ABCB

NCC Volume Two Energy Efficiency

PERFORMANCE SOLUTION FOR P2.6.1

CLIMATE ZONE 1

Case Study

NON-MANDATORY DOCUMENT

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Case Study 4

NCC Volume Two Energy Efficiency Performance Solution for P2.6.1 - climate zone 1

General Information

Compliance Solution	Performance Solution
	NCC 2016, Volume Two – Performance Requirement P2.6.1
Climate zone	NCC climate zone 1
Building Classification	Class 1a detached dwelling
Construction Type	Timber frame with cement sheet cladding
Design Type	Hybrid Design (free-running and conditioned)

Preface

The Inter-Government Agreement (IGA) that governs the ABCB places a strong emphasis on reducing reliance on regulation, including consideration of non-regulatory alternatives such as non-mandatory guidelines, handbooks, case studies and protocols.

This Case Study is one of a series produced by the ABCB. The series of Case Studies has been developed in response to comments and concerns expressed by government, industry and the community that relate to the built environment. The aim of a Case Study is to provide construction industry participants with non-mandatory advice and guidance on specific topics.

This subject has been identified as an issue that requires consistent uniform guidance. It has been developed to explain the application of the NCC to northern Australia climate responsive designs. This Case Study addresses the issues in generic terms, and is not a document that sets out a specific NCC solution. It is expected that this Case Study will be used to assist practitioners develop solutions relevant to specific situations in accordance with the generic principles and criteria contained herein.

Contents

Introduction

This Case Study describes the development of a Performance Solution which could be used to meet the NCC Volume Two energy efficiency Performance Requirement, P2.6.1.

It is targeted at practitioners with a basic understanding of the NCC energy efficiency provisions and an overall understanding of the NCC performance-based code. For new users, introductory information on the NCC energy efficiency provisions, including their overarching intent, is provided in the Further Reading section and Appendices A to C.

Purpose and Limitations

This Case Study aims to demonstrate the practical application of the NCC when proposing to design a dwelling that takes account of passive design principles with the intention of minimising the need for artificial cooling of the dwelling. Further information on passive design principles for Northern Australian climates is covered in Appendix A.

The Case Study design is responsive to the tropical climate in which the dwelling is to be located. It allows all living/dining and sleeping areas the ability to be air-conditioned if the occupant chooses, while also limiting the amount of energy used. This is known as a conditioned design for the purposes of this Case Study and is further explained in Appendix B of this document.

The guidance in this Case Study is limited to the NCC Performance Requirement P2.6.1 and the development of a Deemed-to-Satisfy (DtS) Solution using the associated DtS Provisions. This does not demonstrate full NCC compliance, as all NCC Performance Requirements need to be met. Further information on compliance with the NCC can be found in Appendix C.

In order to achieve the desired outcome in practice, the dwelling and its occupants would need to consider factors not covered by the NCC. These include, but are not limited to:

- the appropriate use of trees, shrubs or alternative shading devices to shade the house and outdoor entertainment areas,
- the appropriate selection and use of air-conditioning systems by occupants to reduce overall energy consumption,
- the adaptive responses used by occupants to reduce overall energy consumption, and
- on-going scheduled building and system maintenance.

The Case Study does not consider other design issues such as construction in cyclone, bushfire or flood prone areas. Diagrams included in the Case Study are only intended to explain issues directly relating to Performance Requirement P2.6.1.

Users of the Case Study are encouraged to check for any relevant State and Territory NCC variations and additions that may apply in their jurisdiction. Furthermore, users should be aware of any applicable legalisation within their jurisdiction that may have a bearing on the content of this Case Study.

The Design

A client has approached a design firm to come up with a passive solar, climate responsive house for a plot of land in the top end of the Northern Territory. The house is to include 3 bedrooms and open plan living spaces, and is approximately 113 square meters (excluding deck space).

The living spaces are to have a strong indoor/outdoor relationship, allowing the occupants to open up their living room to an outdoor entertainment area. The building is to be constructed out of lightweight timber construction and be clad in decorative cement sheet cladding. The roof is to be a sloping skillion roof with large overhangs for protection from the sun and rain.

The client would like to minimise the amount of energy used for cooling, for both financial and sustainability reasons, by using passive cooling principles where applicable. This will likely reduce the number of days they will need to rely on air-conditioning for cooling.

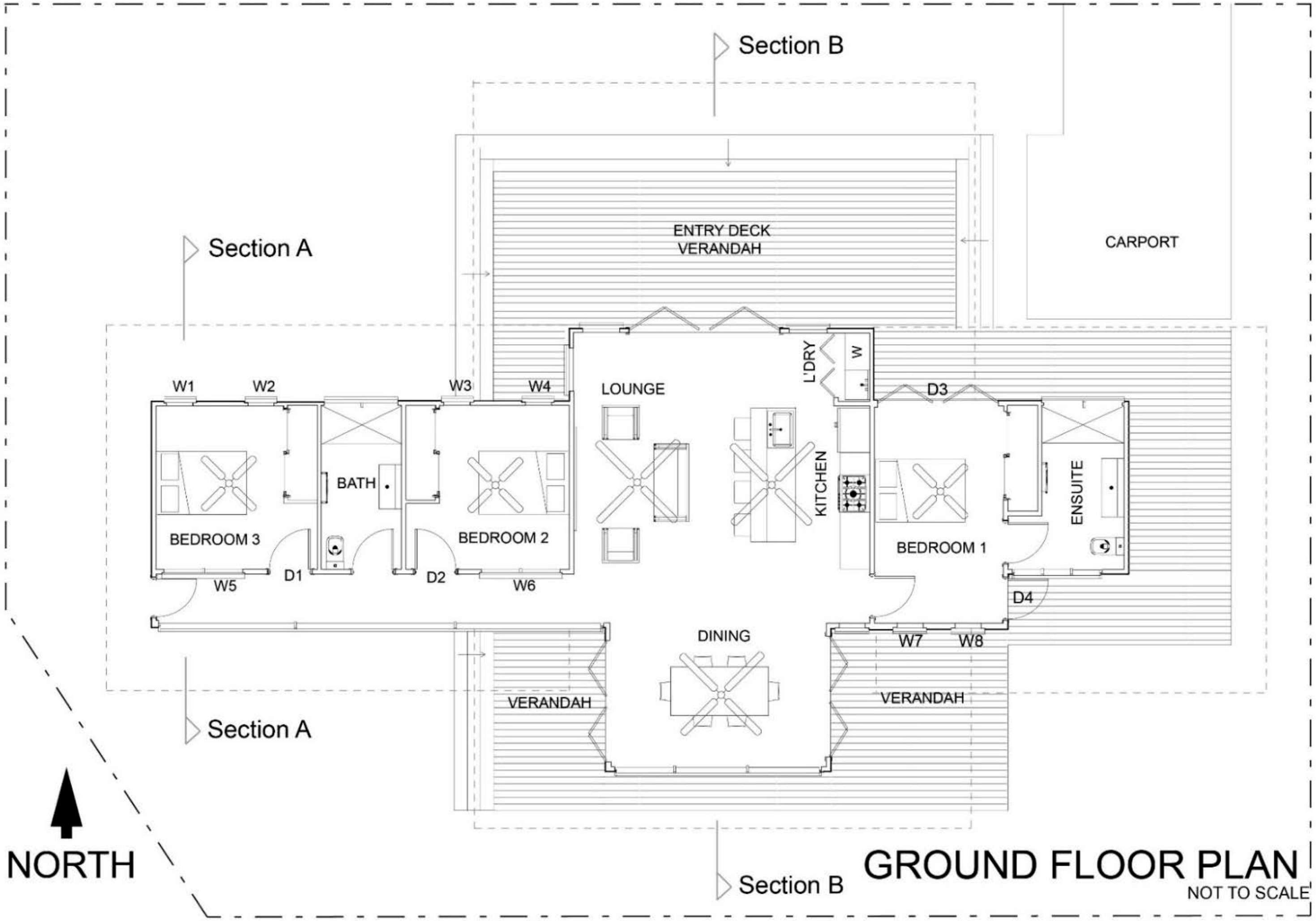
This means their preference is to be able to open the house up to prevailing breezes in order to cool the house under various weather conditions for all of the year, but still have the option of using air-conditioning in bedrooms when needed.

All areas of the house, excluding the bedrooms, are designed so that they do not need any artificial heating or cooling. The bedrooms have been designed so that if needed, they can accommodate an air-conditioning system for cooling, but can also be naturally cooled.

The house is situated in NCC climate zone 1, which has a hot, humid climate only requiring cooling, not heating. In designing the building, the designer/architect intends to use several key passive design principles including orientation, site considerations, shading, ventilation and air movement, and appropriate material selection.

The proposed building design is shown in plan view in Figure 1, and cross-section views in Figure 2 and Figure 3.

Figure 1 Ground floor plan



Note: Not all windows and doors have been identified, only those where a conditioned space is proposed.

Figure 2 Section A view

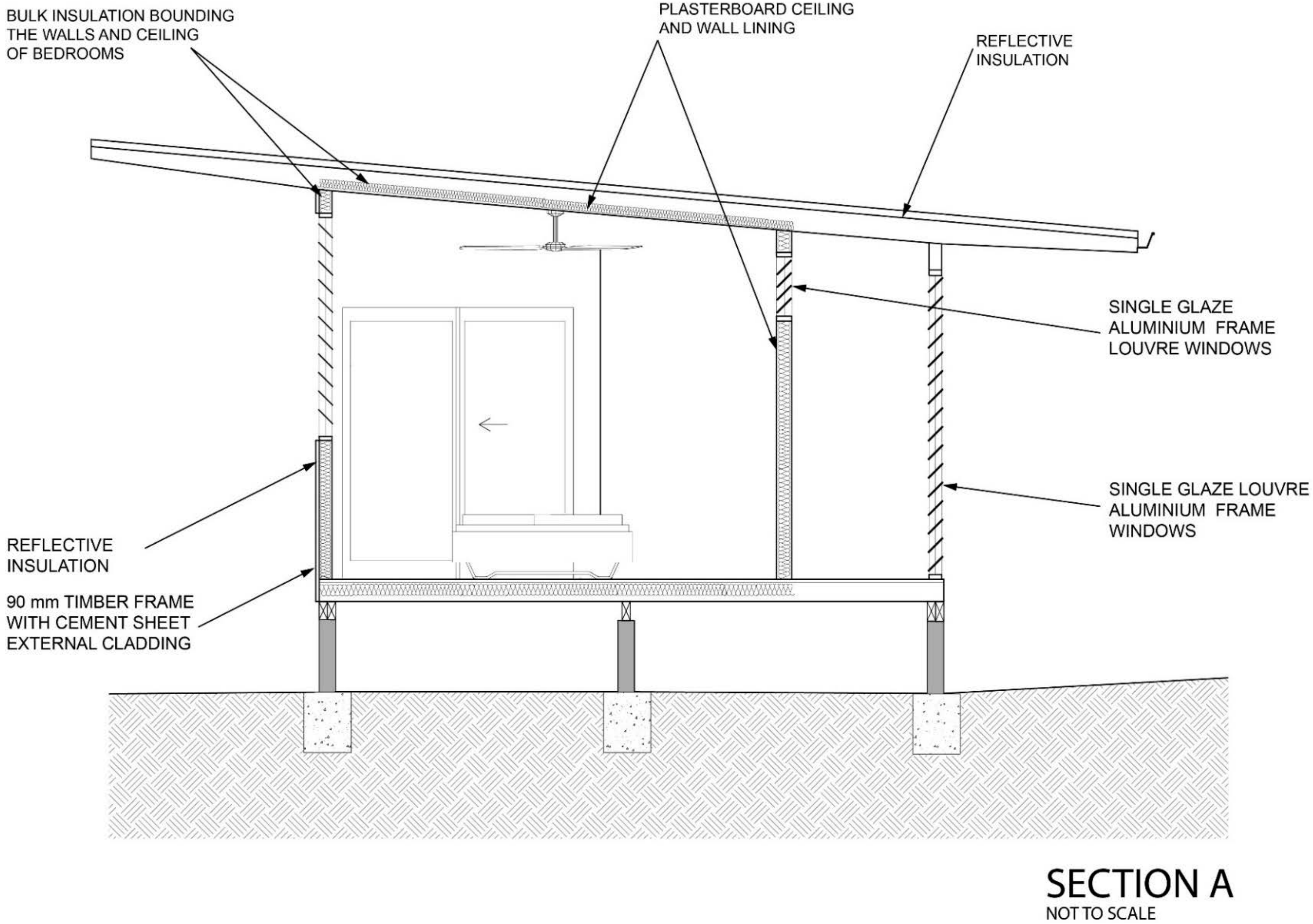
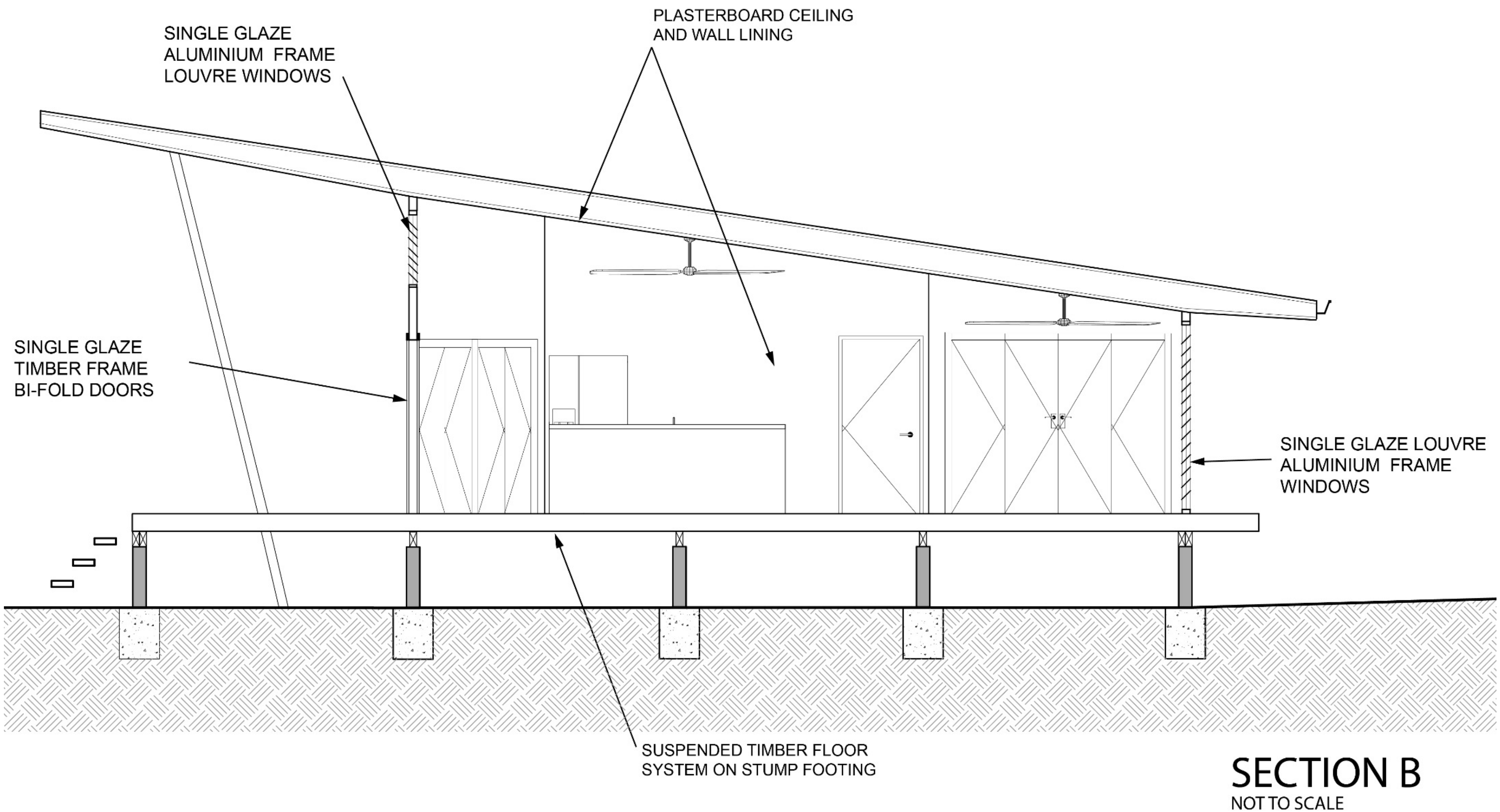


Figure 3 Section B view



The Solution

The NCC Volume Two DtS Provisions were developed primarily for dwellings designed to have an artificial cooling and/or heating system installed during construction or on the assumption that one will likely be installed later. This reflects typical construction practices in most Australian locations.

For free-running or hybrid designs, a Performance Solution is likely to be the only option to satisfy Performance Requirement P2.6.1. This type of solution maintains the design integrity of the dwelling, whilst aligning with the intent of the energy efficiency measures in the NCC; being the reduction of greenhouse gas emissions through the efficient use of energy. Note that ultimately the documentation required to demonstrate that a hybrid, passive designed dwelling's Performance Solution complies with P2.6.1 will be the decision of the appropriate approval authority (building certifier/surveyor).

For the purpose of this Case Study, it has been decided to use the ABCB's four step Guidance Document to assist in developing a Performance Solution. The four steps outlined in the Guidance Document can be used for the development of not only energy efficiency Performance Solutions, but also for fire, access, health and amenity Performance Solutions.

The Guidance Document uses the following four steps:

1. Stakeholders develop a performance-based design brief (PBDB).
2. Specialist practitioners carry out analysis, modelling or testing.
3. Specialist practitioners collate and evaluate results.
4. Stakeholders draw conclusions and prepare a final report on the process and outcomes.

Step 1 - Prepare a Design Brief

A PBDB is a document that is developed in collaboration with a group of key stakeholders as part of a proposed performance-based design and approval process. When completed, the PBDB becomes the platform upon which the proposed design is constructed. It also puts in place an agreed methodology, acceptance criteria and process for how the performance-based design will be developed.

Stakeholders

For this Case Study, it has been identified that the following people will likely need to be part of the key stakeholder group:

- the building designer,
- the client,
- the appropriate approval authority (building surveyor/certifier), and
- the builder/project manager.

The role of the appropriate approval authority may be limited due to potential conflicts of interest. However, it is important that the appropriate approval authority have input into the acceptance criteria for the Performance Solution.

As the building designer is in charge of the project documentation stage, they will be the main party developing and coordinating the Performance Solution.

The Design Brief

The building designer has facilitated the development of the PBDB in the form of a written statement based on client input, building constraints and information as requested by the appropriate approval authority. This is known as the acceptance criteria for the PBDB.

Information included in, and agreed upon, as part of the PBDB may include:

- building address,
- building classification,
- floor area,
- NCC climate zone,
- basic design intent, such as “the house has been designed with the incorporation of significant ‘free-running’, passive solar design principles’, and
- heating and cooling requirements.

All areas of the house, not including the bedroom areas, have been designed so that they do not need any artificial heating or cooling. The bedrooms have been designed so that if needed, they can accommodate an air-conditioning system for cooling but also can be naturally cooled.

The NCC Performance Requirement that is being met is P2.6.1.

In accordance with NCC Part 1.0.2, a Performance Solution will be developed to directly address the Performance Requirement. This will be done by using Assessment Method (c), Expert Judgement, in accordance with Part 1.0.5. The building designer will fulfil the role as the ‘expert’ in accordance with the applicable building practitioner’s registration within their jurisdiction. The building designer will develop a cover letter and associated building drawings that articulate how the building is deemed to be of a hybrid design, and how compliance with Performance Requirement P2.6.1 will be achieved.

Reminder

Part 1.0.2 of the NCC outlines how the NCC Performance Requirements must be met. The Performance Requirements can only be satisfied by a Performance Solution or a Deemed-to-Satisfy Solution, or a combination of the two.

Part 1.0.5 lists the Assessments Methods that must be chosen from in order to develop a Performance Solution. One or more of these Assessment Methods must be used.

The following acceptance criteria have been agreed upon by the stakeholder group:

The agreed thermal comfort temperature range for the building is to be between 22.8 and 29.4 degrees.

Thermal comfort temperatures

The temperature at which a human will feel comfortable is not a figure easily determined. Thus, a range where the majority of occupants will feel comfortable is normally given. ASHRAE Standard 55-2013 specifies conditions for acceptable thermal environments and is intended for use in design, operation, and commissioning of buildings and other occupied spaces that can be applied universally across the world. Using the ASHRAE Standard 55-2013, an upper and lower level of adaptive comfort using natural ventilation can be derived. This range depicts the typical thermal comfort level of occupants using natural ventilation, and is designed to have an acceptability limit of 90%.

Based on the acceptance criteria, the following assumptions and methodologies have been agreed upon by the stakeholder group.

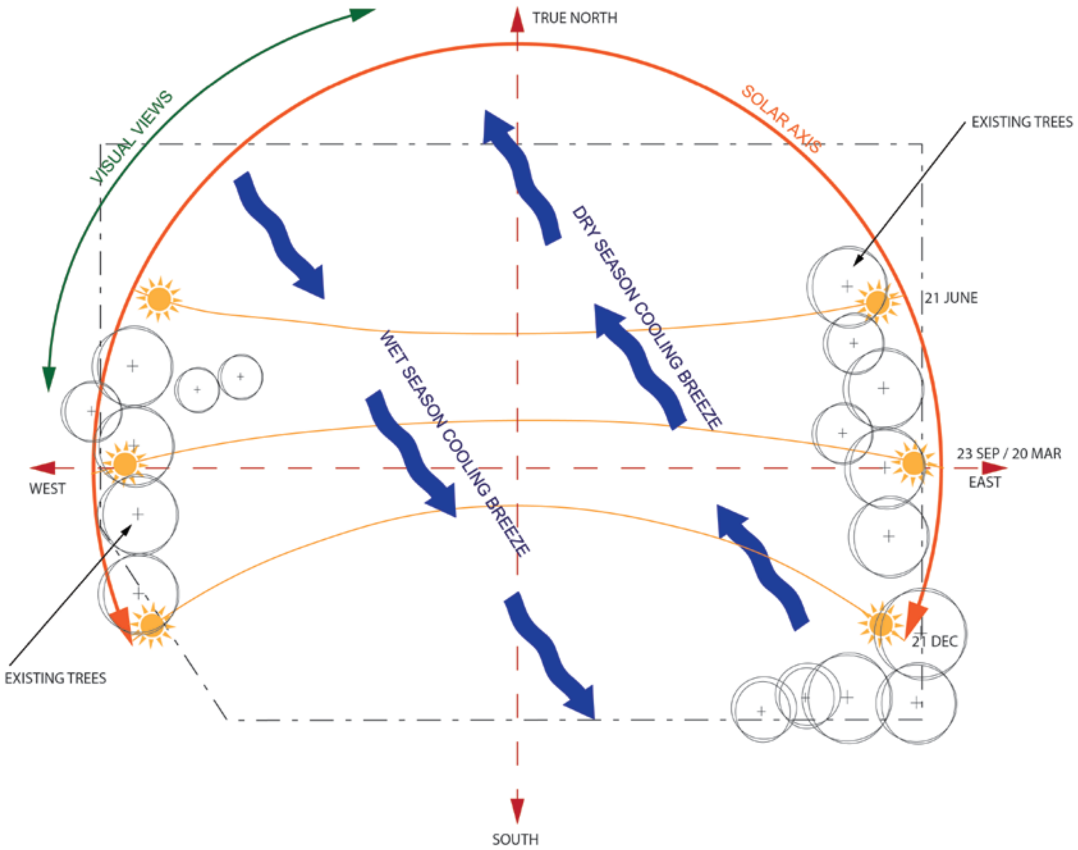
Climate characteristics

The most recent Bureau of Meteorology (BOM) historical data will be used to determine the main climatic characteristics of the site including:

(a) temperature (dry bulb),
(b) humidity,
(c) wind speed, and
(d) wind direction.

Figure 4 shows solar analysis and microclimate analysis of the site. This was agreed by the stakeholders as being representative of the site.

Figure 4 Site Analysis



Ventilation

Ceiling fans will be provided in all habitable rooms of the house with an operating air velocity of 3.6 meters per second.

Occupant clothing choice

The clothing choice of occupants will have an insulating value (clo) of 0.6 to 1.2. This is described as occupants wearing light weight cotton clothing.

Clo values

The type of clothing that occupants wear has a noticeable effect on human comfort. Based on various international studies, insulating values of various clothing elements have been established. These values are expressed as 'clo' values. Shorts and shortsleeved shirts would be 0.25 ‘clo’, while winter clothing such as an overcoat would have a ‘clo’ of 2. A typical business suit has a ‘clo’ value of 1.

Metabolic rates

The determined typical metabolic rates of building occupants are deemed to be no higher than 2.0 met watts or 116 W/m^2. This was determined by the stakeholder group to be typical of tasks undertaken by occupants in the house.

Metabolic rates

Metabolic rates are the rate of transformation of chemical energy into heat and mechanical work by metabolic activities within an organism, usually expressed in terms of unit area of the total body surface. Metabolic rates are expressed in met units. Typically, the harder the body works, the higher the metabolic rate. Some metabolic rates for various tasks are:

- sleeping – 0.7
- reclining, lying in bed – 0.8
- seated – 1.0
- very light work (cooking, shopping) – 1.6
- medium light work (typical house activity, cleaning) – 2.0
- heavy work (running, playing sport) – 6.0

Step 2 – Carry out analysis, modelling or testing

Step two of the development of the Performance Solution involves the building designer developing documents that demonstrate how and why the building will not require air-conditioning in the majority of spaces. The documentation of such evidence should directly address the components of Performance Requirement P2.6.1 and outline how each component will be met.

The complexity of the Performance Solution will depend on the level of explanation required to address the items of consideration within the Performance Requirement.

A method of working out how the building design is proposed to comply with the Performance Requirement can be achieved by a comparative analysis of typical passive design principles with the individual parts of the Performance Requirement. Limitations are then applied to the parts of the Performance Requirements in terms of whether they are relevant to the project. For example, NCC climate zone 1 is deemed to only require cooling, not heating. Thus Performance Requirement P2.6.1(e) referring to "solar radiation being used for heating" does not apply.

The final step is to consider how each design solution will address each of the passive design principles and Performance Requirement's clauses. There are various ways in which the building's designer might go about doing this. Predominately it is likely the designer will draw upon the passive design principles and address components of the design where the principles have been addressed. This might be done using explanatory text, diagrams and possibly comparative analysis to the elemental DtS Provisions. Furthermore, calculations may also be used or other scientific reasoning adopted, such as comparative analysis to climate data and how the building is intended to thermally respond to the climate.

For the Case Study, this process has been summarised in Table 1.

Table 1 Passive solar design principle and link to Performance Requirement P2.6.1 and supporting documents

Design Principle	***Applicable sub-clause within Performance Requirement P2.6.1***	***Supporting Documents***
Orientation	a) the function and use of the building c) the geographic location of the building d) the effects of nearby permanent features such as topography, structures and buildings	• Site analysis • Explanatory, comparative analysis of the architectural drawings
Shading	e) solar radiation being controlled to minimise energy for cooling	• Shading analysis
Passive cooling	b) the internal environment g) the utilisation of air movement to assist cooling	• Air flow calculations • Psychrometric chart
Passive heating[1]	e) solar radiation being controlled to minimise energy for cooling	• Notation on the drawing set outlining that climate zone 1 does not require heating

[1] Concerned with minimising solar heat gain only in climate zone 1

Design Principle	*Applicable sub-clause within Performance Requirement P2.6.1*	*Supporting Documents*
Building sealing[2]	a) the function and use of the building f) the sealing of the building *envelope* against air leakage	• Explanatory, comparative analysis of the architectural drawings • Comparison to DtS Elemental Provisions 3.12.3.
Insulation	b) the internal environment e) solar radiation being controlled to minimise energy for cooling	• Explanatory, comparative analysis of the architectural drawings • Comparison to DtS Elemental Provisions 3.12.1.
Glazing	e) solar radiation being controlled to minimise energy for cooling	• Comparison to shading projection • Explanatory, comparative analysis of the architectural drawings

Climate data

To assess each of the passive solar principles, it is important to understand the specific climatic characteristics that will affect the passive nature of the building and how the building is designed to keep occupants comfortable. This is typically done using three methods:

1. Analysis of BOM data

Accessed from the BOM website, climate data from the nearest weather observation point can be accessed. Such data that might be considered is:

(a) monthly mean maximum and minimum temperatures,
(b) monthly average relative humidity, and
(c) air movement (dominant wind direction and speed data).

[2] Only applicable to rooms deemed to be air-conditioned (i.e. bedrooms in this Case Study)

2. Analysis of specific microclimate characteristics

This approach requires the collection of weather data specific to the site. Data such as maximum and minimum temperatures and humidity are difficult to collect due to the amount of time needed to collect a sufficient data set. However, the analysis of the dominant wind pattern can be somewhat easier. For the purpose of understanding wind patterns for natural ventilation, it is important to understand which direction the wind blows at different times of the year. Wind patterns observed on the site may be significantly different to the ones observed at the nearest weather station. This may be because of factors including topography, surrounding buildings, and vegetation coverage.

3. Combination of BOM data analysis and microclimate analysis

Specific climatic characteristics will typically draw upon both BOM data and microclimate observations. This is usually the most realistic way of understanding the true climatic characteristics of the site.

Understanding climate data

The relationship between humidity and air temperature is studied using psychrometry.

The psychrometric chart is used to map temperature, vapour pressure, relative humidity, comfort indices (like apparent temperature), wet bulb temperature, air density, and importantly the heat content of the air. In building design, psychrometry is a tool used to compare broad changes in comfort, climate, and building response in a visual way.

Figure 5 shows climate data for Darwin plotted on a psychrometric chart. Plotting the data can be done manually using collected weather data or using software that will plot the data for you.

Figure 5 Psychrometric chart from Darwin (Source: Climate Consultant 6.0)

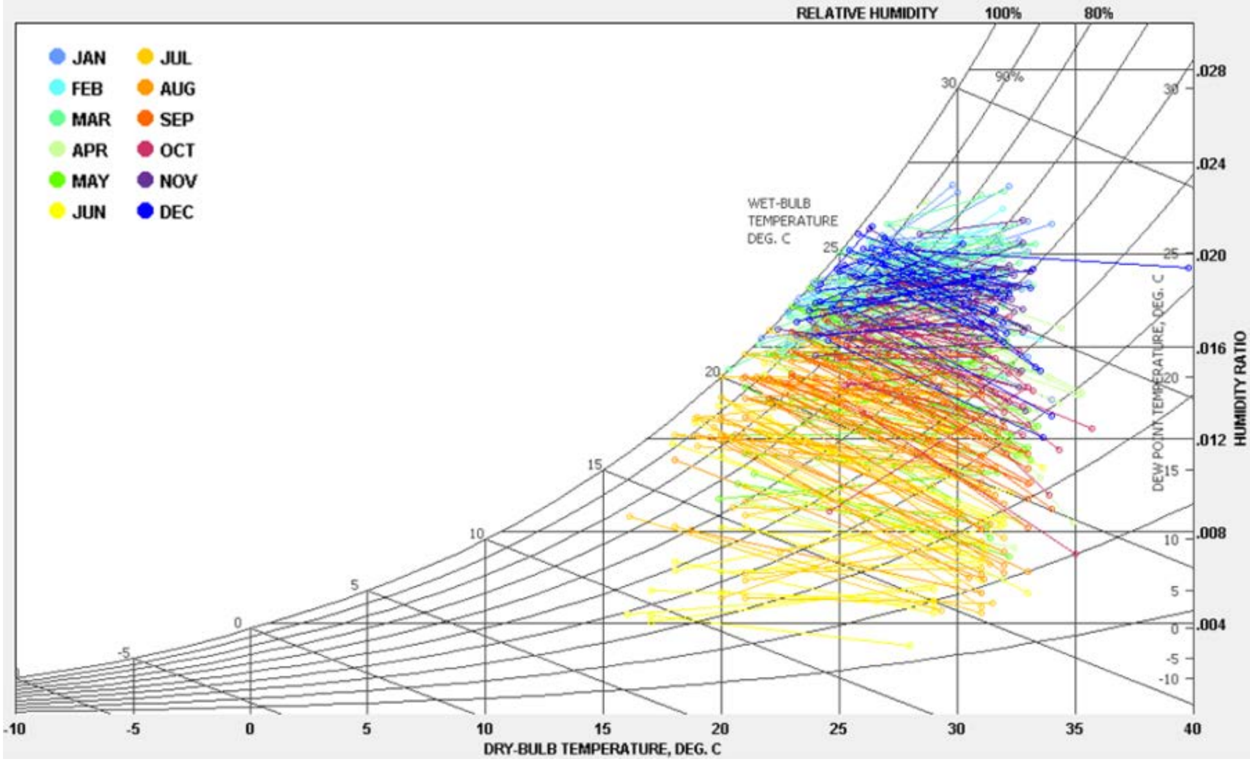
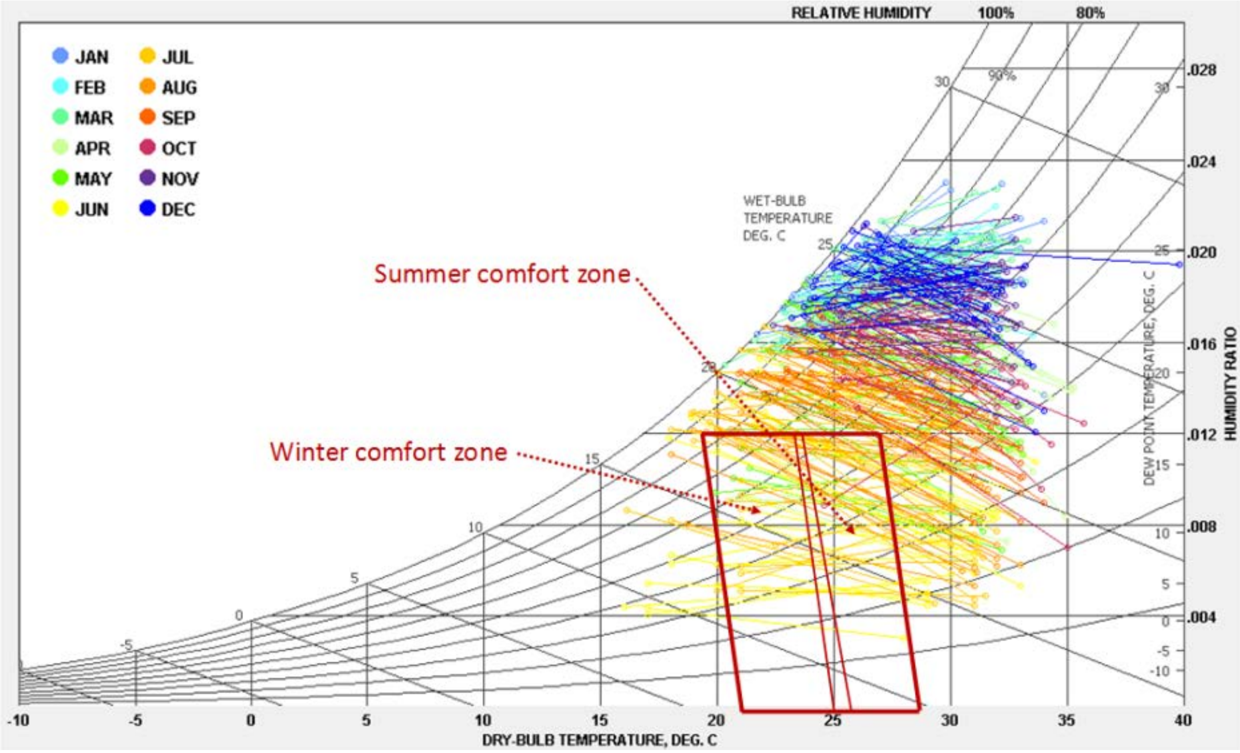


Figure 6 shows the same climate data as Figure 5 with the relevant ASHRAE Standard 55-2013 comfort zone overlayed. This enables a comparative analysis of known climatic characteristics to how comfortable occupants will feel within the climate. The comfort zone (shown in red) is derived from the thermal comfort ranges previously agreed to by the stakeholder group. For example, the ASHRAE Standard 55-2013 comfort zone takes into account the agreed clo rating, metabolic rates of occupants, humidity and average outdoor air temperatures. The model assumes only natural ventilation and no artificial heating or cooling will be used to make an occupant feel comfortable.

Figure 6 Psychrometric chart from Darwin with the ASHRAE Standard 55-2013 comfort zones relevant to summer and winter overlayed (Source: Climate Consultant 6.0)



Observation of Figure 6 shows the ASHRAE Standard 55-2013 comfort zones corresponding with the climate data for winter and summer in Darwin (see red boxes). The majority of the climate data falls outside of these comfort zones. This means the thermal comfort of the occupants will not be achieved if they are exposed directly to the climate's temperature and humidity characteristics. In terms of the built environment, the severity and degree as to which an occupant is exposed to these climatic characteristics can be manipulated by using passive solar principles. For most designs, the equalisation of human comfort and climatic conditions is typically achieved by using an air-conditioning system and some passive solar design principles.

The passive solar design principles as outlined in Table 1 can be used to collectively manipulate the apparent air temperature within the building to make it as thermally comfortable as possible without the need for an air-conditioning system. This means running the house in a free-running mode.

Design Principles

This section links each of the design principles listed in Table 1 to the Case Study and includes an example of supporting documents that may be used to demonstrate compliance with the Performance Requirement.

Orientation

Reference to orientation affects a number of aspects of building design. Firstly there may be a number of considerations that affect the orientation of the building. For this Case Study, building orientation has been used to address two main issues:

- solar radiation of external walls, and
- dominant wind patterns.

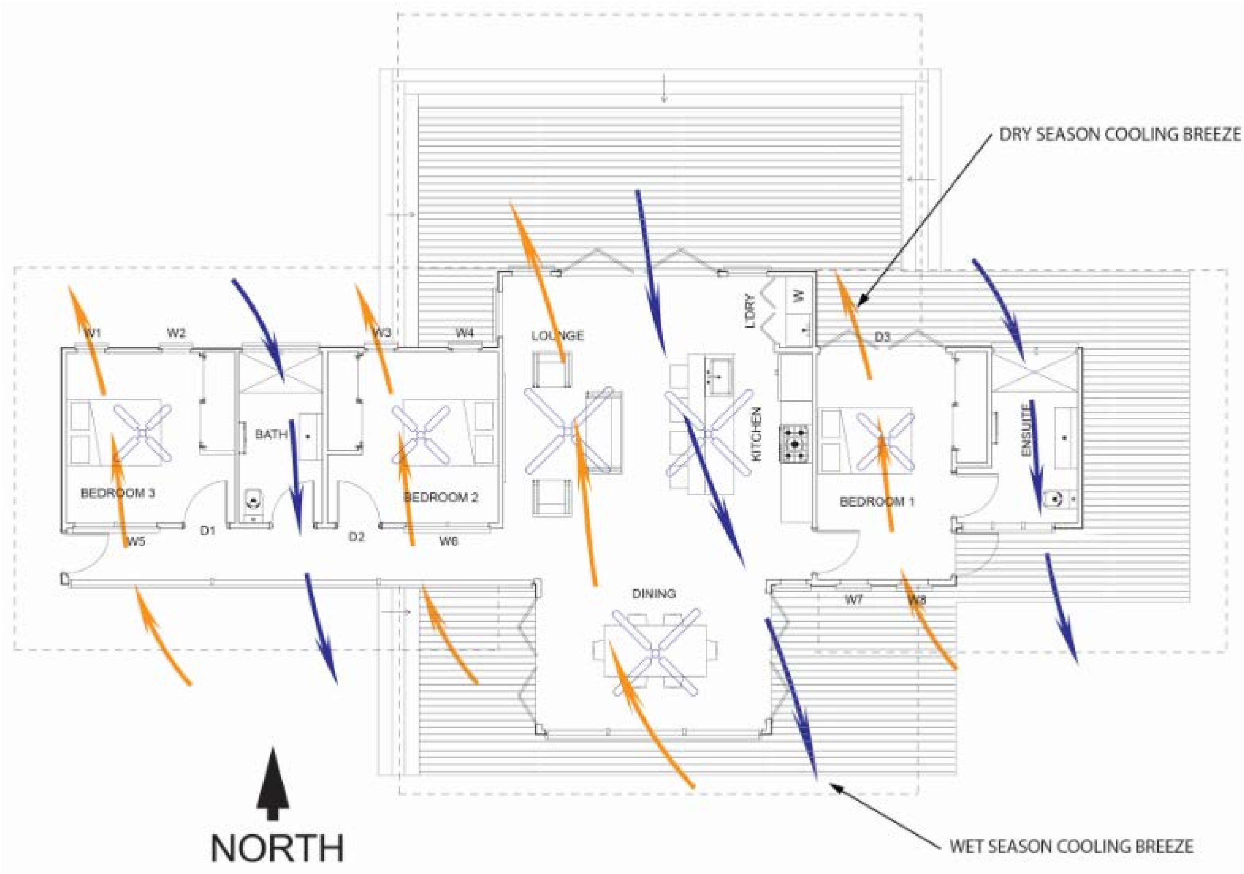
The shape of the allotment has allowed the house to run on a direct east to west axis, with the majority of the building envelope being exposed to north and south orientations. The eastern and western sun can be particularly harsh and provide unwanted heat gain into the building. The less east and west building area there is, the less the building envelope will be subjected to unwanted heat gain.

Large roof overhangs on the northern and southern elevations are designed to reduce solar heat gain during the middle of the day. This will be explored later under the consideration of shading. For the eastern and western elevations, tree and shrub plantings will be placed near and around the perimeter of the building to offer additional shade protection of the building envelope.

Figure 7 Trees and shrubs on the east and west elevations

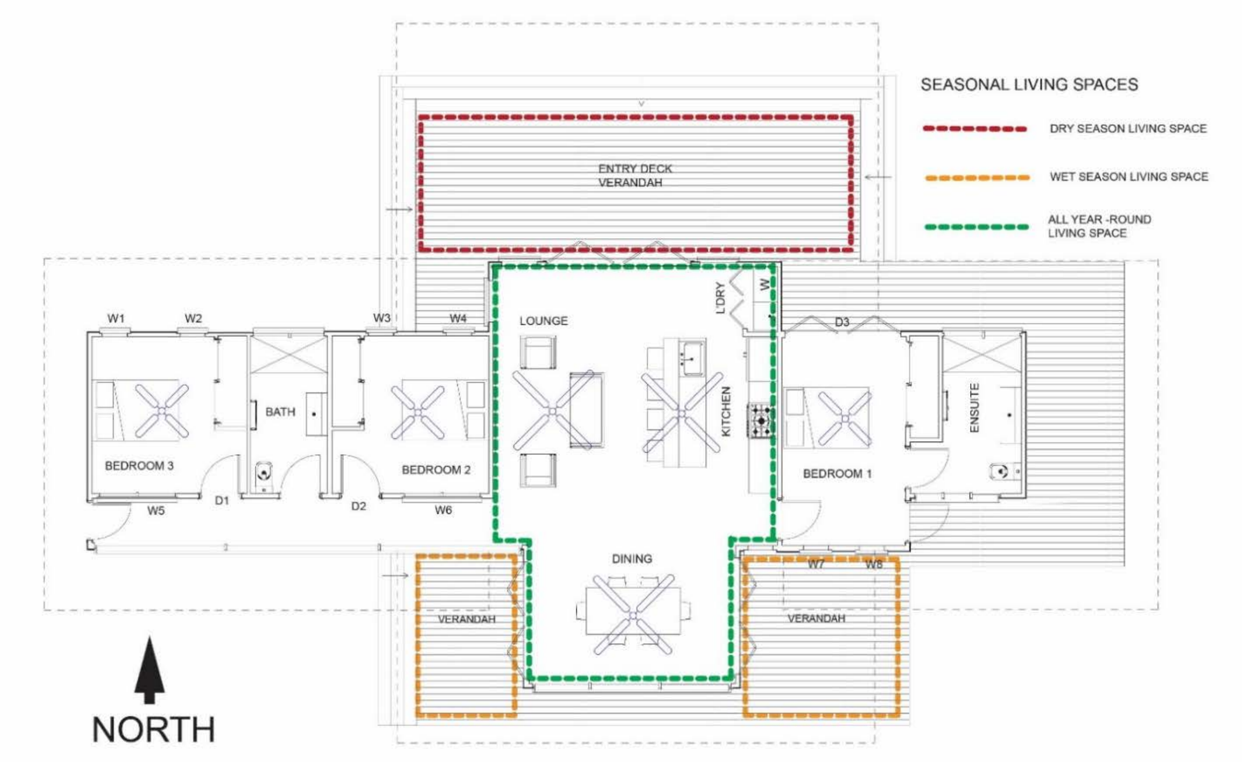
The second consideration for building orientation is the direction of dominant wind patterns. Predominant cooling breezes in Darwin are from the north-west in the wet season and the south-east in the dry season. As a result, the building layout has been configured to best channel these breezes through the building. This is shown in Figure 8.

Figure 8 Diagram showing the building layout and dominant wind patterns



Trees and shrubs have been strategically located to allow these breezes to penetrate the building while also providing shading for the building. The location of indoor/outdoor living spaces is also important. The floor plan shows several optional indoor/outdoor living spaces that the occupants can choose to use depending on the weather conditions on any particular day. The ability to have choice about where the occupants can situate themselves depending on weather conditions is important when demonstrating that the building will not rely on air-conditioning to keep its occupants thermally comfortable, outside of the bedroom spaces.

Figure 9 Seasonal external living spaces



Supporting Documents

The following documents may be used to demonstrate how the orientation of the building affects compliance with the Performance Requirement:

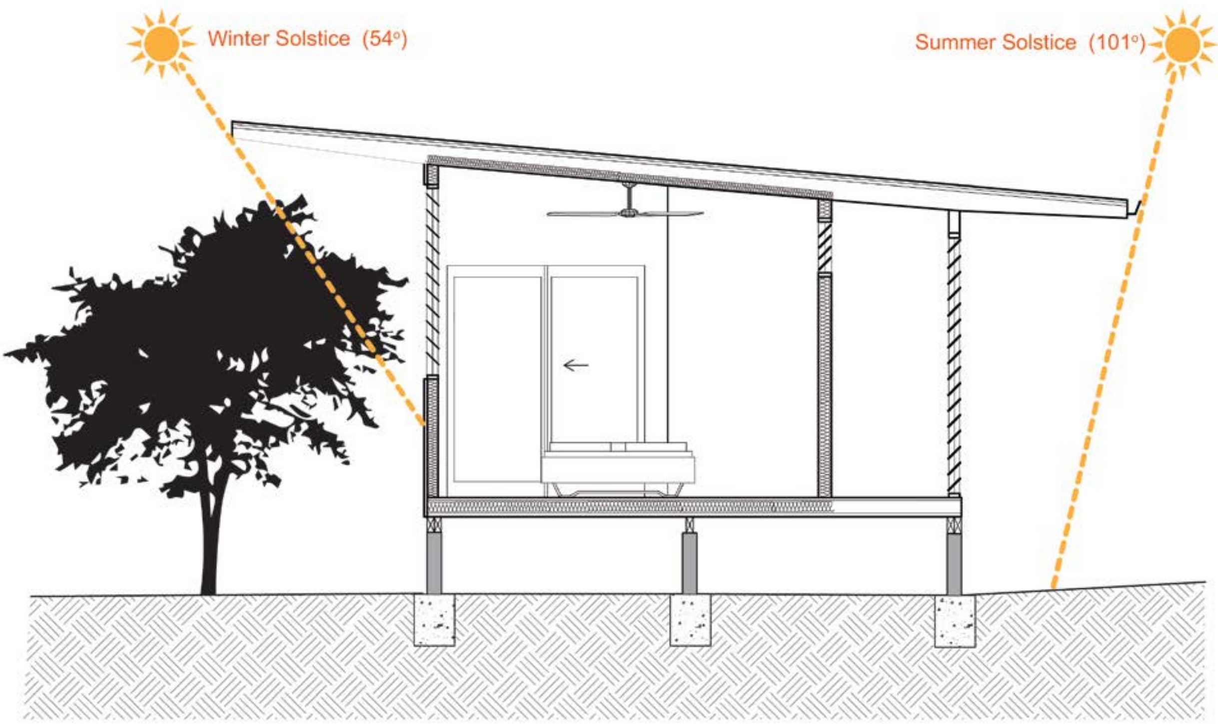
- A site analysis drawing showing the solar access, dominant wind patterns and shading from trees or adjoining buildings.
- A building function diagram showing where and how spaces within the house will be used. This might typically be shown on a floor plan. However, there may be benefits in showing such explanation on an additional plan for clarity. Annotations may include notes about wet and dry season outdoor spaces.

Shading

Direct sun can generate the same amount of heat as a single bar radiator over each square metre of a surface, but effective shading can block up to 90% of this heat. By shading the entire building, including outdoor spaces, the apparent temperature can be reduced significantly, bringing the temperature down within thermal comfort limits. In climate zone 1, solar heat gain should be reduced as much as possible, even in the winter months, as heating is not required.

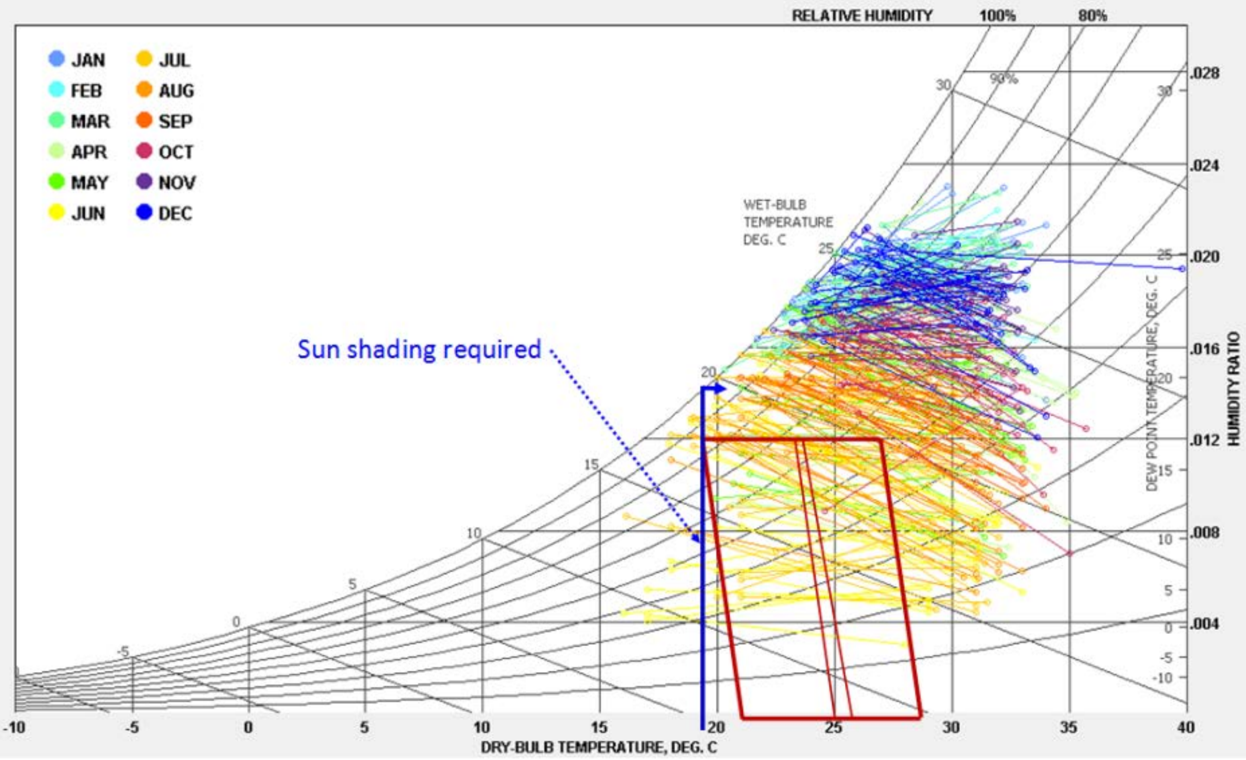
For the Case Study, large roof overhangs provide full shade of all external walls in both winter and summer. This means that the building envelope will not be subjected to solar heat gain, nor will the internal parts of the building where direct sunlight can enter in through openings. This solution still allows for the house to achieve appropriate amounts of natural light but eliminates direct solar gain. The extent of the building shading is shown in Figure 10.

Figure 10 Roof overhangs shading the building walls



Confirmation that shading is required can be determined using the psychrometric chart in Figure 11. The data points to the right of the blue line indicates the days that would require shading to aid in achieving occupant thermal comfort (shown by in the red boxes). The chart shows that for the majority of days, shading is required to reduce excess solar heat gain.

Figure 11 Psychrometric chart showing when shading is required (Source: Climate Consultant 6.0)



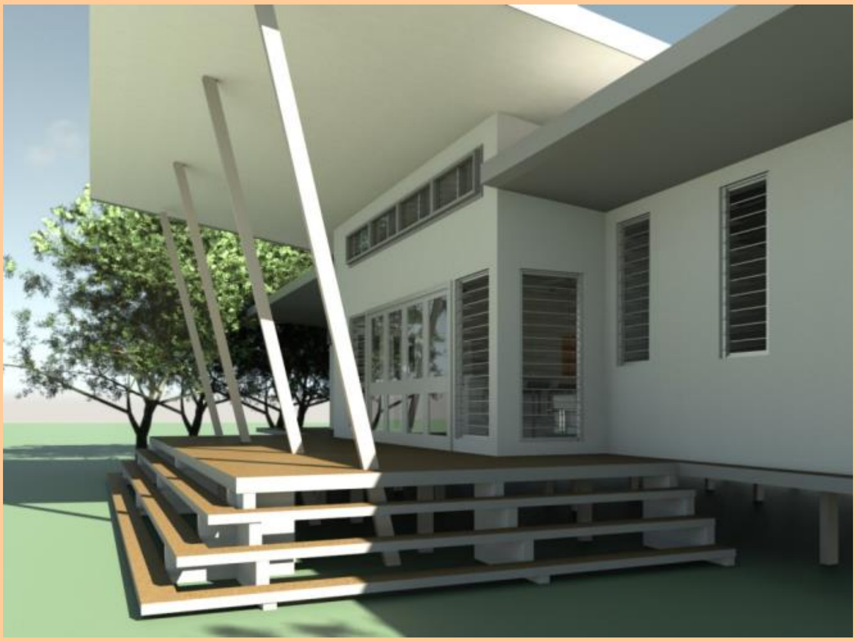
Supporting Documents

The following document may be used to demonstrate how the shading of the building effects compliance with the Performance Requirement:

- Shading diagrams of the building envelope showing the extent of shading on the building envelope. This may include floor plans, sections or perspective diagrams showing shading of the building elevations. The inclusion of trees and shrubs may also be factored into these drawings. Examples of these diagrams are shown in Figure 12 and Figure 13.

Figure 12 External perspective of the building showing the extent of shading

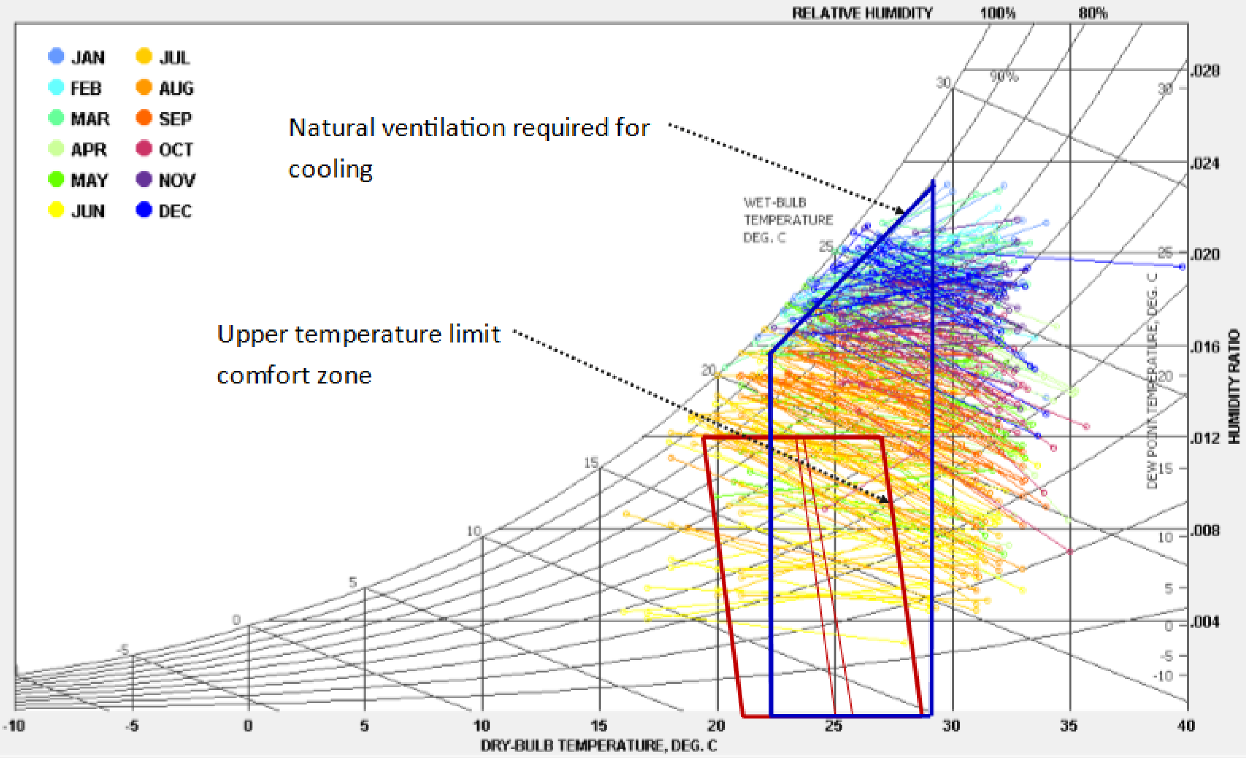
Figure 13 External perspective of the outdoor deck area showing the extent of shading



Passive cooling

The term passive cooling refers to the building's ability to naturally cool itself in order for the occupants to feel thermally comfortable. Evaporation of perspiration is the most effective physiological cooling method for the human body. Evaporation occurs when dry air moves across human skin, in turn having a cooling effect on the body. Comparing the blue box to the red boxes in Figure 14 shows the possible increase in thermal comfort to occupants when natural ventilation is provided.

Figure 14 Psychrometric chart showing when natural ventilation is required (Climate Consultant 6.0)



A building's ability to facilitate unimpeded air movement is very important to ensuring that occupants will be subjected to moving air. The physiological cooling effect from air movement depends not only on the atmospheric conditions, but also on the activity and clothing people are wearing. For persons at medium activity (met rating of 2) and wearing lighting clothing (clo of 1), the physiological cooling effect can be approximated as:

$$\textit{Cooling effect} = 6 \times ws - ws^2 \text{ °C}$$

Where ws = air speed in meters per second.

Under warm conditions, an air movement of 1 m/s is taken as tolerable and the upper limit for normal building occupancy is about 1.5 m/s, higher air movement may be intolerable and become a nuisance. Light objects such as paper on a table might blow away if the air movement is too high. Table 2 shows the relationship between the rate of air movement and the apparent temperature that is observed by air movement.

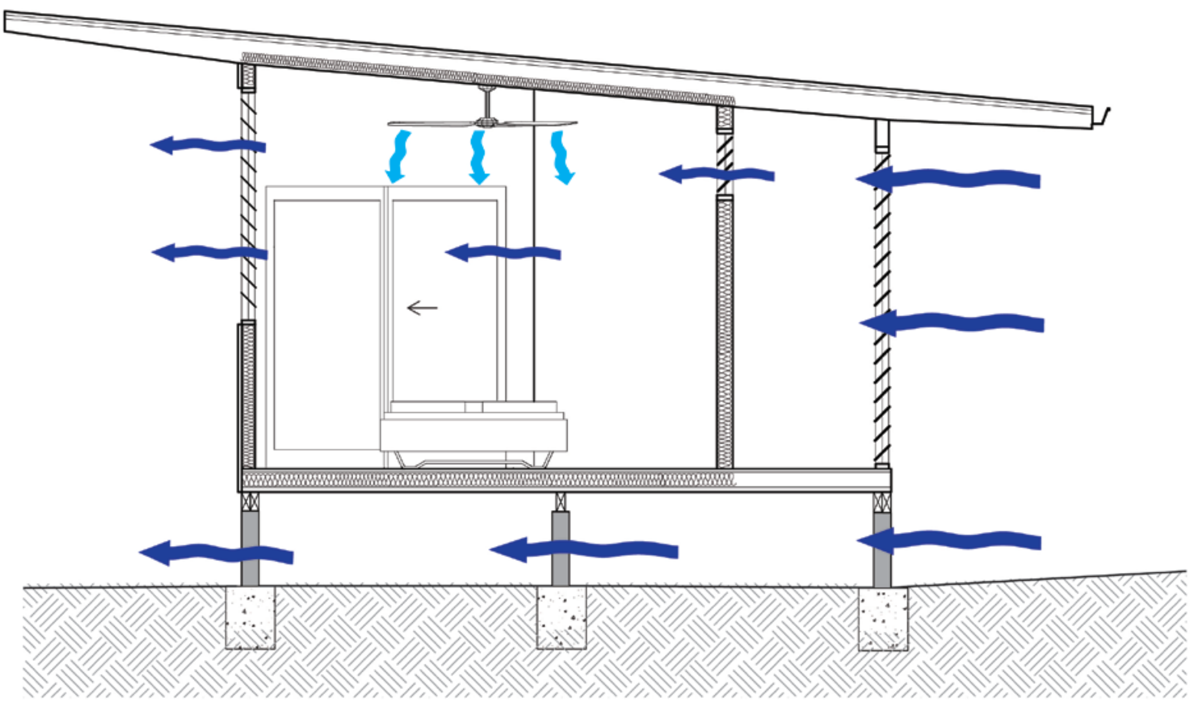
Table 2 Typical air flow rates and temperature limits

Air flow rate (m/s)	Potential drop in apparent temperature (°C)
1	5
2	8
3	9

An example of the temperature change using a dry bulb temperature of 32 degrees and an air movement of 1 m/s was applied, the human body would perceive the apparent temperature to be 27 degrees.

Air movement can also play a critical role in replacing hot air in buildings with cooler air. Still air can be heated by radiation from direct sunlight and convection from building elements such as the floor, walls and ceilings. The longer the period this air is stagnant, the hotter the air can get. If the air in a building is being moved about and replaced with makeup air from either outside the building or within other areas of the building, the ability for this air to heat up is greatly reduced. Air movement within the Case Study building is demonstrated in Figure 15.

Figure 15 Air movement within the building



The use of louvres throughout the entire building allows for the house to be opened up and funnel air through. Compared to other window types, louvres have an openable area of 80% while a casement window only has a 50% openable area. Thus louvre windows provide a good option in terms of maximising air movement through the building. The placement of louvre windows is also important, ensuring that there are direct, clear and unimpeded ventilation pathways. The effectiveness of cross flow ventilation is reduced when objects such as wall petitions, furniture and other objects block the pathways. Figure 16 shows the location of large amounts of louvre windows along the south elevation, allowing air movement into the living and bedroom spaces.

Figure 16 Placement of louvre windows on the south elevation

The use of louvres also allows for the angle of the incoming air to be varied in order to direct airflow. In the Case Study, the ceiling pitch is raked in a single upward direction with clerestory louvre windows at the highest point of the ceiling. The angle of the louvres along the lowest point of the raked ceiling can be directed upwards, subsequently directing air movement in an upward trajectory, forcing the hot air located near the ceiling out of the building via the clerestory windows. Hot air rises which typically means that within a room, the volume of air closest to the ceiling is hotter than the air around floor level. As the air temperature within the building increases, the volume of hotter air drops lower and lower towards the floor. This also results in an overall increase in the temperature within the room.

Louvre windows also allow for continued ventilation during periods of high winds or rain where other window types would typically need to be closed. This is simply achieved by varying the angle of the louvre to accommodate for the climatic conditions.

Elevating the house off the ground significantly reduces air temperatures in and around the building. Similar to air movement within the building, air movement in the sub floor area helps to remove hot still air, as well as providing a cooling affect over the building elements.

Ceiling fans

There may be periods of time during the year when natural ventilation is not enough to provide the required air movement within a building, particularly on still days. The placement of ceiling fans in the living spaces and bedrooms play a significant role in contributing to additional air movement. Fans should be located in key areas over key furniture clusters (couch setting and dining table) as well as over working areas such as the kitchen.

Similarly to natural air movement, the cooling effects of a ceiling fan on occupants can be calculated once the air speed of the fans operation is known. The additional benefit of ceiling fans is that they can be used to flush the building quickly of unwanted heat when run at a higher velocity. Figure 17 shows the location of ceiling fans in the living room space, noting their location over furniture clusters and working spaces.

Figure 17 Location of ceiling fans in the living room area

Steady state heat flow calculations

The term steady state heat flow refers to the thermal energy between physical construction systems such as walls, floors and ceilings. The rate of heat transfer is dependent on the temperatures of the systems and the properties of the construction materials through which the heat is transferred. The three fundamental modes of heat transfer are conduction, convection and radiation. It is possible to undertake steady state heat flow calculations for the house to help quantify the thermal performance of the building envelope, however this involves a deep understanding of building science.

The use of steady state heat flow calculations should be limited to situations where the true effects of the building system and occupant comfort need to be fully understood. Such situations may be where the building uses higher mass building materials or is significantly enclosed while still claiming the ability to be naturally cooled without the need for an air-conditioning system.

Supporting Documents

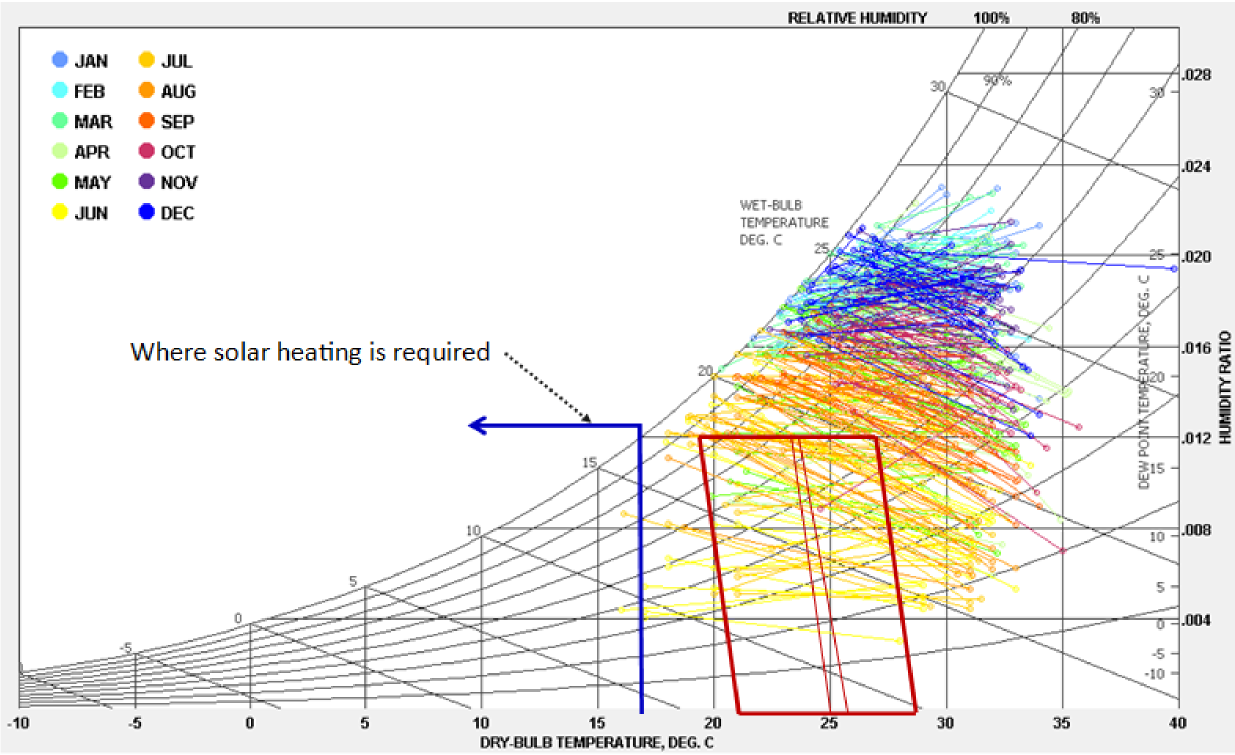
The following documents may be used to demonstrate how the passive cooling of the building effects compliance with the Performance Requirement:

- Ventilation air flow diagrams showing air movement pathways through the building. This may include plan view and section view diagrams.
- Notations on the location and specification of ceiling fans on the drawing set.
- Air flow calculations outlining what the air temperature reductions are likely to be in key areas of the home.
- Steady state heat flow calculations for the whole house, where applicable.

Passive heating

The nature of climate zone 1 conditions typically dictates that no heating of any nature is required for occupants to feel comfortable. ASHRAE Standard 55-2013 states that occupant heating is really only required when temperatures drop below 17 degrees. Figure 18 shows the number of days during the year in which temperatures fall to a level where heating may be required. This is indicated by the data points to the left of the blue line, which shows there are only a few days in a year where solar heat gain may be required for heating.

Figure 18 Days when solar heating is required (Climate Consultant 6.0)



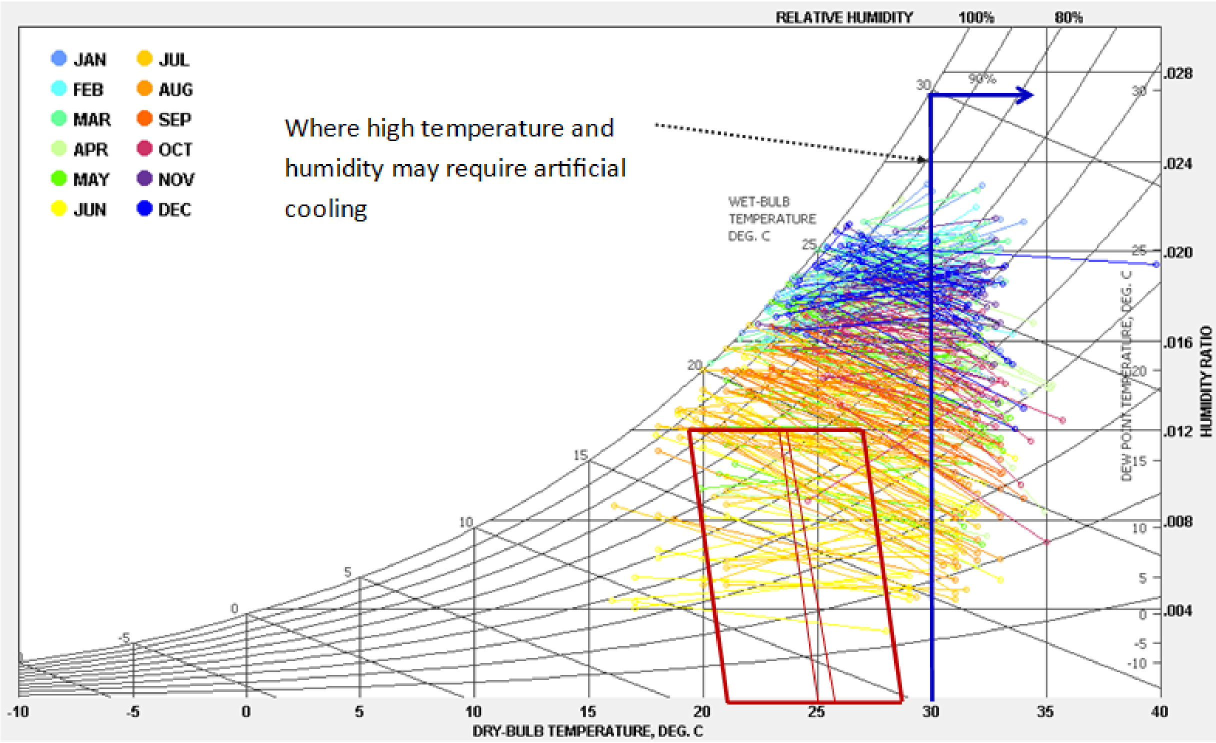
Supporting Documents

A statement included as part of the building specifications outlining that due to the climatic conditions of where the building is to be built, no heating is required may be used to demonstrate that no heating of the building is required in order to meet the Performance Requirement.

Building sealing

The reason for sealing a building envelope is to restrict the unintended leakage of outdoor air into the dwelling and the loss of conditioned air from the dwelling. Air-conditioning systems have been nominated to specific areas of the Case Study house, namely the bedrooms. There are particular times of the year when natural cooling will not be enough to satisfy the thermal comfort of the building’s occupants. This is demonstrated in the psychrometric chart shown in Figure 19 by the data points to the right of the blue line as they represent particular days where artificial cooling might be required at particular times of the day.

Figure 19 Psychrometric chart showing the need for artificial cooling (Climate Consultant 6.0)



During a typical day, the morning and early afternoon periods are usually the coolest time periods. The house will typically be the warmest in the late afternoon and early evenings as the house has been exposed to significant prolonged periods of heating. Typically, as the sun sets, heating of the building will cease and the building temperature will then drop during the night time.

Occupants will feel most uncomfortable with increased temperature and humidity when trying to sleep. Unlike other typical day-to-day activities, it is unreasonable for occupants to move from one part of the building to another to feel thermally comfortable while sleeping at night.

In nominating the bedrooms as the only air-conditioned spaces within the building, occupants can retreat to the bedrooms where the air temperature and humidity can be set at a suitable temperature. Small spaces such as individually air-conditioned bedrooms do not take very long to artificially cool. Typically if sealed and insulated well, the space can be cooled within an hour of the air-conditioning being turned on.

The Case Study uses the idea of hybrid thermal comfort for cooling. The design of the bedrooms including the placement of openable windows, cross ventilation and the addition of a ceiling fan dictates that for the majority of the time, the room can be naturally cooled. However, to deal with the uncomfortable evening and night time temperatures at the peak of summer, an air-conditioning system can be turned on in each bedroom to efficiently cool the space.

The treatment of these bedrooms can be considered as individual boxes that are sealed and insulated to facilitate the efficient use of energy to cool the space. This approach addresses the intent of the DtS energy efficiency provisions, but instead of applying the provision to the whole house, the intent of sealing and insulating the building is concentrated to individual rooms. Figure 20 and Figure 21 show the extent of the spaces within the house that may be artificially cooled.

Figure 20 Plan view the house showing the conditioned spaces

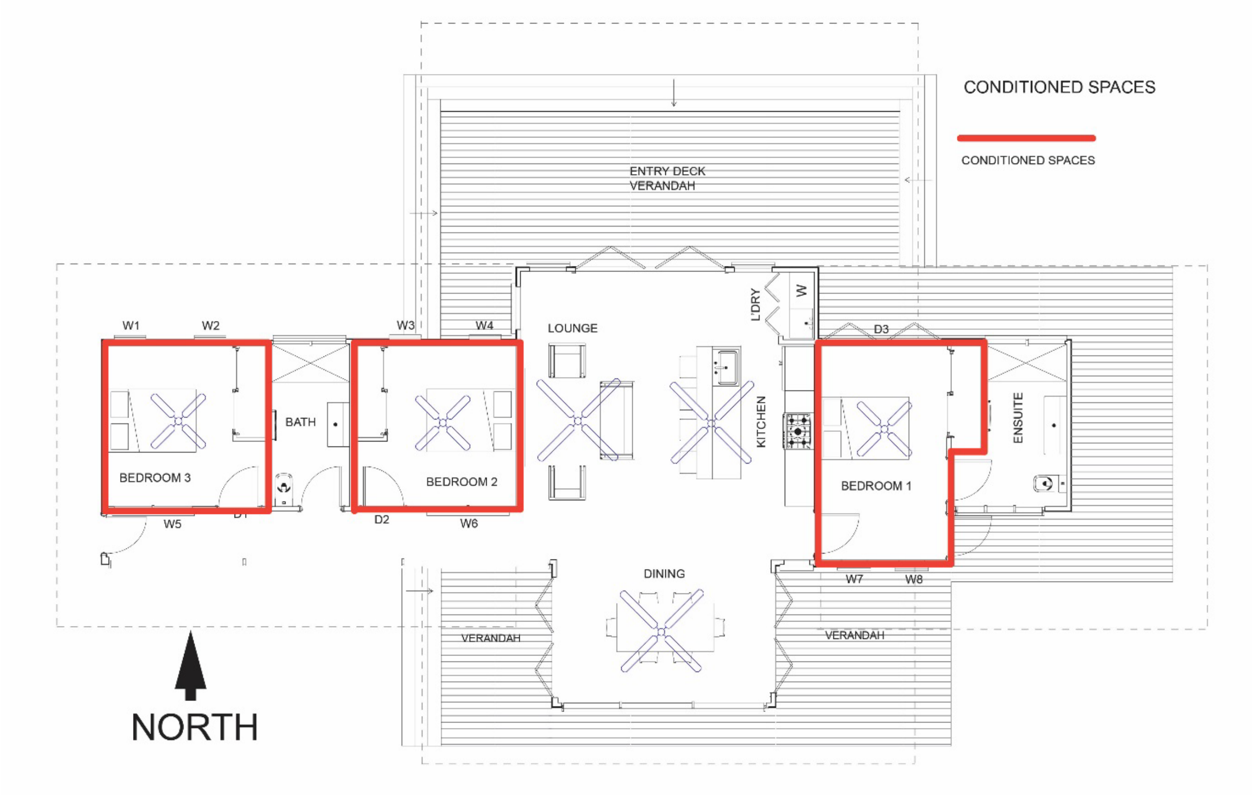
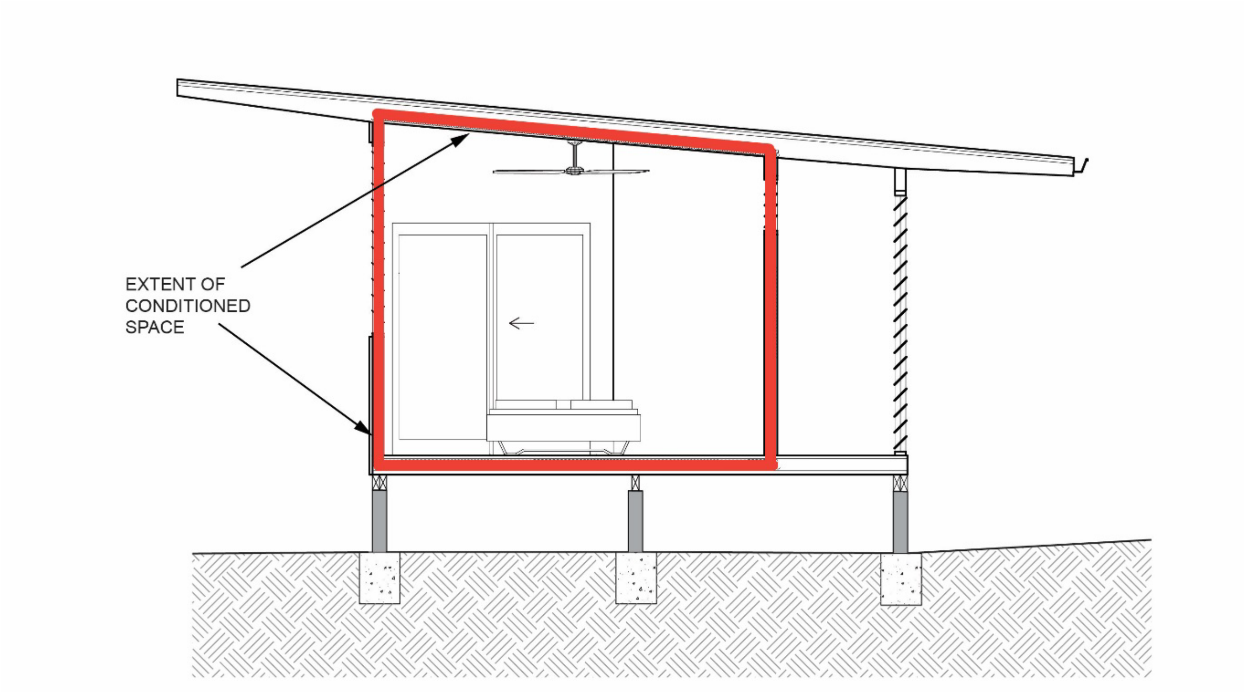


Figure 21 Section view the house showing the conditioned spaces



The bedrooms are designed to be insulated and glazed to align with the DtS Elemental Provisions adopting comparative principles used to seal a whole building. Insulation and glazing will be covered in greater detail in later sections of this Case Study.

Where insulation is installed around the envelope of the bedrooms, it should be installed in a similar nature to that required in Part 3.12.1.1 and Part 3.12.3 of the DtS Elemental Provisions in NCC Volume Two. That is, the insulation should form a continuous blanket around the conditioned spaces, paying particular attention to ensuring that air leakage from these spaces is minimised. This should include sealing around penetrations in the envelope such as downlights, extraction fans and evaporative coolers. Attention should also be given to the sealing of roofs, walls, floors and any openings such as a window and door frames to minimise air leakage.

Supporting Documents

The following documents may demonstrate how the sealing of the building effects compliance with the Performance Requirement:

- Diagrams similar to Figure 20 showing the air-conditioned areas of the building, highlighting that these areas will be required to be sealed to prevent air leakage.

- Notation on the drawings outlining how these spaces will prevent air leakage. This would be specific to the construction type and manufacturers specification of the insulation and sealing products used.

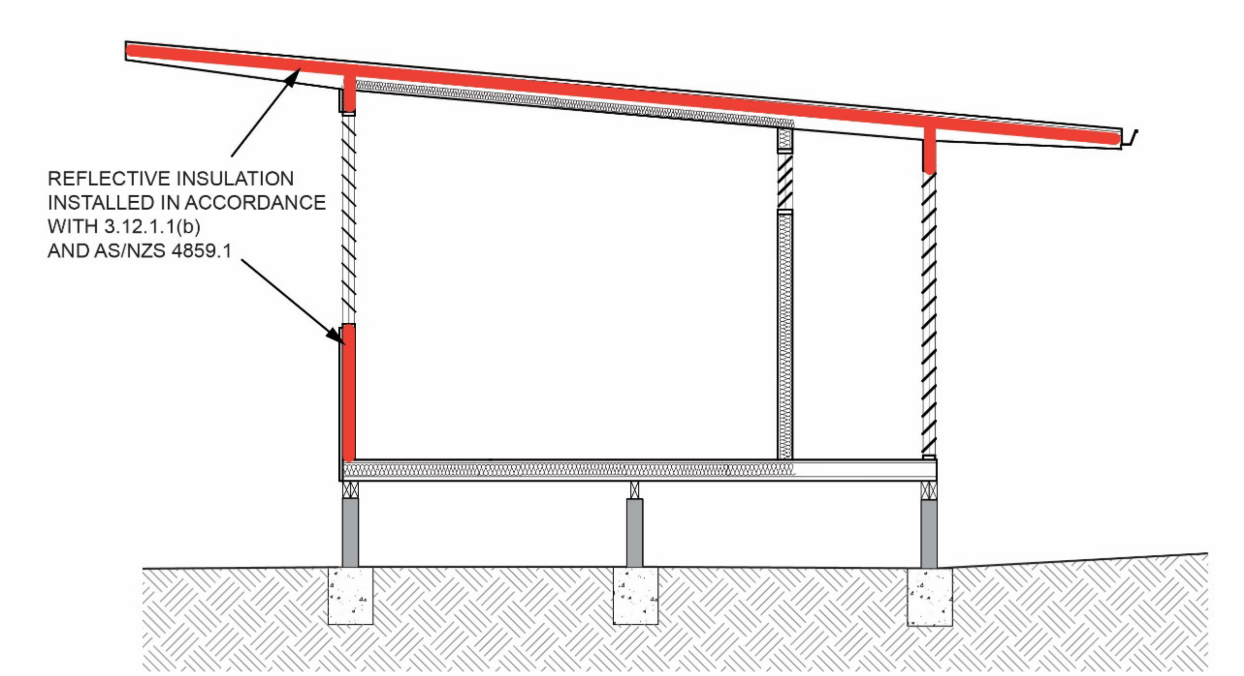
Insulation

The use of insulation in tropical house designs plays two key roles:

- prevention of unwanted heat gain into the whole building, through the walls and roof, and
- prevention of unwanted heat gain and cool air loss in and out of the air-conditioned rooms, concentrating on the complete envelope of these rooms, including the walls, floors and ceiling.

Preventing unwanted heat gain into the building is critical to ensuring appropriate thermal comfort levels for occupants. In tropical climates, the use of reflective foil insulation can help to reduce daytime heat transfer and allow quick night time heat loss. The benefit of installing reflective insulation is that it can prevent the building from holding and retaining heat. Figure 22 shows the extent of reflective insulation in the building.

Figure 22 Location of reflective insulation in the building



To enhance the benefits of reflective insulation, consider the colour of external finishes, particularly the colour of the roof coverings. A low solar absorptance material reduces the flow of heat from solar radiation more efficiently than a high solar absorptance material. A roof with a solar absorptance value of less than 0.4 typically corresponds to a light roof colour such as white, off-white or cream. In the Case Study, a light grey roof covering will be used, which is deemed to have a medium to low solar absorptance value of 0.45.

Lightweight building materials

A key consideration is the use of appropriate building and cladding materials. Materials absorb heat at different rates and by different amounts depending on its conductivity and heat capacity. In a particular building or landscape context, a mass may absorb or lose heat to the environment in an amount that alters the surrounding air temperature or impacts thermal comfort through radiant heat.

The effectiveness of thermal mass as a source of heating or cooling is dependent on factors including the material properties of:

- conductivity;
- resistivity; and
- specific heat.

The surface of the material is critical to its behaviour as a thermal mass, including the properties of:

- emissivity and exposure (surface resistance);
- area; and
- temperature differential.

In tropical climates, especially when designing passive buildings, high mass building materials such as concrete and blockwork should be minimised. Instead, materials that have a low thermal mass, such as timber cladding, cement sheet and metal sheet cladding should be used.

It may be necessary to consider the use of a pliable building membrane when specifying different types of building and cladding systems. Installing a pliable building membrane may have benefits including shielding radiant heat, reducing air infiltration, managing condensation risk, reducing draughts, and acting as a water barrier for certain external wall claddings.

Conditioned spaces

As noted, the bedroom spaces within the building have been nominated to be air-conditioned at particular times of the day. The intent is not to run the air-conditioning system constantly within these spaces but rather use them as a device to flush warm air from the room prior to using it for sleeping.

To maximise the performance of the air-conditioning system, conditioned spaces should be insulated as tightly as possible, preventing external hot air entering the room and limiting the conditioned air leaving the space.

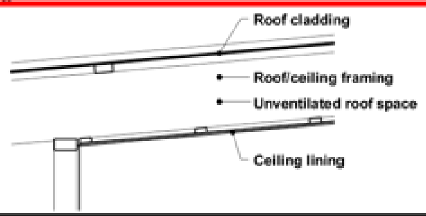
To determine the appropriate insulation R-Values for the bedroom envelopes, a comparison with the elemental DtS Provisions for system R-Value requirements may be made. The process of determining the amount of insulation required to be added is shown below.

Roof

To determine the R-Value of the insulation needed to meet the minimum Total R-Value for the roofing system, the contribution of the roofing materials and any pliable building membranes needs to be accounted for. This calculation process is outlined in Table 3.

Table 3 Roof insulation R-value calculation steps

Step	***Calculation***	***R-Value***
1	Determine the **required Total R-Value** by the Provision 3.12.1.2 (from Table 3.12.1.1a). This is the minimum R-Value that the total roof system must achieve where heat flow is in the downward direction.	**4.1**

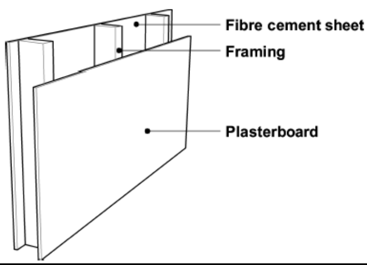
<table>
<tr><th>Step</th><th>Calculation</th><th>R-Value</th></tr>
<tr><td>2</td><td>
Determine the Total R-Value for the roof construction (from Figure 3.12.1.1). This is the R-Value of the roof construction without insulation added.
As per Figure 3.12.1.1(a) the roof construction is deemed to be:
Flat roof, skillion roof and cathedral ceiling – ceiling lining under rafter and unventilated. This has a system R-Value of 0.48.
Figure 3.12.1.1 TOTAL R-VALUE FOR TYPICAL ROOF AND CEILING CONSTRUCTION
<table>
<tr><th colspan="3">Roof construction description</th><th colspan="2">Total R-Value</th></tr>
<tr><td rowspan="2">(a)</td><td rowspan="2">Flat roof, skillion roof and cathedral ceiling — Ceiling lining under rafter

</td><td rowspan="2">Unventilated</td><td>Down</td><td>0.48</td></tr>
<tr><td>Up</td><td>0.36</td></tr>
</table>
</td><td>0.48</td></tr>
<tr><td>3</td><td>
Determine the R-Value of any added pliable building membranes (from explanatory information after the Provision 3.12.1.2(d)).
A reflective insulation with an emittance of 0.2 outer, 0.05 inner is to be added to the roof. The Total R-Value of this reflective insulation 1.28.
<table>
<tr><th rowspan="3">Emittance of added reflective insulation</th><th rowspan="3">Direction of heat flow</th><th colspan="6">R-Value added by reflective insulation</th></tr>
<tr><th colspan="2">Pitched roof (>10°) with horizontal ceiling</th><th rowspan="2">Flat skillion or pitched roof (≤10°) with horizontal ceiling</th><th colspan="3">Pitched roof with cathedral ceilings</th></tr>
<tr><th>Unventilated roof space</th><th>Ventilated roof space</th><th>15° to not more than 25° pitch</th><th>more than 25° to not more than 35° pitch</th><th>more than 35° to 45° pitch</th></tr>
<tr><td>0.2 outer
0.05 inner</td><td>Downwards</td><td>1.12</td><td>1.21</td><td>1.28</td><td>0.96</td><td>0.86</td><td>0.66</td></tr>
</table>
</td><td>1.28</td></tr>
<tr><td>4</td><td>Determine the Total R-Value of the roof system by adding the R-Value of the roof construction (from Step 2) and the pliable building membrane (from Step 3) (i.e. 0.48 + 1.28 = 1.76).</td><td>1.76</td></tr>
<tr><td>5</td><td>Determine the R-value of insulation required to be added by subtracting the roof system Total R-Value (Step 4) from the required Total R-Value (Step 1) (i.e. 4.1 – 1.76 = 2.34).</td><td>2.34</td></tr>
</table>

This means that a minimum R-value of **R 2.34** insulation is required to be added to the roof cavity.

Walls

The Total R-Value for the wall system is calculated in Table 4:

Table 4 External wall insulation R-value calculation steps

<table>
<tr><th>Step</th><th>Calculation</th><th>R-Value</th></tr>
<tr><td>1</td><td>Determine the required Total R-Value using Table 3.12.1.3a.
This is the minimum R-Value that the total wall system must achieve.</td><td>2.4</td></tr>
<tr><td>2</td><td>Determine the Total R-Value of the external wall construction (from Figure 3.12.1.3(b)). This is the R-value of the wall construction without insulation added.
As per Figure 3.12.1.3(b) the external wall construction is deemed to be fibre-cement sheet on timber frame which has a Total R-Value of 0.42.
Figure 3.12.1.3 TOTAL R-VALUE FOR TYPICAL WALL CONSTRUCTION
<table>
<tr><th>External wall construction description</th><th>Total R-Value</th></tr>
<tr><td>(b) Fibre-cement sheet

</td><td>0.42</td></tr>
</table></td><td>0.42</td></tr>
<tr><td>3</td><td>Determine the R-Value of the wall cavity that is to be filled with insulation.
The wall cavity is deemed to have an R-Value of 0.17.
This value is found in the explanatory information following Figure 3.12.1.3 (point 1).</td><td>0.17</td></tr>
<tr><td>4</td><td>The Total R-Value for the external wall is calculated by subtracting the Total R-Value for the wall cavity that is to be filled with insulation from the Total R-Value for the external wall construction (i.e. 0.42 – 0.17 = 0.25).</td><td>0.25</td></tr>
<tr><td>5</td><td>The Total R-Value for the external wall then needs to be subtracted from the required Total R-Value from Table 3.12.1.3a, which equals the minimum R-Value of the insulation required to be installed (i.e. 2.4 - 0.25 = 2.15).</td><td>2.15</td></tr>
</table>

The minimum amount of insulation required to be added to the external wall system is **R 2.15**.

Note that as the wall cavity is to be completely filled with insulation, in this instance, no additional R-Value is achieved by adding a pliable building membrane.

Floor

The Total R-Value for the floor system is calculated in Table 5.

Table 5 Floor insulation R-value calculation steps

<table>
<tr><th>Step</th><th>Calculation</th><th>R-Value</th></tr>
<tr><td>1</td><td>Determine the required Total R-Value by the Provision 3.12.1.5 (from Table 3.12.1.4). This is the minimum R-Value that the total floor system must achieve.</td><td>1.5</td></tr>
<tr><td>2</td><td>Determine the Total R-Value for the external floor construction. This is the R-Value of the floor construction without insulation added.
This R-Value is taken from Table 3.12.1.5 for a suspended timber floor which is unenclosed and heat flow is in the upward direction.
Table 3.12.1.5 TOTAL R-VALUE FOR TYPICAL SUSPENDED FLOOR CONSTRUCTION
<table>
<tr><th rowspan="2">Enclosure and height of floor</th><th rowspan="2">Direction of heat flow</th><th colspan="4">Total R-Value</th></tr>
<tr><th>Cavity masonry</th><th>190 mm concrete masonry</th><th>Single skin masonry</th><th>9 mm fibre-cement sheet</th></tr>
<tr><td colspan="6">(a) Suspended timber floor</td></tr>
<tr><td rowspan="2">Enclosed - not more than 0.6 m high</td><td>Upwards</td><td>1.00</td><td>0.93</td><td>0.88</td><td>0.77</td></tr>
<tr><td>Downwards</td><td>1.11</td><td>1.06</td><td>1.01</td><td>0.90</td></tr>
<tr><td rowspan="2">Enclosed - more than 0.6 m but to not more than 1.2 m high</td><td>Upwards</td><td>0.86</td><td>0.81</td><td>0.76</td><td>0.65</td></tr>
<tr><td>Downwards</td><td>1.00</td><td>0.94</td><td>0.89</td><td>0.77</td></tr>
<tr><td rowspan="2">Enclosed - more than 1.2 m to not more than 2.4 m high</td><td>Upwards</td><td>0.76</td><td>0.72</td><td>0.67</td><td>0.57</td></tr>
<tr><td>Downwards</td><td>0.89</td><td>0.84</td><td>0.79</td><td>0.69</td></tr>
<tr><td rowspan="2">Unenclosed</td><td>Upwards</td><td colspan="4">0.39</td></tr>
<tr><td>Downwards</td><td colspan="4">0.51</td></tr>
</table></td><td>0.39</td></tr>
<tr><td>3</td><td>The Total R-Value for the floor needs to be subtracted from the Required Total R-Value from Table 3.12.1.4, which equals the minimum R-Value of the insulation required to be installed. (i.e. 1.5 – 0.39 = 1.1)</td><td>1.1</td></tr>
</table>

The minimum amount of insulation required to be added to the floor system is **R 1.1.**

Supporting Documents

The following documents may demonstrate how the insulation of the bedrooms satisfies the Performance Requirement:

- Notes on the drawing set noting the required R-Values for the air-conditioned building fabric and insulation for the all floor, wall and roof systems.
- Note on the drawing set noting the use of low thermal mass building materials for external claddings

Glazing

The Case Study uses a significant amount of glazing, particularly in the living and circulation spaces. The primary purpose of the glazing is to allow an abundant amount of natural light into the building while also facilitating good cross ventilation for natural cooling.

The DtS Elemental Provisions have requirements for the type and amount of glazing used in a building. Glazing, and window systems in general, are typically the weakest component in the building envelope, in terms of preventing unwanted heat gain and preventing conditioned loss of cool air. As the bedrooms are to be air-conditioned, these rooms need appropriate glazing that can aid in the efficient cooling of the spaces.

The quality and amount of glazing used in the remainder of the building is not a significant issue, considering it is intentional that the building be as open to cross ventilation as possible. The Case Study house acknowledges that by using large amounts of glazing, the house could be subjected to large amounts of solar heat gain. However, this has been addressed by shading, where it was noted that the building elevation, including all glazed elements are shaded by large roof overhangs and lower level shading by trees and shrubs (see Shading section of this Case Study). As a result, the glazing used in parts of the building not being air-conditioned have been specified as single glazed systems.

Glazing associated with spaces that have the ability to be air-conditioned need to be treated somewhat differently. Using the same philosophy as the walls bounding the bedrooms, the performance of the windows needs to minimise the loss of cool, conditioned air and prevent unwanted heat gain. Where the windows do not achieve this performance, the air-conditioning system in the bedrooms will have to work harder, and subsequently, not facilitate efficient use of energy to condition the space.

The easiest way to assess the appropriateness of the amount and type of glazing used in the bedrooms is to undertake a comparative analysis to the DtS Elemental Provisions. This has been done using glazing calculations in the ABCB's Glazing Calculator for each air-conditioned space. Using the Glazing Calculator in this situation is somewhat different to its normal application in developing a DtS Elemental Solution. Part 3.12.2.1 of the BCA requires the use of the Glazing Calculator to be applied to each "storey" of the building. The application to each storey assumes the whole house is to be air-conditioned. In this Case Study, the Glazing Calculator has been applied to each individual air-conditioned space. These calculations are shown in Figure 23, Figure 24 and Figure 25. Further details on complying with the DtS Elemental glazing requirements can be found in Chapter 9 of the *NCC Volume Two Energy Efficiency Provisions Handbook.*

Figure 23 Bedroom Three glazing calculations

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: Bedroom 3

Climate zone: 1

CONSTANTS: C_U 1.485; C_{SHGC} 0.063

Storey: 1

Air Movement: High

Floor Construction – Area: Direct contact: ; Suspended: 10m²; Area of storey: 10m²; *Area of glazing* 2.5m² (25% of area of storey)

Wall insulation option chosen for 3.12.1.4: *No wall insulation concession used*

ALLOWANCES: C_U x Area 14.9; C_{SHGC} x Area 0.6

Number of rows for table below: 3 *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	W1	N	1.60	0.50		6.00	0.43	1.90	2.10	0.90	0.20	0.80	4.80	32% of 100%	0.1	35% of 33%
2	W2	N	1.60	0.50		6.00	0.43	1.90	2.10	0.90	0.20	0.80	4.80	32% of 100%	0.1	35% of 33%
3	W5	S	0.50	1.75		6.00	0.43	2.40	0.60	4.00	0.16	0.88	5.25	35% of 100%	0.1	30% of 33%

If inputs (including air movement levels) are valid ✓

Figure 24 Bedroom Two glazing calculations

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: Bedroom 2

Climate zone: 1

CONSTANTS: C_U 1.485; C_{SHGC} 0.063

Storey: 1

Air Movement: High

Floor Construction – Area: Direct contact: ; Suspended: 10m²; Area of storey: 10m²; *Area of glazing* 2.5m² (25% of area of storey)

Wall insulation option chosen for 3.12.1.4: *No wall insulation concession used*

ALLOWANCES: C_U x Area 14.9; C_{SHGC} x Area 0.6

Number of rows for table below: 3 *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	W3	N	1.60	0.50		6.00	0.43	1.90	2.10	0.90	0.20	0.80	4.80	32% of 100%	0.1	41% of 29%
2	W4	N	1.60	0.50		6.00	0.43	4.00	2.10	1.90	0.12	0.80	4.80	32% of 100%	0.0	25% of 29%
3	W6	S	0.50	1.75		6.00	0.43	2.40	0.60	4.00	0.16	0.88	5.25	35% of 100%	0.1	35% of 29%

If inputs (including air movement levels) are valid ✓

Figure 25 Bedroom One (master bedroom) glazing calculations

NCC VOLUME TWO GLAZING CALCULATOR (first issued with NCC 2014)

Building name/description: Bedroom 1 (master bedroom)

Climate zone: 1

	C_U	C_{SHGC}
CONSTANTS	1.485	0.063

Storey: 1

Air Movement: High

Floor Construction / Area:
- Direct contact:
- Suspended: 14m²
- Area of storey: 14m²
- *Area of glazing* *5.3m²* *(38% of area of storey)*

Wall insulation option chosen for 3.12.1.4: *No wall insulation concession used*

	C_U x Area	C_{SHGC} x Area
ALLOWANCES	20.8	0.9

Number of rows for table below: 3 *(as currently displayed)*

GLAZING ELEMENTS, ORIENTATION SECTOR, SIZE and PERFORMANCE CHARACTERISTICS								SHADING		CALCULATION DATA			CALCULATED OUTCOMES - OK (if inputs are valid)			
Glazing element		Orientation	Size			Performance		P&H or device		Exposure		Size	Conductance - PASSED		Solar heat gain - PASSED	
ID	Description (optional)	Facing sector	Height (m)	Width (m)	Area (m²)	Total System U-Value (AFRC)	Total System SHGC (AFRC)	P (m)	H (m)	P/H	Es	Area used (m²)	U x area	Element share of % of allowance used	SHGC x Es x area	Element share of % of allowance used
1	D3	N	2.00	2.10		3.80	0.42	1.90	2.20	0.86	0.21	4.20	15.96	78% of 99%	0.4	70% of 59%
2	W7	S	1.40	0.40		4.10	0.60	1.90	1.80	1.06	0.24	0.56	2.30	11% of 99%	0.1	15% of 59%
3	W8	S	1.40	0.40		4.10	0.60	1.90	1.80	1.06	0.24	0.56	2.30	11% of 99%	0.1	15% of 59%

IMPORTANT NOTICE AND DISCLAIMER IN RESPECT OF THE GLAZING CALCULATOR

If inputs (including air movement levels) are valid

The Glazing Calculator has been developed by the ABCB to assist in developing a better understanding of glazing energy efficiency parameters. While the ABCB believes that the Glazing Calculator, if used correctly, will produce accurate results, it is provided "as is" and without any representation or warranty of any kind, including that it is fit for any purpose or of merchantable quality, or functions as intended or at all. Your use of the Glazing Calculator is entirely at your own risk and the ABCB accepts no liability of any kind.

Step 3 – Collect and evaluate results

The next step of the performance-based design process is to evaluate and validate the results. The purpose of this step is to ensure that the agreed acceptance criteria, assumptions and design outcomes are deemed reasonable enough to allow construction of the building to proceed.

The extent of the Performance Solution will dictate how complicated this step will be. For the Case Study, it may be necessary to go back over the design outcomes for each tropical response design aspect to ensure there is a direct linkage to complying with the Performance Requirements. This work might be solely undertaken by the building designer or perhaps a review by other design members to ensure the validity of the proposal.

Further validation of the building design may be sought from the stakeholder group. Different members of the stakeholder group will have varying capacity to supply input into the validity of the design depending on their experience and qualifications. It may be at this stage that the appropriate approval authority is involved and the question asked as to whether the proposed design meets the acceptance criteria and Performance Requirement. It will depend on the situation as to how much feedback the appropriate approval authority can provide, keeping in mind the potential issue of conflict of interest. The appropriate approval authority may only be limited to asking for more information or greater detail to increase the strength of the Performance Solution. Typically, the approval authority will not be able to interfere with the actual design, but rather provide advice and feedback on aspects of the design that may not have been adequately addressed.

Peer Review

There may be situations where the appropriate approval authority does not have the experience or expertise to determine whether the design presented satisfies the Performance Requirement. This is where the use of a peer review process may be useful. Commonly used for structural and fire engineering designs, peer review involves getting a suitably competent person/s to review the design against the Performance Requirement. For the Case Study, this may involve an independent architect, building designer, energy efficiency assessor or other suitably qualified person to validate the design outcomes presented in the proposal. Using the expertise of independent peer reviewers allows for an objective analysis of the key aspects addressing the passive design of the building, and the assurance that the building fulfils the intent that it will not require an air-conditioning system outside of the bedrooms to ensure the thermal comfort of the occupants.

In some state and territory jurisdictions, formal energy assessment peer review systems already exist. The Queensland Government has a peer review process with details outlined on their website. Where formal peer review systems do not exist, it may be up to the appropriate approval authority to determine the extent of a peer review process and the type of reviewer who would be suitable to undertake the work.

Depending on the outcomes of analysing the proposed design, the proposed design may need to be amended. This will depend on the overall suitability of the original design proposal. Further work may include additional drawings and explanatory diagrams, written statements or more testing to validate design decisions.

Step 4 – Prepare a final report

The final step in the process is to bring together all the relevant documentation required for the appropriate approval authority to make a final decision on the proposal. The extent of the documentation required will depend on the complexity of the project. For the Case Study, the following documentation is considered appropriate:

- A cover letter including an overview of the PBDB. This may include:
  - scope of the project,
  - list of relevant stakeholders,
  - applicable NCC Performance Requirement,
  - outline of the approaches and methods used to demonstrate compliance,
  - any additional assumptions that were made during the design process,
  - an overview of the acceptance criteria as agreed in the PBDB,
  - outline of the assessment method used,
  - a brief overview of how each part of the Performance Requirement has been met, making any necessary references to associated documents such as drawings,
  - details of any review or peer review process used, and
  - any other information required by the appropriate approval authority.
- Information outlined within the construction specifications, such as:
  - location and type of air-conditioning,
  - glazing and window types,
  - location and speed of ceiling fans, and
  - insulation and building membrane specifications.
- Drawings and diagrams in the drawing set, including:
  - detailed site analysis,
  - sections showing shading projections,
  - air flow diagrams,
  - air-conditioned space diagrams, and
  - perspective drawings of the building.
- Specific Performance Solution details, including:
  - air flow calculations,
  - glazing calculations, and
  - any other relevant calculations undertaken to determine compliance.

Glossary

Climate zone means an area defined in Figure 1.1.4 and in Table 1.1.2 of NCC Volume Two for specific locations, having energy efficiency provisions based on a range of similar climatic characteristics.

A climate zone is defined as part of Australia with broadly similar climatic conditions. The zones have been adjusted to simplify use of the NCC provisions. The definition includes a map of Australia indicating the various climate zones together with a table specifying the zones for major cities and towns. Refer to the ABCB website for the current NCC climate zone map.

Compliance Solution means a Performance Solution or a Deemed-to-Satisfy Solution that meets the Performance Requirements.

Conditioned space means a space within a building that is heated or cooled by the building's domestic services, excluding a non-habitable room in which a heater with a capacity of not more than 1.2 kW or 4.3 MJ/hour is installed.

Envelope, for the purposes of Part 3.12, means the parts of a building's fabric that separate artificially heated or cooled spaces from—

(a) the exterior of the building; or

(b) other spaces that are not artificially heated or cooled.

This term was developed to describe the location of the thermal barrier to prevent unnecessary energy loss or gain between a conditioned space (including a potentially conditioned space) and a non-conditioned space. The defined term conditioned space should be read in conjunction with the term envelope.

Expert Judgement means the judgement of an expert who has the qualifications and experience to determine whether a building solution complies with the Performance Requirements.

Fabric means the basic building structural elements and components of a building including the roof, ceilings, walls and floors.

Glazing, for the purposes of energy efficiency, means a transparent or translucent element and its supporting frame located in the envelope, and includes a window other than a roof light. This means windows, glazed doors or other transparent and translucent elements (such as glass bricks) including their frames, located in the building fabric.

Habitable room means a room used for normal domestic activities, and—

(a) includes a bedroom, living room, lounge room, music room, television room, kitchen, dining room, sewing room, study, playroom, family room, home theatre and sunroom but;

(b) excludes a bathroom, laundry, water closet, pantry, walk-in wardrobe, corridor, hallway, lobby, photographic darkroom, clothes-drying room, and other spaces of a specialised nature occupied neither frequently nor for extended periods.

Lightweight construction means construction which incorporates or comprises—

(a) sheet or board material, plaster, render, sprayed application, or other material similarly susceptible to damage by impact, pressure or abrasion; or

(b) concrete and concrete products containing pumice, perlite, vermiculite, or other soft material similarly susceptible to damage by impact, pressure or abrasion; or

(c) masonry having a thickness less than 70 mm.

Microclimate means the climate of a very small or restricted topographical area, especially when this differs from the climate of the surrounding area.

NatHERS is the Nationwide House Energy Rating Scheme, which provides a framework that allows accredited computer software tools to rate the potential energy efficiency of Australian homes, by assessing the thermal performance of the building's design.

Passive solar design means the building design, windows, walls, and floors are made to collect, store, and distribute solar energy in the form of heat in the winter, and reject solar heat in the summer.

Performance Requirement means a requirement which states the level of performance which a Performance Solution or Deemed-to-Satisfy Solution must meet.

Performance Solution (Alternative Solution) means a method of complying with the Performance Requirements other than by a Deemed-to-Satisfy Solution.

R-Value (m^2.K/W) means the thermal resistance of a component calculated by dividing its thickness by its thermal conductivity.

Reflective insulation means a building membrane with a reflective surface such as a reflective foil laminate, reflective barrier, foil batt or the like capable of reducing radiant heat flow.

This means a material with a reflective surface capable of reducing radiant heat flow across an adjacent airspace. It may be a sarking-type material that has specific reflective qualities, such as reflective foil laminate or it may be combined with other insulation material.

Site analysis is the study of allotment size, shape and gradient, orientation, solar axis and shading, prevailing wind directions, and other non-passive design considerations such as views and vistas of an associated topographical location.

Solar absorptance is the classification of colours based on solar absorptance. A value of 0 indicates that a roof absorbs none and a value of 1 indicates that a roof absorbs 100% of the incoming solar radiation.

Total R-Value (m^2.K/W) means the sum of the R-Values of the individual component layers in a composite element including any building material, insulating material, airspace and associated surface resistances.

Total System Solar Heat Gain Coefficient (SHGC) means the fraction of incident irradiance on glazing or a roof light that adds heat to a building's space.

Total System U-Value (W/m^2.K) means the thermal transmittance of the composite element allowing for the effect of any airspaces and associated surface resistances. In simple terms, the Total System U-Value is the opposite of the Total R-Value as an expression. That is, Total System U-Value is the ability of a composite element, such as glazing, to conduct heat, while the Total R-Value measures the ability of a composite element, such as a wall construction, to resist heat flow.

Ventilation opening means an opening within the building envelope that permits the movement of air through a building.

Window includes a roof light, glass panel, glass block or brick, glass louvre, glazed sash, glazed door, or other device which transmits natural light directly from outside a building to the room concerned when in the closed position.

Further Reading

The following references are recommended if further information is required regarding the tropical house design, passive solar design and NCC energy efficiency requirements:

- *NCC Volume Two Energy Efficiency Provisions* non-mandatory handbook. The handbook provides details of the energy efficiency requirements of NCC Volume Two. It aims to provide practitioners with sufficient knowledge to successfully apply the energy efficiency requirements for residential dwellings and can be downloaded for the ABCB website.

- *Your Home: Australia's guide to environmentally sustainable homes* is published by the Commonwealth of Australia, Department of Industry, Innovation and Science. Your Home is a comprehensive guide to environmentally sustainable homes including information on passive designed homes. The guide can be accessed from the Your Home website.

- The Cairns Regional Council has produced a number of resources on their website concerning smart design for the tropics and sustainable tropical building design.

- The Tropical Green Building Network and James Cook University has produced a number of case studies of tropical house design projects in Cairns and Far North Queensland. The case studies feature constructed examples of tropical house design and can be accessed from their website.

- *Warm House Cool House, Inspirational Designs for Low-Energy Housing* by Nick Hollo. This book contains useful information about sustainable Australian house design incorporating information on passive solar design and energy efficiency.

- WoodSolutions Australia has produced a number of technical design guides on the thermal performance in timber-framed buildings which include guidance on NCC energy efficiency compliance and passive solar design principles. They can be accessed from the WoodSolutions website.

Appendix A Passive design principles

Passive design uses a building's local environment, climate, specific design techniques and appropriate material selection to reduce, or in some instances eliminate, reliance on artificial heating and cooling, whilst allowing reasonable occupant comfort, and reducing energy consumption.

Passive design can facilitate heating, cooling, or both by maximising the effect of beneficial climate conditions and minimising the impact of unfavourable climate conditions. The design techniques used depend on the climate, and the heating or cooling requirements for a specific dwelling.

In tropical climates of Australia, cooling is typically the dominant requirement for dwellings, with little or no need for heating throughout the year. Passive cooling involves minimising unwanted heat gain by a dwelling, maximising the ability of the dwelling to expel heat to the outside, and facilitating natural cooling of the occupants.

These principles, in relation to passive cooling, are utilised in the design described in this Case Study, and are explained in the following sections.

A.1 Orientation and site considerations

In a tropical climate, orientation and site considerations can contribute to passive cooling by minimising solar gains and maximising exposure to prevailing cooling breezes.

The angle of the sun in the sky changes throughout the year and as a result, the solar heat gains experienced by a building differ throughout the day and during different seasons. Solar radiation is greater when the sun strikes a surface at a more direct angle. This means that eastern and western walls are typically exposed to greater solar radiation as the sun angle is low around sunrise and sunset.

Northern and southern walls in northern Australian climates receive less radiation due to the sun being higher in the sky. As a result, a dwelling should aim to be oriented along the east-west axis to minimise the solar gains. While consideration of the orientation to minimise solar gains is important, precise solar orientation is not critical for reducing solar gain. Effective solar heat gain reduction can usually be achieved by orienting a building within 20^{o} west and 30^{o} east of north.

Orientation should be balanced with access to prevailing cooling breezes to determine the most effective dwelling orientation. Minimising the exposure of the dwelling to warm breezes and utilising prevailing cooling winds can greatly assist with providing occupant comfort in hot, humid climates.

The microclimates and other features of the site can also impact on the ideal orientation of the building and should also be taken into consideration. Surrounding structures, landscape features, and vegetation can impact on radiation heat gains and the prevailing cooling breezes.

Other features of the individual site can also assist with orienting a dwelling to maximise passive cooling potential. This could include utilising a south facing slope to assist with shading, or situating the dwelling in order to access cooling breezes channelled down a valley. Each site will have a different microclimate that will necessitate careful consideration of the building orientation.

A.2 Shading

The primary source of heat gain for buildings in tropical climates is solar heat gain through solar radiation and conduction. This can be reduced by appropriate shading.

Sunlight is a broad spectrum of radiation from very short ultraviolet wavelengths to long infrared wavelengths. The wavelength emitted from a surface depends on the surface temperature. Short wavelengths typically hit a building surface, and are partially absorbed. As the surface is relatively cool, longer infrared wavelengths are re-emitted.

Conduction is the process of energy transfer through building parts caused by a temperature difference between the parts. An example may be heat conduction through windows, where the temperature on one side is greater than the other, and where heat is passed from the hotter side to the cooler side.

Glazing, external walls and the roof all facilitate heat gain, however, glazing is usually the greatest source of unwanted heat gain when not correctly shaded. In tropical climates all walls, and in particular glazing, should be shaded. This assists greatly in reducing unwanted heat gain.

Shading can be achieved through roof overhangs and eaves, screens, and also supplemented with appropriate planting and vegetation. The most effective shading techniques for minimising heat gain will involve external shading of the entire surface of the building. This will also involve shading of southern elevation in buildings located north of the Tropic of Capricorn where the sun travels through the southern part of the sky in summer.

While external shading is the most effective method for reducing solar heat gain, full external shading may not be possible on eastern and western orientations. Low Solar Heat Gain Coefficient (SHGC) glazing may assist with reducing solar heat gain in these instances, which can also be paired with internal shading devices.

Where possible, shading the roof of the building will also assist with reducing solar heat gains and can be achieved by utilising shade from trees and other buildings.

A.3 Ventilation and air movement

Ventilation can assist with removing heat that accumulates in a building, as well as cooling the building occupants. Heat accumulates in a building due to solar gains, and from heat generated by appliances, lights, and occupants. Orientation, shading, and materials can assist with reducing the amount of heat entering a building, and ventilation can help to remove the accumulated heat, and cool the building occupants.

Natural ventilation for passive cooling is most effective when the building is long, narrow, and oriented towards prevailing cooling breezes. To maximise cross ventilation, the building should be single room depth, open plan, have openings on the cooling breeze side of the building, and larger openings on the leeward side. The positioning of the openings and the use of external devices can be adjusted to suit the desired air flow pattern for a particular room. For example, a louvre or canopy over a window has the potential to deflect the airflow upward or downwards inside the room.

Cross ventilation is achieved by a pressure differential. When the windward side is exposed to a cooling breeze, the lower pressure on the leeward side draws the cool breeze through the building. The size and positioning of the openings on the windward side can also vary the speed of the airflow through a building. Generally openings positioned near the centre of walls on the windward side experience the greatest pressure and will offer the greatest cross ventilation. Planting and vegetation can also assist with directing and channelling breezes, and ceiling fans can be used to supplement natural ventilation during still periods to ensure that air movement is sufficient.

In regions with low relative humidity, evaporative cooling can be used as a method of passive cooling. Positioning a pond, water feature, or other water source outside a window and in the path of a cooling breeze can reduce the apparent temperature of the air before it enters the building. Water sources with a large surface area are most effective – particularly mists and fountains.

A.4 Material selection

Selecting appropriate building materials and internal finishes will help to reduce initial heat gain, and allow the building and its occupants to reject heat quickly to the outside. Lightweight materials are generally preferred where cooling is the dominant requirement. Lightweight materials don't store heat in periods of high temperature, and respond quickly to temperature changes - rejecting heat quickly when temperatures drop. They also respond faster to cooling breezes and cooler night time temperatures. Light, low mass materials also assist with occupants rejecting heat to their surroundings. These materials should be used for roofs, walls, shading devices, and internal surfaces. Thermal mass is generally not effective in tropical areas with a limited diurnal range. In these climates, thermal mass may reradiate absorbed heat, and may limit the ability of a dwelling to shed heat overnight.

The construction of the roof is a key consideration for effective passive cooling. Roofs can be difficult to shade so the materials selected should minimise heat gain. A highly reflective roof surface will assist with reflecting heat, as will the use of reflective insulation. Reflective insulation reduces radiant day time heat gains, and allows for effective discharge of heat at night time when the outside temperature cools. Bulk insulation should be used carefully in passive cooling applications in cooling dominated climates as it does not allow effective night time heat loss. A well ventilated roof space can also contribute to the passive cooling of a building.

Appendix B Types of designs used in hot and tropical climates

B.1 Free-running Design

Free-running designs rely entirely upon passive heating and/or cooling. Free-running dwellings require careful consideration and balancing of passive design features. There should be no intention to include air-conditioning at a future date unless major renovation works are completed – for example adding insulation, altering the amount of glazing, and improving the building sealing to contain air that has been cooled using an air conditioner.

B.2 Conditioned Design

A conditioned design means the building is designed to contain an air-conditioning system that artificially heats and cools. Air-conditioning is the process of altering the properties of air (primarily temperature and humidity) to more thermally comfortable conditions. To achieve this efficiently, the building needs to be well sealed and insulated to stop internal conditioned air loss and unwanted external temperatures impacting upon internal conditions.

B.3 Hybrid Design

Passive design can also include a hybrid design – a combination of free-running and conditioned spaces. The conditioned space may be a living area that can be used during periods of extreme heat and humidity. The envelope of the conditioned space should be well sealed and insulated from the external environment and the free-running spaces to achieve maximum efficiency of the air-conditioning system. The conditioned space(s) may be able to be opened up and utilise passive cooling when not in use.

The conditioned space(s) should be protected from excess exposure to heat. This could include positioning the conditioned space in the centre of a building with the remaining part of the building providing a buffer, and ensuring that the conditioned space is not positioned in an area that would receive large solar gains.

Appendix C The National Construction Code

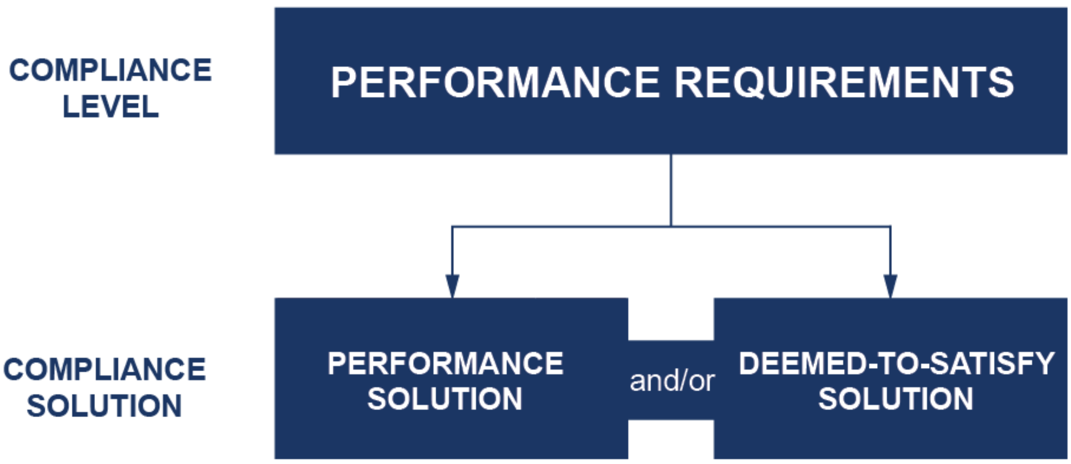
The NCC contains a set of technical provisions for building, and plumbing and drainage work undertaken in Australia.

The mandatory requirements of the NCC are the Performance Requirements. Demonstrating compliance with the Performance Requirements can be achieved by:

- Developing a Performance Solution
- Developing a DtS Solution or
- A combination of the two.

This is shown in Figure 26 below.

Figure 26 NCC Compliance Structure



C.1 NCC Volume Two

Volume Two of the NCC is primarily concerned with the design and construction of Class 1 and 10 buildings. They are typically houses, garages, sheds, carports, and swimming pools.

C.2 Performance Requirement P2.6.1

The Performance Requirement in NCC Volume Two related to the energy efficiency of a house is P2.6.1. It requires the performance of the house to allow for the efficient use of energy for artificial heating and cooling. This Performance Requirement is shown below.

P2.6.1 Building

A building must have, to the degree necessary, a level of thermal performance to facilitate the efficient use of energy for artificial heating and cooling appropriate to—

(a) the function and use of the building; and
(b) the internal environment; and
(c) the geographic location of the building; and
(d) the effects of nearby permanent features such as topography, structures and buildings; and
(e) solar radiation being—
  (i) utilised for heating; and
  (ii) controlled to minimise energy for cooling; and
(f) the sealing of the building *envelope* against air leakage; and
(g) the utilisation of air movement to assist cooling.

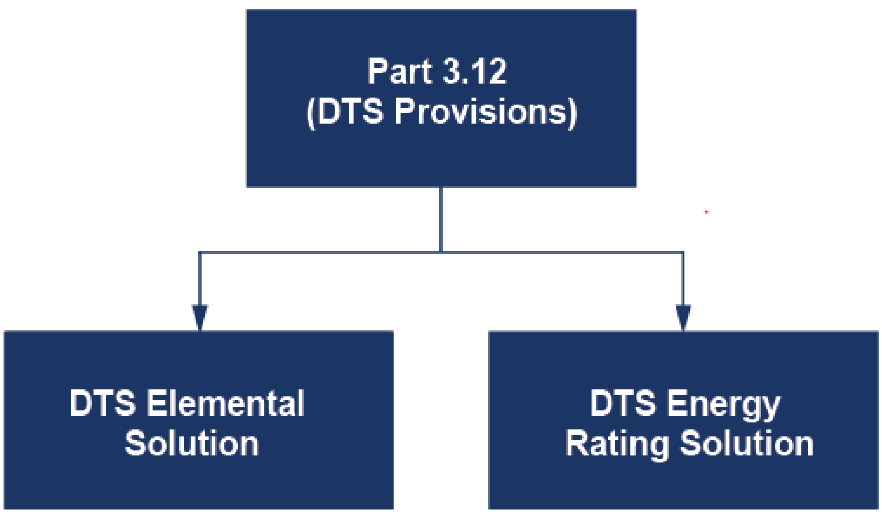
There is a second Performance Requirement related to energy efficiency in NCC Volume Two. Performance Requirement P2.6.2 relates to the domestic services associated with a house and is not covered by this Case Study.

C.3 Compliance Solutions

C.3.1 DtS Solution

There are two DtS Solutions outlined in NCC Volume Two in Part 3.12; the DtS Elemental Solution and DtS Energy Rating Solution. The use of either of these solutions is deemed to comply with Performance Requirement P2.6.1.

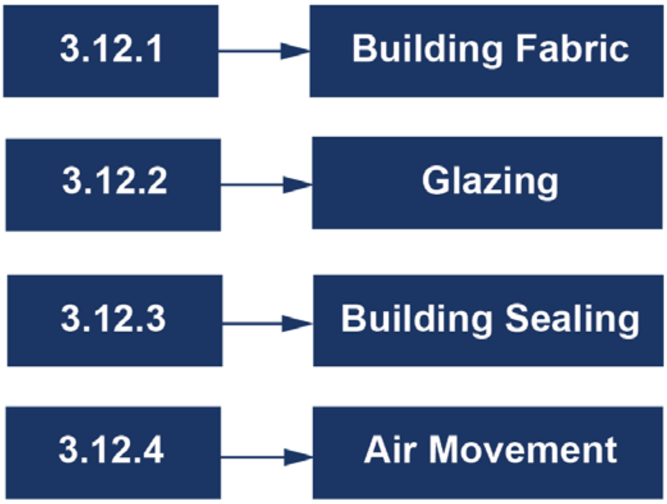
Figure 27 DtS Solutions in NCC Volume Two for P2.6.1



DtS Elemental Solution

A DtS Elemental Solution for meeting the Performance Requirement P2.6.1 uses the DtS Provisions that are specified in the Parts 3.12.1 to 3.12.4 of NCC Volume Two. These provisions are shown in the following figure.

Figure 28 Relevant DtS Provisions for an Elemental Solution



DtS Energy Rating Solution

The DtS Energy Rating Solution of meeting the Performance Requirement P2.6.1 is a method of satisfying the DtS Provisions using software accredited under the NatHERS to work out the relevant energy rating. The method also requires compliance with certain additional requirements in the DtS Elemental Provisions to achieve full compliance.

C.4 Performance Solution

Performance Solution means a method of complying with the Performance Requirements other than by a DtS Solution. A Performance Solution addresses the individual relevant Performance Requirements using one or more of the NCC's Assessment Methods.

Further information on developing a Performance Solution can be found at [www.abcb.gov.au.](http://www.abcb.gov.au)