected e.g. where tinted glazing was required it was sufficient to only apply this to living rooms. In several cases bedroom ceilings were not required to be insulated if reflective foil was used under the roof. This is a very much lower specification than required by the Deemed–to-Satisfy elemental provisions.

A lower thermostat setting for bedrooms would also assist to increase minimum fabric requirements in the hottest climates when using NatHERS software to assess compliance with the NCC. It would also better align it with the elemental provisions, as well as recognised good practice.

⁷ The Predicted Mean Vote allows the calculation of an average occupant comfort score between 1 (much too hot) and 7 (much too cool) based on environmental conditions and factors, such as clothing and metabolic rate. Note this concept is now considered inferior to adaptive comfort.

6.2 IMPACT ON HOUSE COOLING LOADS WITH LOWER THERMOSTAT SETTING FOR BEDROOMS

Lowering the thermostat setting in bedrooms would increase the cooling load requirements of all houses, in all climates. In the standard house designs used for this study the increase in cooling loads in bedrooms were found to be significantly greater than for those in the traditional hot climate house designs. Figure 4 shows the impact on total cooling loads in Darwin for the traditional house (using the updated C19 style design) compared to a standard house design (Henley Luna) at different orientations.



Figure 4 Impact of lower bedroom cooling thermostat on cooling energy load

While cooling loads for the traditional design (updated C19 style design) were increased by around 60 MJ/m².annum, the standard house design increased by between 105-125 MJ/m².annumresulting in a difference of between 45-65 MJ/m².annum. To give an indication of the significance of changing the cooling load requirement for bedrooms in summer in the Darwin climate file, the step from 4 to 5 stars is 67 MJ/m².annum and the step from 5 to 6 stars is 64 MJ/m².annum. The potential improvement in the star rating of traditional hot climate designs could therefore be around one star in Darwin.

Loads in standard design were also increased by more than traditional designs in other climates, though the impact was not as pronounced as it was in Darwin. For example in Brisbane, where the cooling load is much lower, the relative difference equated to around half a star.

7 DISCUSSION

Several leading tropical design practitioners have expressed concern that the use of NatHERS software does not deliver suitable design outcomes i.e. lower ratings for traditional style houses than expected and a low penetration of these design techniques in the volume market. This study has shown that any inappropriate outcomes are not because NatHERS software simulates a sealed box. It has also proposed potential improvements to NatHERS software which could deliver more appropriate design outcomes. However, it is still unlikely, even if these improvements were incorporated into the software, that the volume market would significantly change the way they design their houses at the current compliance level.

It is important to remember that the use of NatHERS software provides more flexible compliance option than the NCC's elemental provisions to achieve compliance. In this context, the software performs well and has widespread use across the building industry. The following sections discuss this issue.

7.1 EXISTING ENERGY EFFICIENCY STANDARDS AND TRADITIONAL HOT CLIMATE DESIGN TECHNIQUES

This study assessed housing designs with a minimum 5 star standard for the energy efficiency of the building envelope. This is because a one star credit is typically given for an outdoor living area in Queensland and Northern Territory. At 5 stars, standard low cost house design techniques such as higher insulation levels, smaller tinted windows and ceiling fans can be used in these climates to reduce cooling loads to meet minimum requirements. If a higher star rating requirement was set, use of standard design techniques would reach an upper limit, and traditional hot climate design features would become the only options left to achieve compliance. The substantial rating advantages associated with deeper shading (e.g. eaves and verandahs), external blinds, and better room layout and higher window openability would see designers with little alternative but to use these techniques to achieve higher ratings.

If the rating standard was increased and more traditional design techniques were employed the cost of compliance would most probably be increased. Traditional hot climate design techniques like deep verandahs or louvre windows are more expensive than higher insulation levels, ceiling fans or reducing window area. Such a change would be subjected to a cost benefit analysis. In subtropical climates like Brisbane, the low cooling loads may mean that this approach would not have a sufficient benefit to cost ratio to justify an increase in the star rating level.

The findings of this study suggest that the predominance of southern climate style designs in northern Australia is not a result of an error in the NatHERS software – windows are used extensively by NatHERS tools to provide comfort. It appears to be a result of the relatively low level at which the minimum rating is set and the subsequent design and materials needed for compliance. At this level, it is simply cheaper to use standard house design techniques. While this may be a less than desirable outcome it should be remembered that the energy efficiency standard sets a minimum compliance level. It is not an optimum performance prescription i.e. the NatHERS scale goes up to 10 stars and the performance required by the NCC is only 6 stars or 5 stars with an outdoor living area.

Generally, the market will use least-cost methods to achieve compliance. In this respect, greater consumer awareness of traditional hot climate design techniques can lead to greater demand for their inclusion.

7.2 WELL-DESIGNED FREE RUNNING HOUSES AND AIR CONDITIONING

If houses designed for good free running performance can avoid the use of air conditioning altogether, then they are meeting the objectives of the NCC. However, the question of whether good free running performance can avoid the use of air conditioning *altogether* is not straightforward. For example, Darwin is a very hot and humid climate, it has an annual maximum mean temperature of 32.0°C and minimum of 23.2°C and high humidity levels. In the traditional hot climate design house (updated C19) the temperature - allowing for the comfort impact of internal air movement - is over 27°C for almost half (46 per cent) of hours in the year and over 30°C for around one-sixth (16 per cent) of hours in the year⁸. While this represents very good free running performance, many people, particularly the elderly, young or infirm would not find these temperatures comfortable.

The fact that the climate in Darwin is uncomfortable for much of the year can be seen by the rates of air conditioner ownership. In 2008 the ABS householder survey reported (ABS, 2008) that 93.6 per cent of households in the Northern Territory owned air conditioners and many owned multiple air conditioners. Greater use of traditional hot climate design would likely see air conditioning ownership reduce. Given the severity of some northern climates, however, it is not likely that better design would eliminate air-conditioning entirely. There is also a wide variety of comfort expectations among home owners so what would eliminate air-conditioning for one person may not for another. Given the very high prevalence of air conditioners in hot climates, designing houses to minimise cooling loads is a reasonable outcome for a minimum standard.

Even in Brisbane where the milder climate (annual maximum mean temperature of 26.5°C and minimum of 16.2°C) makes it more likely that cooling loads could be eliminated with traditional hot climate design techniques, this is not straightforward. Brisbane has a small but significant heating load in winter and design features such as extensive shade or lightweight construction materials typically used in traditional hot climate design would increase the heating load.

⁸ This is consistent with measurements taken in a number of free running houses as shown in Soebarto, 2000

8 CONCLUSION

This study was initiated to examine concerns that NatHERS software did not properly model house designs for performance in hot climates. The analysis presented above identifies how NatHERS software models cooling loads in hot climates. It also explains how traditional hot climate design techniques are modelled, particularly the impact of natural ventilation and air movement. After extensive modelling and analysis of a range of sample house designs, there appears to be no evidence to support concerns that NatHERS software models a 'sealed box' design in these climates.

This analysis has demonstrated that the Chenath engine:

- opens windows far more than it uses air conditioning to provide comfort,
- models significantly greater comfort benefit due to air movement for houses which are specifically designed to promote cross ventilation than in standard house designs,
- can potentially provide a substantial star rating benefit with the use of traditional hot climate design techniques, such as light coloured roof and walls, louvre windows, ceiling fans and deep verandahs.

However, this does not mean that the NatHERS software is operating perfectly. This study also found:

- the benefits of traditional hot climate design in bedrooms in tropical climates may not be appropriately reflected by the software, and
- significant cost effective energy savings are being lost for some designs at the 5 star level in tropical climates. For example, this study found that at a 5 star minimum requirement level, bedroom ceilings in standard houses can be left uninsulated (if there is reflective foil in the roof) and there is very little need for treated glazing (like low-e glass or window tinting) to meet existing energy efficiency requirements.

The one traditional hot climate design strategy which did not improve star ratings was the use of light weight construction. Concrete slab on ground floors provide a higher rating than timber floors over subfloor spaces. This study has thrown new light on this phenomenon. Houses with slab floors do not receive better star ratings because of the thermal mass of the slab. Instead, the lower temperatures under slab floors compared to timber floors mean that the heat gain from the floor is much lower during the day. Because the cooling loads required are highest during the day, houses with slab floors received a better star rating.

Houses with timber floors were shown to cool down more quickly at night than houses with slab floors. However, because cooling loads are lower at night this advantage is not reflected in the star rating. The theory of human comfort shows that lower temperatures are needed to sleep at night. There have also been several studies showing that the use of air conditioning at night tropical regions is greater than in living rooms. Therefore using a lower overnight thermostat setting for bedrooms in the NatHERS software may be appropriate. Further research on the most appropriate thermostat settings to use in hot climates is recommended.

A lower overnight bedroom thermostat was shown to potentially increase the rating of traditional hot climate designs by 0.5 to 1 stars. It may also re-dress any imbalance in the performance between

slab and timber floors in tropical climates. However, such a change will require significant work, including re-calculation of the NatHERS star bands and evaluating the potential impact on current stringency levels. While it may be desirable to improve the star rating of traditional designs, if this also means that the rating of standard designs is reduced, then the cost of compliance could be increased. Achieving the right balance between encouraging traditional designs without increasing costs will require significant time and effort.

This study has shown that the NatHERS software benchmark engine, Chenath, makes extensive use of ventilation to provide comfort in warm to hot climates in Australia. It has dispelled the myth that NatHERS software ignores the use of cross ventilation as a means of providing comfort in hot climates. Analysis of the simulation outputs shows that traditional designs do achieve higher levels of comfort in the absence of artificial cooling than standard house designs. On this evidence, the engine appears to be modelling houses in these climates appropriately.

However, this study has also identified that the outcomes of the NatHERS scheme depend not only on the quality of the simulation engine, but also on the underlying user behaviour assumptions. The Scheme's assumptions and settings could be modified to more appropriately reflect these climates and, in the process, improve support for the uptake of traditional hot climate design techniques.

Further improvements to the simulation engine could also be made by testing and verifying the software's predictions of internal air speeds, through monitoring air speeds in real houses and/or comparing predicted air flows to results obtained from Computational Fluid Dynamics simulation. Additional research to improve the understanding of how Australians use their houses in hot weather e.g. thermostat settings, operation of doors and windows and use of adjustable external shade, would assist with testing the underlying assumptions of the scheme, thereby ensuring that they are appropriate and deliver better outcomes.

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