
Architecture
Interior Design
Landscape Architecture
Planning
Urban Design
Australia
PR China
Hong Kong SAR
Singapore
Thailand
KARRATHA VERNACULAR_
DESIGN PRINCIPLES
Prepared for LandCorp
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HASSELL

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Content

1.0____Introduction

This document has been prepared to inform developers of the expectations of the Shire of Roebourne in conjunction with LandCorp and their partners to create a new paradigm for development in Karratha. There is a strong acknowledgement that current development practices are not delivering the required social benefits for the community of Karratha that will secure its transformation from a resource town into a City of the North. A key objective for this paradigm shift is to set a new benchmark for “beauty” and “excellence” in design, built form and service delivery.

The purpose of this document is to outline a set of design principles that developers will need to address for new developments within the city centre and residential estates. Whilst providing a focus on the ‘city core’ and ‘Mulataga’ developments this document is intended to be a guide for all developments within Karratha. This should be seen as an opportunity to create a standard of design for the built form and public realm not before seen within arid climates in Australia. This document does not provide an exhaustive list of design principles or set criteria for inclusion into development proposals however it does seek to inform developers of important built form and public realm elements that when taken holistically, will contribute towards an intended vernacular for Karratha.

For statutory planning provisions the reader must refer to the Shire of Roebourne Town Planning Scheme No. 8, local planning policies and any adopted Development Plan; relevant legislative requirements; relevant planning policies, development control policies and planning bulletins published by the Western Australian Planning Commission; and other publications or guidelines produced by state agencies.

Figure 1: Karratha is set to become a major regional centre in Western Australia and the principal city of the Pilbara.

1.0____Introduction

Karratha's vernacular is informed by the climate, its landscape, people and activities, availability of materials, governance systems and availability of skills. These elements influence how buildings and public spaces are designed, located and brought together to create a town and a sense of place.

For Karratha to evolve into a 'city of the north', a focus on design, quality, liveability and enjoyment is imperative. No longer can the focus be on the functional and temporary. A sense of permanence and quality must be established throughout Karratha for it to flourish.

The Karratha Vernacular study identifies matters that influence design and suggests a new approach to building and public realm design.

Figure 2: Sense of Karratha palette

This diagram shows the existing morphology of Karratha. The hills, tidal flats and Nickol Bay contain the urban spread into a linear pattern. The residential expansion area of Mulataga is to the east, with the city core being at Karratha's heart. Linear drainage lines are key features in the constructed landscape.

Figure 3: Karratha's Morphology

2.0____The Informing Elements

This chapter outlines the three elements that inform the Karratha Vernacular. These elements are:
_Natural Systems and Processes
_People and Activities
_Buildings and Technology

Each of these elements is broken into groups, which then inform the design principles that need to be taken into account for Karratha.

Natural Systems and Processes
The climate and landscape are key factors influencing Karratha's sense of place. In the absence of high quality built form, Karratha is largely understood through its landscape and climate. Historically, Karratha's buildings have not responded to the climate or landscape, but rather fought against or ignored it. This is evident in the way buildings are inwardly focused and turn away from streets and movement lines. By responding to Karratha's natural systems and processes, the built form and public realm will be more usable, enjoyable and sustainable.

People and Activities
Karratha's people are its life blood and their activities give meaning to Karratha beyond a mining town. Building and public realm design needs to understand the priorities of the local population - not just today, but for a city of 50,000 plus residents. Necessarily then, attitudes, activities and needs of buildings, precincts and the public realm will change over time. Design needs to be robust, to ensure it is appropriate for today and tomorrow.

Buildings and Technology
Karratha's built form needs to improve so that it can become a more sustainable, place appropriate and liveable city. Buildings and associated technology will form a key part of Karratha's transformation. A robust built form response to exisiting cyclonic and other climatic conditions is required. Buildings need to respond much better to the climate and to the public realm to allow activity and life to emerge, particularly within the city centre.

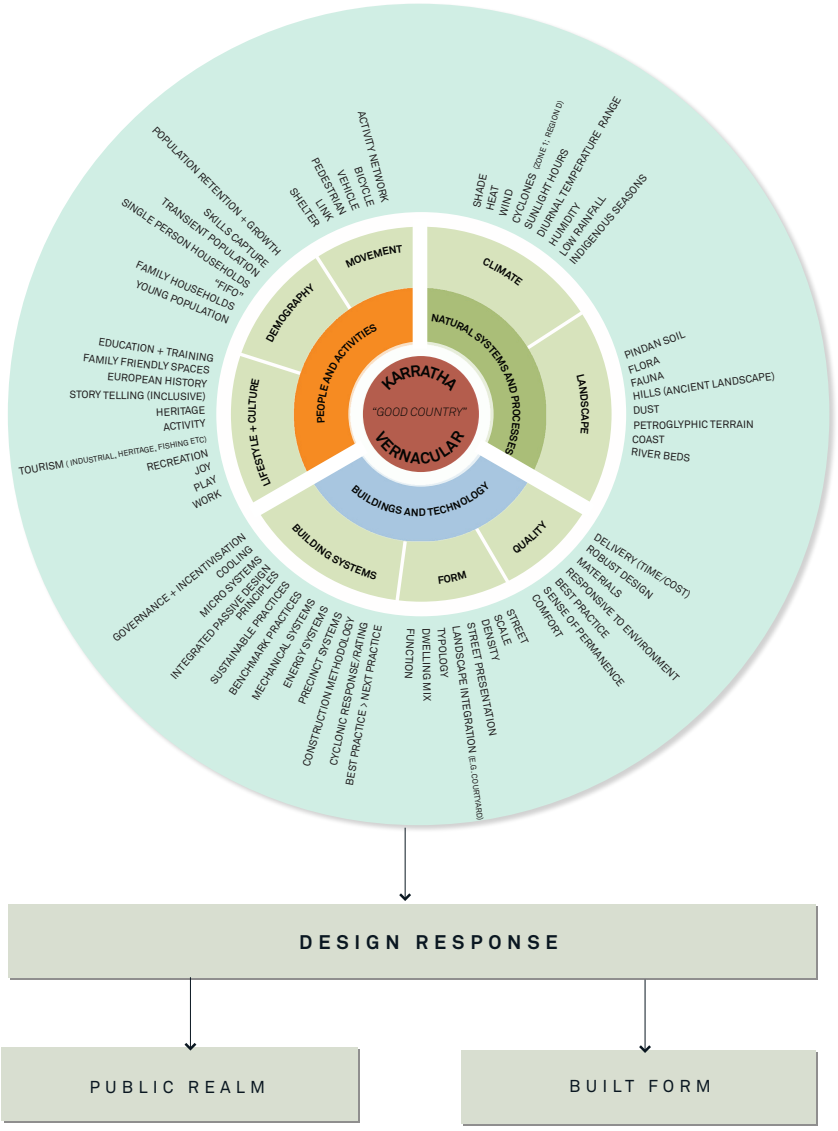


Figure 4: Karratha Vernacular wheel showing the informing elements

2.0____The Informing Elements

Image caption

2.0____The Informing Elements

2.1 Report Structure

This report is structured into the following chapters:

Preliminary Principles_ This section will give a background understanding of the three elements that contribute to Karratha's Vernacular - Buildings and Technology, People and Activities and Natural Systems and Processes

Design Response_ This section will establish how the preliminary principles may be addressed through the public realm and built form

Public Realm_ Strategies to public realm design that improve the quality of life for Karratha residents

Built Form_ Building methodologies and systems appropriate for Karratha

A colour code is used throughout the report to identify where the topics relate to the Karratha Vernacular wheel.

2.2 For the Developer

In considering design for Karratha, and to contribute towards the intended vernacular, developers and designers must consider the elements within the Karratha Vernacular wheel and incorporate them as best as possible into the building. Not all elements will necessarily be relevant or appropriate to each site, however design should be undertaken in good faith to consider the Karratha Vernacular elements where possible.

This document does not seek to inform the architectural style of buildings. It does seek to inform developers of important building and public realm elements that when taken holistically, will contribute towards an intended vernacular for Karratha.

To achieve a Karratha Vernacular, elements from Buildings and Technology, People and Activities and Natural Systems and Processes need to be included in the design.

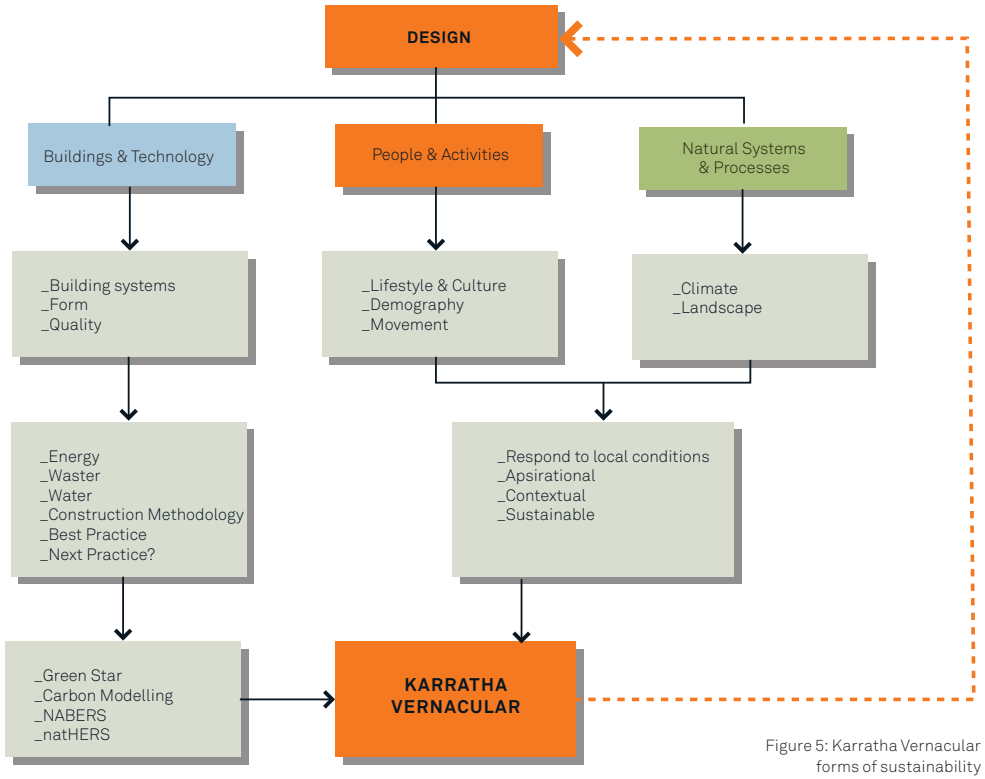


Figure 5: Karratha Vernacular forms of sustainability

This chapter describes the factors associated with Karratha's natural systems and processes to inform the principles that should guide design and development.

3.1 Temperature and Design

Karratha has a very tenable climate from late April through to October for employing natural cooling. It is accepted though, that mechanical cooling will be required during Karratha's hot summer.

The design of a building which is well suited to natural ventilation (high ceilings, high openable area, low thermal mass, relief air louvres) can be in conflict with the design of an air conditioned building (well sealed, minimal volume, well insulated, high thermal mass, continuous impervious vapour barrier etc). Therefore it is difficult to design a building which is well suited to both.

For example, a significant advantage of having an increased set point in air conditioning mode is that the internal dew point will be higher, and therefore the vapour pressure differential between outdoors and indoors will be lower and the risk of condensation problems will be minimised.

A good building design for Karratha will optimise the natural cooling potential during the winter months, and minimise the energy usage of air conditioning systems during summer months. Managing this conflict will go some way to developing a distinctive Karratha vernacular.

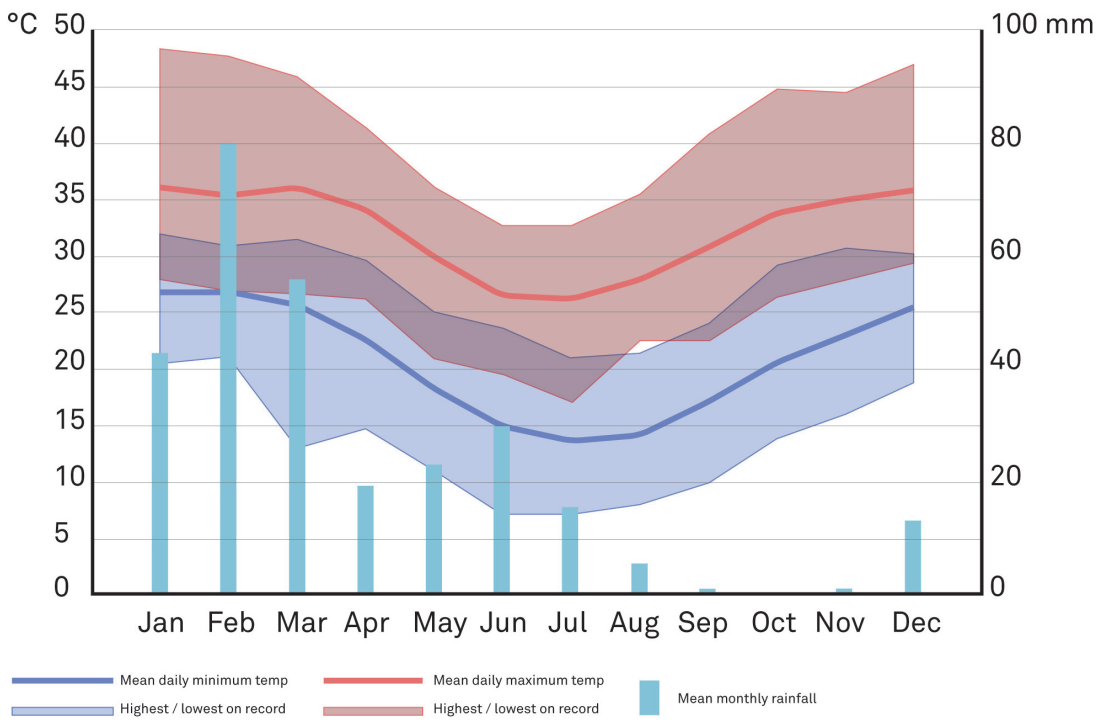


Figure 6: Karratha's yearly air temperatures and average rainfall

Principle:
Design of buildings and the public realm should acknowledge the comfortable winter temperatures and help to moderate hot summer temperatures

Principle:
Buildings should have an openable outer zone and a sealed inner zone to assist efficient cooling during summer and passive ventilation during winter.

3.2 Humidity

Whilst often hot and dry, Karratha can also be particularly humid, though measurement of humidity can be paradoxical based on typical relative humidity (RH) levels. RH alone cannot be used as a meaningful measure of humidity. As an example, 30% RH at 30°C ambient temperature is fairly 'dry' (with a wet bulb temperature of 18°C), however 30% RH at 40°C ambient temperature is extremely 'humid' (with a wet bulb temperature of 25°C and approximately double the moisture content in the air).

A much better way of measuring the humidity is either directly via wet bulb temperature, or by actual moisture content expressed in kg of water per kg of air. The moisture content of the air is much higher in Karratha than it is in Perth, particularly in the summer months. In the summer months Karratha is approximately twice as humid as Perth.

This has implications for the mechanical cooling systems that can be used, and particularly, evaporative cooling will be ineffective. However, for outdoor situations, water misting systems can promote a cooling effect whilst also making spaces 'appear' cooler. Other options may include water features and extensive shading.

Principle:
Internal cooling systems will need to be appropriate for Karratha's humid climate. Evaporative systems will not cope in Karratha.

Principle:
Evaporative cooling such as external misters can have a beneficial psychological cooling effect and should be considered for outdoor spaces.

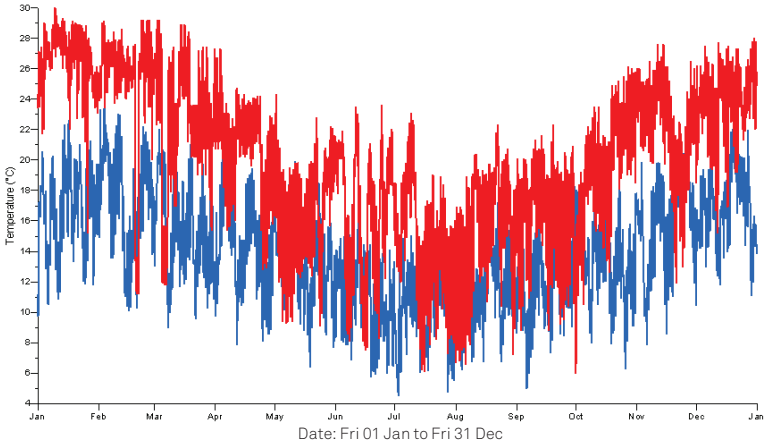


Figure 7: Karratha's yearly 'wet bulb' temperature

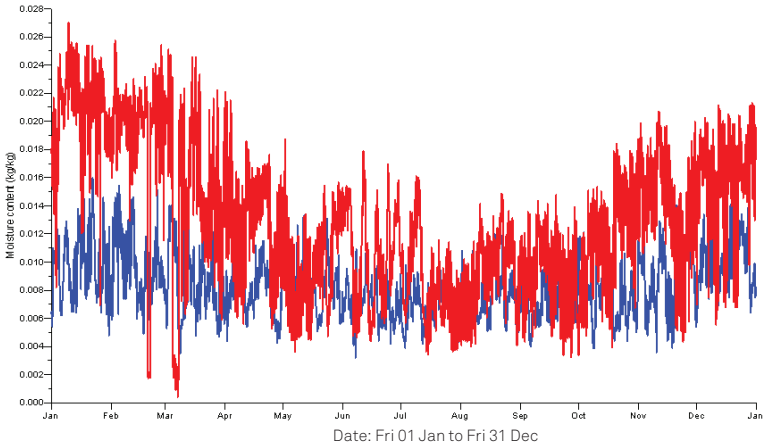


Figure 8: Moisture content in Karratha's air

3.3 Climate Tolerance and Adaptive Comfort

The principle of adaptive comfort dictates, in simple terms, that people who live in warmer climates become more tolerant of higher indoor temperatures.

As seen in the figure to the right, in a climate with an average temperture around 28ºC, an occupant's tolerance level of being 'comfortable' would extend to approcimately 26 – 27ºC. Buildings in Perth would traditionally be cooled to 22-24ºC in the peak of summer. It is estimated that for each 0.5ºC that the set point is increased, the HVAC energy usage reduces by ~5%.

The design set-point norm for buildings in Karratha should be challenged so that if the air-conditioning systems are designed so that they are only capable of achieving 26-27c in the peak of summer, which based on the principles of adaptive comfort should be a reasonable set point for this climate, then it is possible that the energy usage could be reduced by up to 30%.

If buildings are designed to achieve 22-24ºC during peak summer conditions then often the users will set them to achieve these conditions, but by modifying the design capacity, over cooling would no longer be an option and energy waste can be reduced.

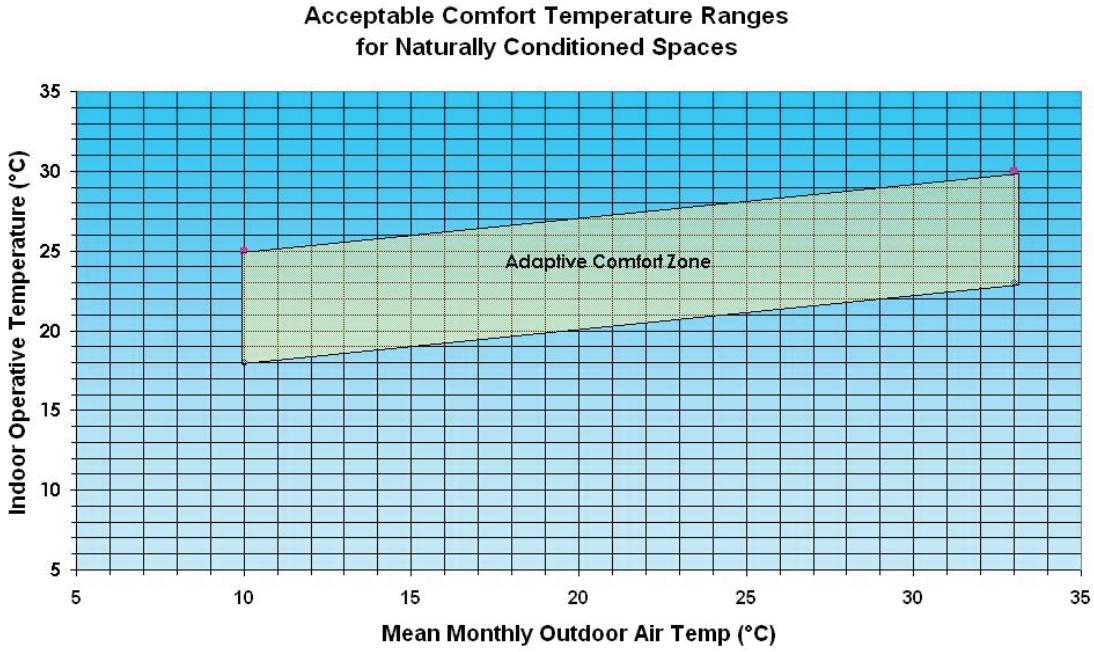


Figure 9: Adaptive comfort graph

Principle:
Buildings must be designed to be comfortable with no assistance from mechanical cooling during winter months.

Principle:
In summer months, it is accepted mechanical cooling will be required. Buildings should be designed to contain cooled air, with appropriate floor zoning.

3.4 Prevailing Winds

Karratha's prevailing winds throughout the year are dominated by westerly breezes. Due to Karratha's location away from the west coast and its hot temperatures, these breezes are heated by the land and provide little to no cooling benefit over the summer months. The wind roses to the right indicate the wind directions throughout the year.

Built form and public realm design will need to attenuate the effect of Karratha's hot winds such that living environments can be more sustainable.

Principle:
Hot westerly winds should be shielded, whilst capturing the benefits of the cooler north-easterly breezes from Nickol Bay.

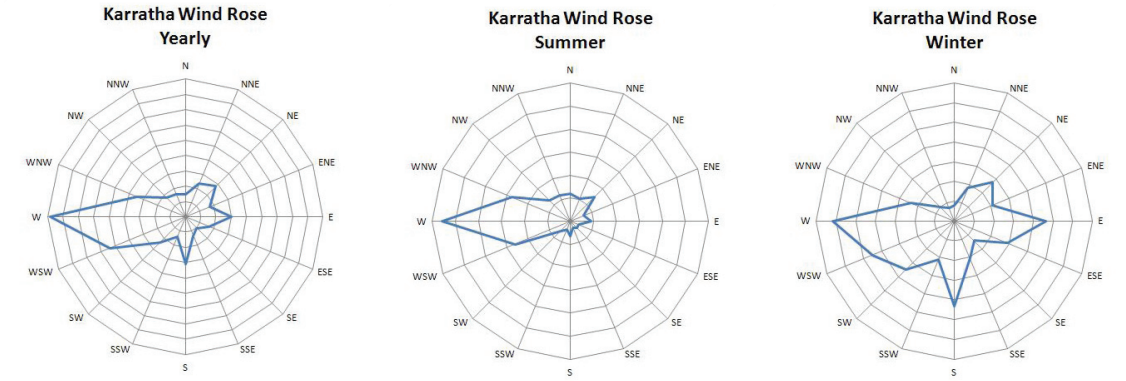


Figure 10: Karratha's prevailing winds

3.5 Wind Speed

The average wind speed for Karratha is 4.8 metres per second. Wind power should be considered for Karratha in suitable locations that do not cause excessive noise pollution, however turbines will need to be appropriately designed to withstand cyclones. Tilt-down turbines are available for cyclone prone regions and can withstand winds up to 250 km per hour.

Principle:
Wind power may be an alternative power source for Karratha in selected cases. 60 turbines would power around 4,500 homes.

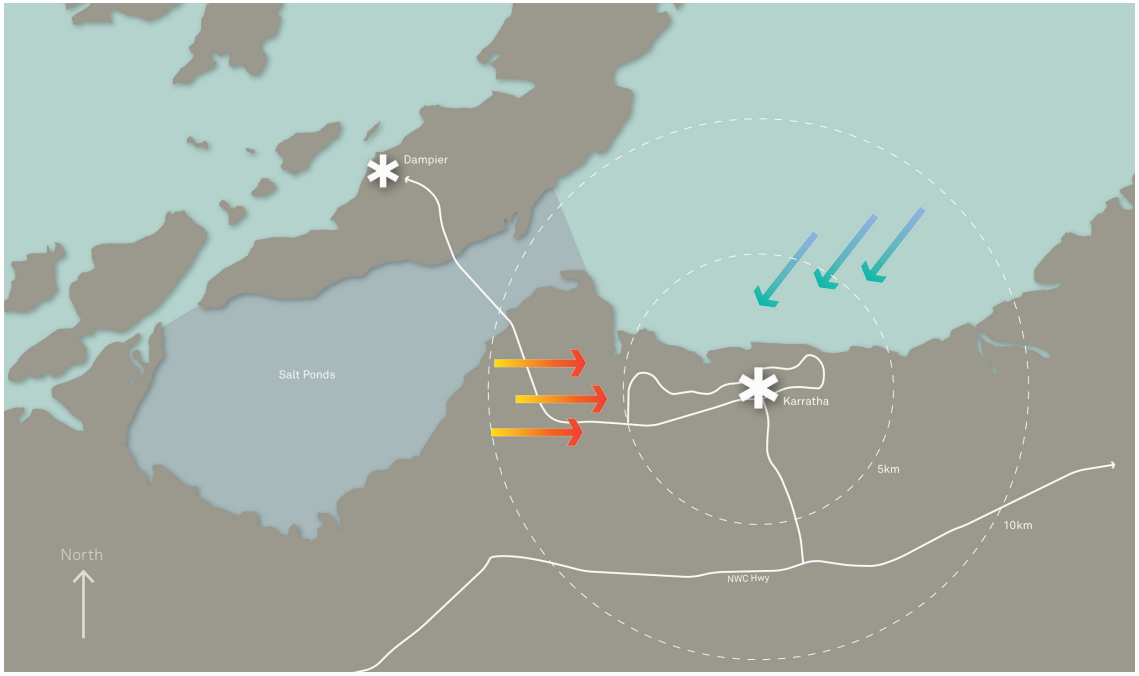


Figure 11: Karratha is located away from the west coast, meaning there is little benefit from cool breezes during the summer

3.6 Cyclones

The Pilbara coast on which Karratha is situated is one of the most prone in Australia to severe tropical cyclones. As such, Karratha is classified by the Building Code of Australia as a Region D environment, where buildings must be designed to withstand extreme winds and pressure differentials.

Historically to withstand these conditions, approaches to design have created 'fortresses' and have often conflicted with opportunities for sustainable and passive design solutions. In particular, window placement and size, door types and external wall requirements have minimised opportunity for cross ventilation.

It should be noted that there are comparatively few settlements within Region D and none that have warranted large scale building development in the past. This has meant there has not been as significant or detailed research into the design of buildings to accommodate liveability and withstand extreme cyclonic events. This is set to change with Karratha evolving from a mining town to a city of 50,000 plus people.

Principle:
Buildings must be designed to withstand cyclonic forces, but should also exhibit beauty and a sense of place.

Figure 12: Region D as identified by the Building Code of Australia, which requires buildings to withstand cyclones up to a category 5 with 280 km/hr wind

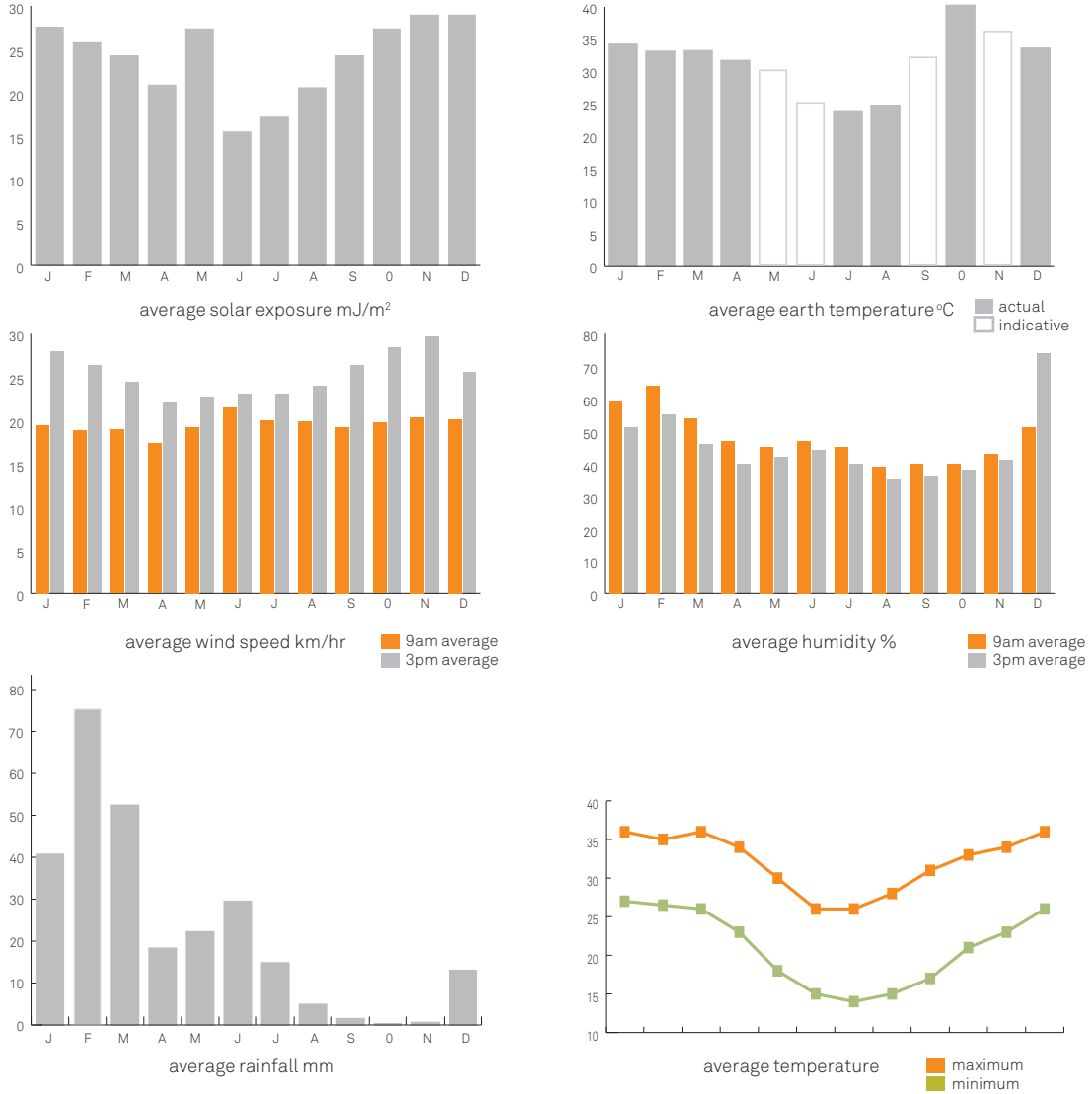


Figure 13: A summary in table form of Karratha's climate

3.7 Rainfall

Karrathas rainfall during the year is generally low and sporadic, with the average being between 254mm and 305mm. Most rain falls in the summer months and can be associated with cyclonic events.

Karratha's hot climate also means evaporation rates are high. This causes soil conditions to be very dry. The approach to planting and landscape design will need to respond to these tough conditions.

3.8 Sunlight Hours

Karratha's low rainfall and clear skies combine to provide long daylight hours. This is conducive to promoting solar as an alternative energy source (refer figure 15). To power 4,500 homes from solar cells, each roof would need 3kW of cells.

Principle:
Photovoltaic cells must be considered for all development proposals.

3.9 Solar Energy

Karratha has an average solar irradiation of 6.62 kWh/m²/day which is 24% higher than Perth, and is amongst the highest in the world (refer figure 14). The viability of photo-voltaic cells and solar thermal is at its highest in Karratha. Extensive use of photo-voltaic cells will be considered favourably. Details on PV cells are in the body of the report. Hot water systems need to take account of the quality of the local water supply.

Principle:
Solar hot water systems are mandatory and PV cells for homes highly encouraged.

Principle:
Public realm and landscape design needs to tolerate dry and hot conditions.

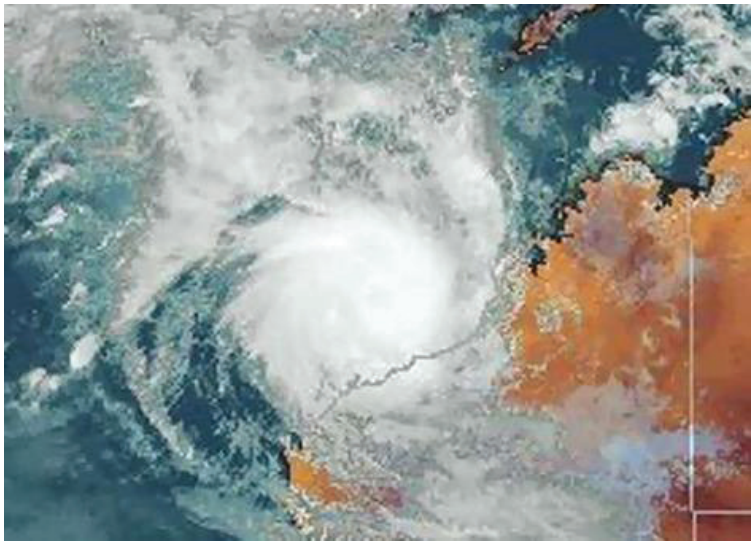


Figure 14: Cyclones and tropical lows bring rain to Karratha, often with large falls over relatively short periods of time. *(source: Bureau of Meteorology)*

Figure 15: Karratha is within a region that receives some of the highest solar irradiation in the world

3.10 Design Response

Design must respond to natural systems and processes. These images below show buildings and public realm landscapes in areas where solar irradiation is high and summer temperatures are very hot.

Principle:
In hot climates buildings must provide extensive shade, promote air movement, bring the outdoors in through interstitial space and create beauty.

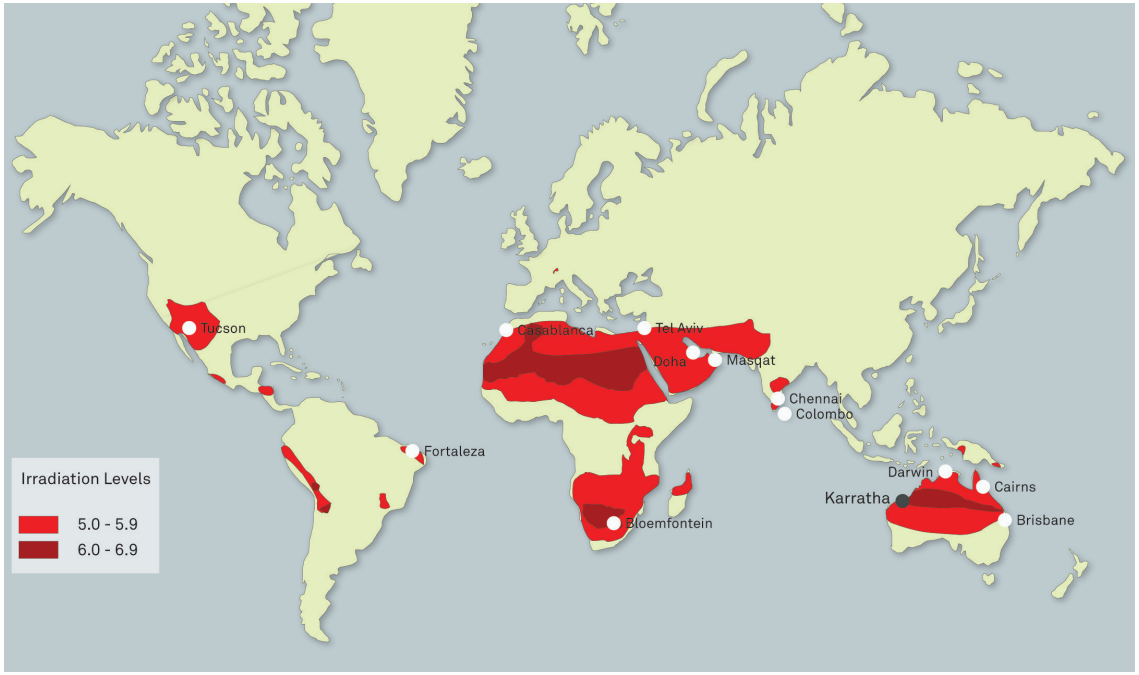


Figure 16: This diagram shows major centres throughout the world where very hot summer temperatures are evident and a local vernacular has been created.

Design Response: Shade


Brisbane


Arizona


Arizona


Darwin


Phoenix

Design Response: Cross Ventilation


Arizona


Brisbane

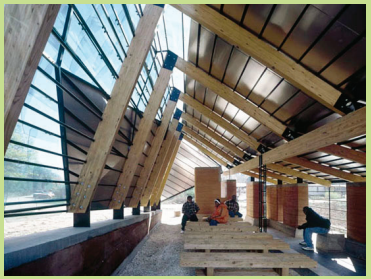

Northern Territory


Tucson


Iran

Design Response: Interstitial Spaces


Brisbane


Arizona


Phoenix


Muscat


Muscat

Design Response: Beauty


Muscat


Arizona


Darwin


Casablanca


Casablanca

3.0___Design Principles

The following table shows demographic characteristics for Karratha, derived from the Karratha City Growth Plan and design responses:

Demographic Characteristic	Design Principles
A transient population, comprising fly-in / fly-out workers and short term residents with financial commitments in other parts of the state or country. The quality of the environment and access to services contributes to people's propensity to stay within the region. As Karratha grows to a city of 50,000 people and services improve, particularly within the city centre, the transient nature of the population should diminish.	**An emphasis on creating quality built form that responds to the local environment and needs of people will improve liveability. Karratha's city core will need to accommodate a range of activities so that it becomes a destination of choice.**
Lower proportions of young people (10-19 years) compared to the State average. Access to quality higher education influences the propensity of families and young peope aged between 10 and 19 to stay in Karratha. In particular, boarding schools in Perth attract young people away from the region. Additionally, a lack of services and recreation opportunities for young adults diminishes the attractiveness of Karratha.	**By improving the quality and mix of functions in the city core and other areas of Karratha, through design quality and intensity of development, young adults are more likely to stay within the region.**
Lower proportions of older people (50 plus years) compared to the State average. The high cost of living means retiring in the Pilbara is financially restrictive. As a region, the Pilbara is not competitive with other areas such as Perth and the South West, where living costs are significantly lower.	**A design response is to provide alternative living opportunities, such as smaller dwellings that have lower running costs.**
A high cost of living, with major factors being the high cost of housing and price escalation when goods are transported to the region. Some housing products, such as glazing, are constructed in Karratha for local conditions, however a significant proportion of materials needs to be transported from Perth or inter-state.	**Development proposals must seek to reduce supply chain costs - these can be reduced through improved efficiencies with local production as well as decreased costs associated with transport, and potentially through diminishing holding costs.**

Demographic Characteristic	Design Principles
A high median weekly household income of $2,078 – double that of regional Western Australia more broadly ($1,005) and the Perth metropolitan area ($1,086) – but significant income disparities within the community. The high median income and propensity for mining industry companies to offset living costs for employees masks the issue of high living costs within the region.	**Alternative housing solutions, such as dwellings designed for shared housing, smaller dwellings and smaller lots will decrease living costs for residents within Karratha.**
A low proportion of owner-occupiers (37%) compared to regional Western Australia (66%) and Perth (73%). This is attributable to mining industry businesses providing houses at subsidised rates to their employees. This in itself is not a negative element, except that it diminishes the emotional ties residents may have to Karratha. To increase home ownership rates, residents must want to stay in Karratha for longer periods.	**Improved quality within the city centre and residential areas, as well as improved access to services and recreation will help to promote greater levels of home ownership.**
17% lone person households (lower than State average). The high cost of living means families or shared households are likely to predominate in Karratha.	**To cater for smaller households, a greater range of small dwellings and lots should be provided, such as apartment living within the city centre and within residential areas near to points of amenity. In residential areas such as Mulataga, this means apartments and smaller dwellings should be located closer to Nickol Bay and areas of open space.**
51% households with children (higher than State average). The high rate of children means appropriate opportunities for low cost activity need to be provided. This has ramifications for open space design and for the provision of slow traffic streets.	**Open spaces should allow informal play, have extensive shade and include meeting points for parents and children. Streets should be narrow and promote slow vehicle movements - long and wide roads should be avoided.**

3.11 Aboriginal Heritage and Liaison

The Ngarluma and Yindjibarndi groups are the traditional landowners of the lands around Karratha. The rich heritage and story of the local Aboriginal people has the potential to bring a unique sense of place to Karratha. Through consultation, the story of the land and people can be woven into the urban fabric of Karratha.

There is a significant number of engraving sites, middens and the like around Karratha. Adequate studies of these sites should be undertaken and strategies to retain and enhance the local Aboriginal heritage should be prepared.

Principle:
Recognition and celebration of local Aboriginal heritage and culture will solidify Karratha's sense of place. It should influence design of the public realm and landscape.

Principle:
Development will need to respect and in many cases retain places of Aboriginal heritage significance. Positive and ongoing consultation will be required with local Aboriginal groups.

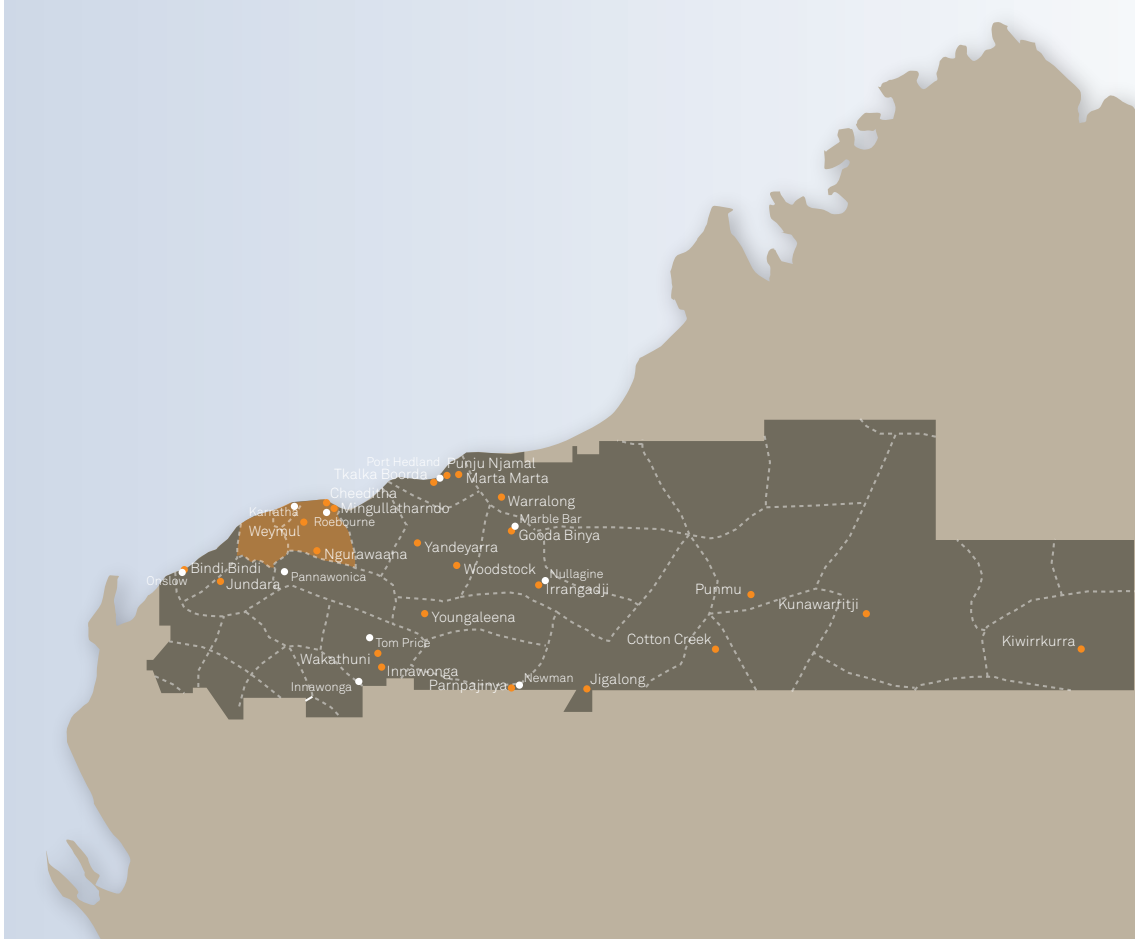


Figure 17: A map of the Pilbarra showing the geographical areas of each indigenous community.

3.12 Lifestyle and Culture

Pilbara and indeed Karratha life is distinct from the goings-on of other regions in Western Australia. The Pilbara's relative isolation, distinct environmental qualities and economy have combined to ensure the community is interconnected.

Notwithstanding a strong community, there have been few places within Karratha's built environment to celebrate it. Sporting clubs and coastal activities such as fishing have been the few outlets for Karratha residents.

Karratha's city centre must develop to become a destination of choice and provide alternative activities for the community. Mulataga and other residential areas must have safe and attractive streets, parks and community centres to promote a sense of place and activity.

Principle:
The city core will be a destination of choice. It must offer activity at ground level and allow that activity to spill out onto streetside footpaths. High quality interstitial spaces will be key.

Principle:
Extensive shade will be necessary to promote comfortable outdoor environments in the city core. This will be achieved by extensive tree planting and fixed shade structures.

Design Response: Activity and Destination


Alfresco


Water


Casual


People


Comfort

Design Response: Aboriginal Culture


Art


Story Telling


Elders


Land

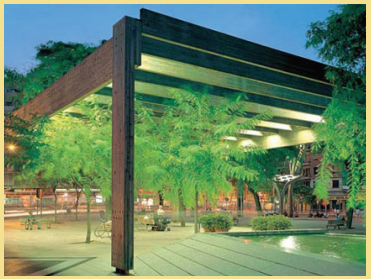

Sea

Design Response: Safety


Slow Streets


Casual Surveillance


Legibility


Lighting


Activity

Design Response: Variety


Quiet and Contemplative


Sculpture and Art

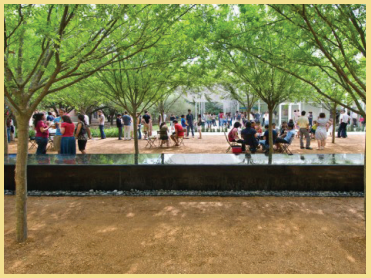

Public Gathering


Intimacy


Active Streets

Design Response: Respite


Water


Shaded Landscapes


Mood Lighting


Constructed Shade

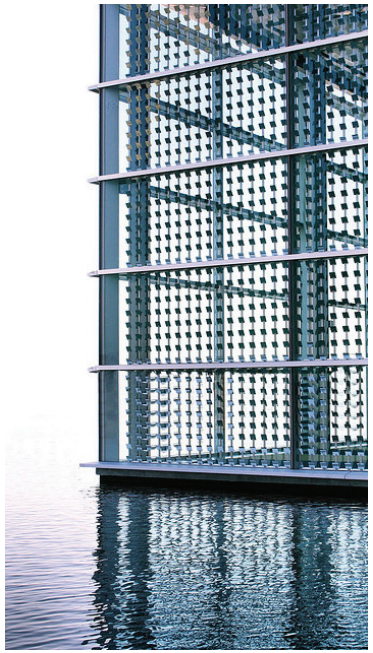

Private Space

3.13 Karratha's Character

Karratha's vernacular will be established over time and be informed by the type and scale of buildings, the materials used, the intensity and type of activity, the composition of urban form and the way these elements are arranged and inter-relate.

Figure 18: Examples of built form and spatial typology responses to Karratha Vernacular design

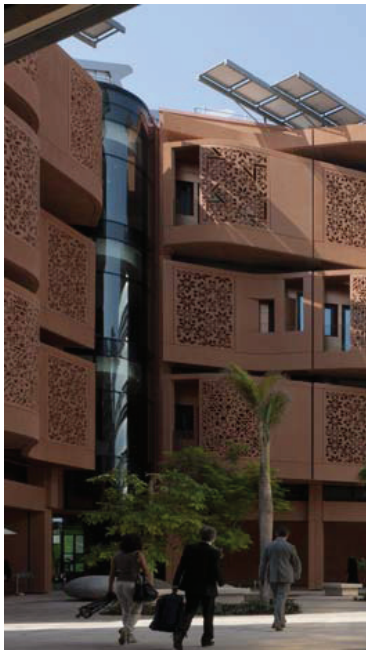
City Core Built Form Principles



Principle:
Beauty and excellence

Principle:
Iconic and easily recognisable

Principle:
Mix of uses and activity



Principle:
Best practice design for arid climates

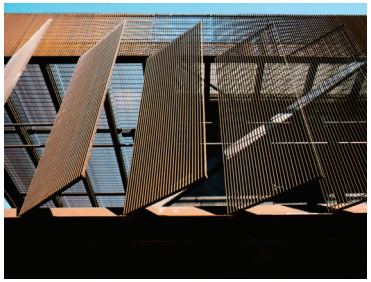
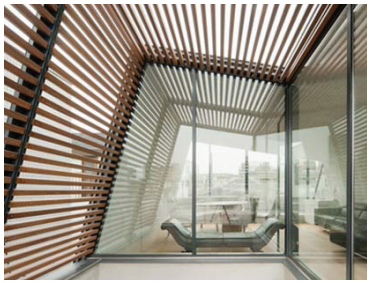
Principle:
Human scale

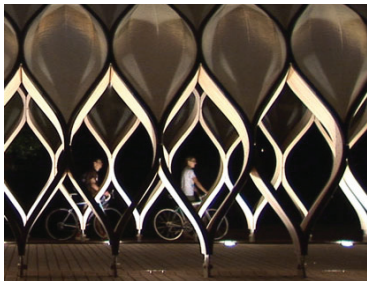
3.13.1 City Core Form

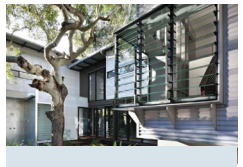
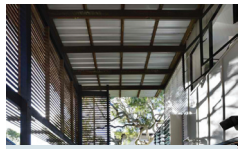
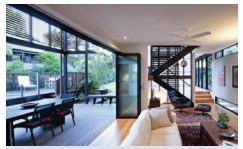
For the city core, it is intended to be a key attraction for residents and visitors to Karratha. The buildings in the city core will contribute to this attraction and be characterised by:

_pedestrian scale at the street interface up to four storeys in height
_additional height up to 8 storeys subject to achievement of identified objectives
_nil setbacks to the street at ground level
_a consistent street wall to contain activity
_pedestrian shelter to provide shade and rain protection along the footpath
_wide eaves
_regular openings (windows and doors) to ground floor tenancies such as shops and restaurants
_alfresco dining on the footpath
_shading devices attached to building facades creating a veil for sun protection
_solid materials such as concrete or brick, mixed with steel, stone, cladding will comprise the majority of building materials, complemented by glazing which is shaded from the sun

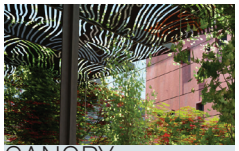




ELEMENTS	MATERIALS AND TEXTURE	FORM
 SCREENS		
 SHADE		
 ROOF		
 OPENINGS		
 VERANDAHS		
 WALLS		

ELEMENTS



CANOPY

TRANSITION

GROUND PLANE

ACTIVITY

STREET

QUALITY

ELEMENTS

SCREENS

SHADE

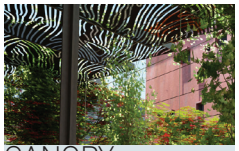
ROOF

OPENINGS

VERANDAHS

WALLS

ELEMENTS



CANOPY

TRANSITION

GROUND PLANE

ACTIVITY

STREET

QUALITY

3.13.4 Containment of Activity

Karrathas city centre suffers from a lack of intensity. Development must contribute to the intended character and intensity through a coordinated growth stratgey. Buildings and their functions need to firstly reinforce the city core and then activate the key movement lines like these other examples from Western Australia.

Karratha

_Location : 1545km North of Perth
_Town Centre: Approx 23ha
_Population: 11,728*

Bunbury

_Location : 173km South of Perth
_Area: Approx 29ha
_Population: 54,482

Albany

_Location : 418km South of Perth
_Area: Approx 74ha
_Population 31,586

Geraldton

_Location : 434km North of Perth
_Area: Approx 23ha
_Population: 36,343

Port Hedland

_Location : 1650km North of Perth
_Area: Approx 6ha
_Population: 12,776

Margaret River

_Location : 269km South of Perth
_Area: Approx 17ha
_Population: 12,776

Town Centre
Centre Frame
Residential
Other Development Area

Figure 19: These town centre diagrams compare Karratha's city centre with other regional centres around WA. These other centres are supported by less intense 'frame' functions that bleed into residential areas. The most successful centres blend functions to create a mixed use environment that is comfortable and attractive to pedestrians. *ABS Data: 2006.

Mulataga Built Form Principles

Principle:
Clear connections to centres and amenity

Principle:
Responsive to local conditions

Principle:
Safe and attractive streets

Principle:
Amenity

Principle:
Mix of dwelling and lot types

3.13.2 Mulataga Key Principles

Mulataga will become a relaxed, comfortable and liveable place that contributes to people's understanding of Karratha as a high quality, beautiful and loved environment. The Karratha City Growth Plan identifies Mulataga as a unique opportunity to create a diverse coastal community with a strong connection to Nickol Bay. In order to contain growth of Karratha and ensure the town remains contiguous, residential densities will need to increase. The Karrata City Growth Plan identifies residential densities between R20 and R80 for Mulataga, meaning there will be a range of dwelling types and lot sizes for single dwellings, grouped dwellings and multiple dwellings. A lower order district centre is also intended to be located at Mulataga to service the adjacent residential areas.

These principles have been used to guide the form of Mulataga and other residential estates, identified in the Karratha City Growth Plan:

The Precinct will be well connected to the coast and the Bulgarra residential area, and designed in a manner that is highly responsive to the surrounding landform and coastal environment. The Precinct will develop from the west, progressing east towards the coast and then south towards the Hills.

The strong focus and connectivity to the water and coast of this precinct is unique to Karratha and should be celebrated in the design of the public realm with more playful responses involving public and community art, lighting, waterplay activities, and densely shaded meeting areas. This amenity should be focussed predominantly around the inlet and higher density areas as an urban response. The coastal nature of this precinct will necessitate the selection of robust and stable materials able to withstand salt laden winds and saline soils. Exotic and native coastal trees should be established which echo its place as a Pilbara coastal community. The colours and textures of materials used in the public realm should reflect the Pilbara coast, its mangroves, and salt marshes.

3.13.3 Mulataga Form

For Mulataga, it is intended to be a key residential area complemented by a district centre with excellent connections to the coast. The buildings in Mulataga will contribute to the relaxed atmosphere, liveability and be characterised by:

_for single dwellings, lot sizes generally from 180 square metres to 500 square metres
_single residential buildings constructed of light weight materials and only selective use of brick
_large verandahs, porches and patios
_single and two storey dwellings
_some dwellings will be raised off the ground on stilts to capture breezes
_roofs of corrugated iron
_shading devices and fixed louvres
_some higher density developments such as town houses and apartment buildings, particularly around parks and close to points of amenity
_buildings oriented to the north and north east to capture available sea breezes
_minimal openings and wall lengths to the east and west to limit heat gain
_single residential dwellings generally set back from the boundaries to provide breeze penetration
_where possible, buildings will be one room deep to promote cross ventilation from the north and north east
_large eaves
_air conditioning to mitigate the effects of extreme temperatures

Principle:
Materials used should be of high quality and not be of an industrial aesthetic. Blue metal and sheet metal fencing on or adjacent to the street verge should be avoided.

Design Response: Scale

Footpath

Street Interface

Street

Residential Scale

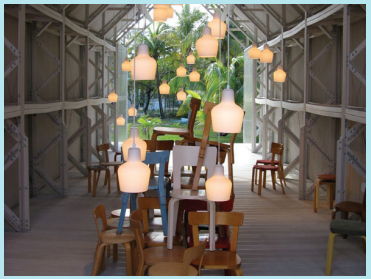
City Core Scale

Design Response: Mixed Use

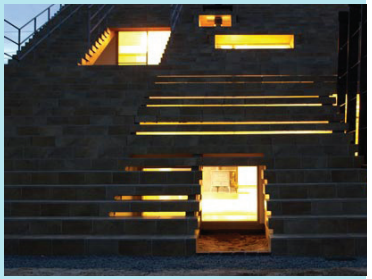
Entertainment

Living

Shopping

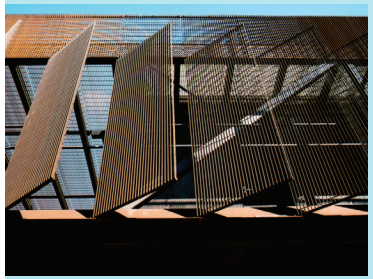


Lifestyle



Work

Design Response: Materials



Shade Screens

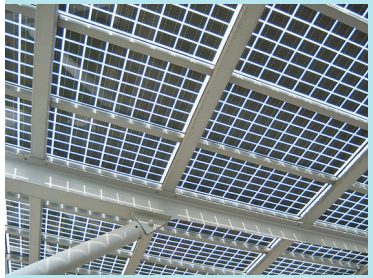
Iron

Stone

Steel

Openings

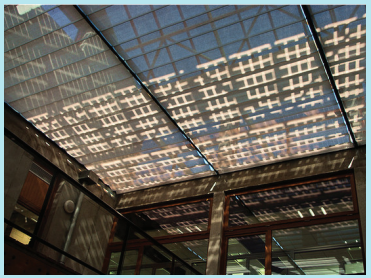
Design Response: Energy



Solar

Wind

Passive Design



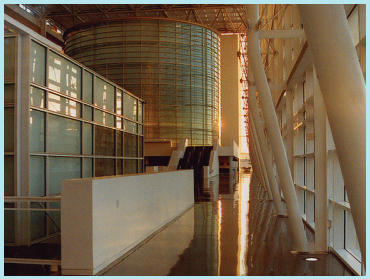
Insulation

Shade Systems

Design Response: Floor Zoning

Internal rooms can be enclosed

Shaded external spaces



Indoor - Outdoor

Openings for winter

Shaded Eaves

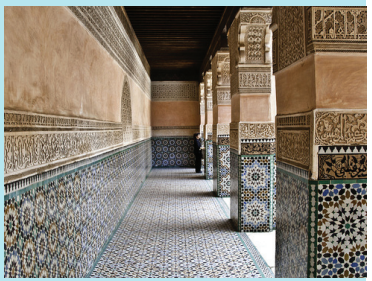
Design Response: Cooling Systems

District Cooling

Water in the Landscape

Shade

Public Shading and Water



Appropriate Materials

4.0____Public Realm Design

4.1 Active Public Realm

An essential part of the Karratha Vernacular is the creation of external spaces that are alive with people enjoying the public realm. The provision of interactive public spaces which incorporate al fresco dining, cafes, bars, shops and community facilities will enliven the city and enrich the quality of the urban experience for the residents and visitors.

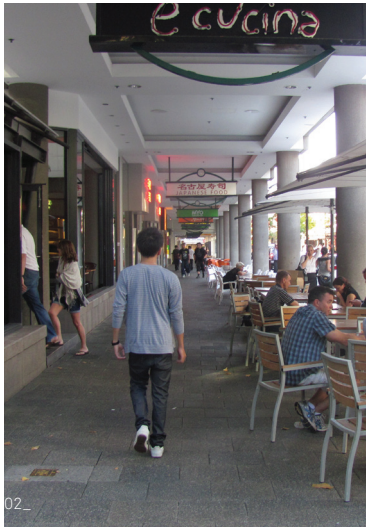
In order to create this activation the planning of streetscapes and the planning of building usages and the orientation of their active frontages is an essential part of the process. The interaction of the frontages with the make up of the sidewalks and the relationship to parked vehicles and tree planting should be considered along with the planning of road widths which are humane in scale.

Due to the hot temperatures experienced year round in Karratha it is imperative spaces are formed which provide shade and opportunities for people to cool down and take refuge from the sun. This principle is relevant for both the city centre and residential estates.

The design process then will need to consider these complementary factors to ensure that people are encouraged to move, relax and play outside but also that this experience is a comfortable and pleasant experience.

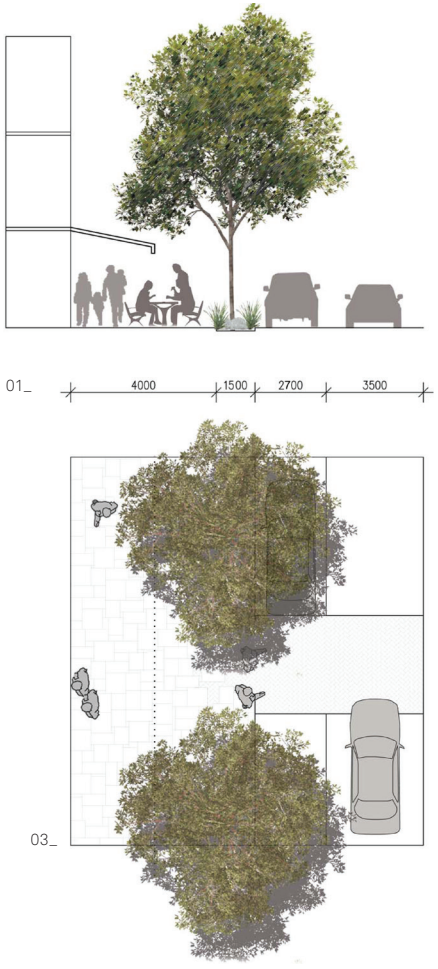
Key Design Principles;

_Buildings which open out onto the street
_Building usages which encourage socialising, recreation and shopping.
_Design attractive streets and open spaces which incorporate shade, planting, attractive building form.
_Sensitively integrate parking and vehicle circulation with pedestrian routes and relaxation spaces.
_Orientate spaces away from the sun.
_Create narrow road reserves and sidewalks to create a humane scale to the urban fabric.



02_

01_ Activated streetscape in section
02_ Al fresco tables and defined walkway
03_ Activated streetscape in plan



4.0___Public Realm Design

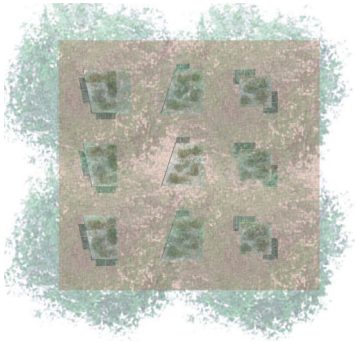
4.2 Cyclone Landscapes

Preventing Cyclone Damage to Trees

Trees can be prone to extensive damage and uprooting during the cyclone season (November to April). However, trees are an essential component of the Karratha Vernacular and efforts should be made within the city centre and residential areas to integrate good practice techniques to help minimise tree uprooting and damage to property and people during a cyclone event.

When planning new tree planting the following advice should be followed;

_Plant slow growing species which will develop strong wood (eg, *Tipuana tipu, Canarium australianum and Allosyncarpia ternata*) and benefit from a deep root system.
_Integrate shrub planting at the base to deflect winds upwards to prevent uprooting.
_Look for opportunities to integrate filter screens which may form interesting architectural elements within public open spaces.
_Plant trees in groves and tight groups to help dissipate wind strength
_Plant smaller species nearer to buildings and larger species at the boundary.
_Involve a local arborist and professional horticulturalist to advise on planting techniques and available species.
_When planting, dig deep pits, integrate strong guying and ensure the plants are well fed and watered.
_Try to ensure the base of the trees do not become waterlogged prior to a cyclone event as the wetness weakens the soil and exposes the tree to uprooting. Ensure there is adequate guying and drainage to the rootball.
_Be aware of the destructive nature of local termites and do not use vulnerable timber.
_If possible, retain areas of well established groundcover and tree planting which have withstood multiple storm events. These plants will also help to filter winds during other cyclone events.
_Do not over prune the lower branches of trees as they may become top heavy and exposed to uprooting.
_Ensure trees are well maintained and branches are pruned when there is evidence of dieback, wood rot, trunk damage and termite infestation.
_Trees with open canopies are suited as they dissipate wind speeds.
_Integrate filter screens around trees to deflect and dissipate wind.



01_ Integrating planting and screens to filter wind with trees planted in groups
02_ Allosyncarpia ternata
03_ Canarium australianum

4.0___Public Realm Design

4.3 Water Sensitive Urban Design

An integrated approach to water management which inputs appropriate water sensitive urban design (WSUD) techniques is required within all new development in Karratha. The landscape design for the city centre and residential areas should take a precinct wide approach to the sustainable use of all forms of water.

In dealing with precipitation, which is both scarce but also heavy in volume during cyclonic storm events, techniques should be used to help store, re-use, infiltrate and harmoniously redistribute the run-off. The dramatic change in conditions from extensive periods of drought to major flooding episodes and the impermeable nature of the local Pindan soil types brings challenges for the adoption of an integrated WSUD approach. Within streetscapes, rain gardens can be introduced with swales and downpipe installations which incorporate remediated soil substrates to aid permeability. Excess water can be stored in sub-surface retention structures for re-use in buildings and irrigation. Water can also be re-directed for infiltration and retention (in subsoil aquifers) in nearby parkland and green links such as the existing 'nature promenade', which runs diagonally across the city centre from Dampier Road to the proposed Nickol Bay Park at the north end of the city.

Within residential estates such as Mulataga, water should be directed for effective storage and re-use in the new houses and mixed use developments. It should be an aim for only recycled household water and captured storm water to be used for irrigation. The adoption of xeriscaping principles in Karratha should minimise the need for irrigation.

Open spaces which are larger and have valuable amenity use can incorporate bioretention, with the installation ensuring water does not linger to create a mosquito hazard.

Throughout the Karratha Vernacular it is essential that water is used effectively and responsibly and through adopting a precinct wide approach, a series of landscape spaces can successfully be created which provide the essential aspects of the vernacular such as provision of shade, greenery, softening and cooling while integrating a modern water wise approach.

01_ Bioretention pools
02_ Downpipe infiltration techniques
03_ Planted swales within tight urban spaces
04_ Extensive area swales

4.0___Public Realm Design

4.4 Open Space Design

Creating Vibrant Spaces for People

At present the open space network in Karratha is not providing the range of spaces which prioritise the needs and requirements of people who wish to enjoy the outdoors.

The recent planning of the city has led to a traffic dominated environment which makes travel by car a necessity, with the subsequent urban fabric too expansive in scale. The wide road reserves and expansive car parks, limited tree cover and low building masses creates a harsh environment which is not conducive to walking or relaxing outside.

The Karratha Vernacular should look to address this issue and through the integration of the landscape and architectural design elements and the crucial issue of scale, form and density create a tighter and more humanely scaled environment which prioritises people over the vehicles.

It is of fundamental importance that all stakeholders and decision making bodies are in tune with the need to address the issue of open space provision and how the principles of scale, form and density challenges the established open space provision in Karratha.

The following spaces require definition and agreement for the creation of the new Karratha Vernacular;

_City centre streetscape
_City centre laneways
_City centre plazas/courtyards
_Green Links
_Roof gardens and community gardens
_Residential streetscapes
_Public open spaces

01_ Humane scale - pedestrian focused streetscape design
02_ Humane density - tight urban grain but still allowing vehicle parking and circulation
03_ Humane form - appropriate scale design elements such as verandas, trees and art work.

4.0___Public Realm Design

4.4.1 City Centre Streetscape

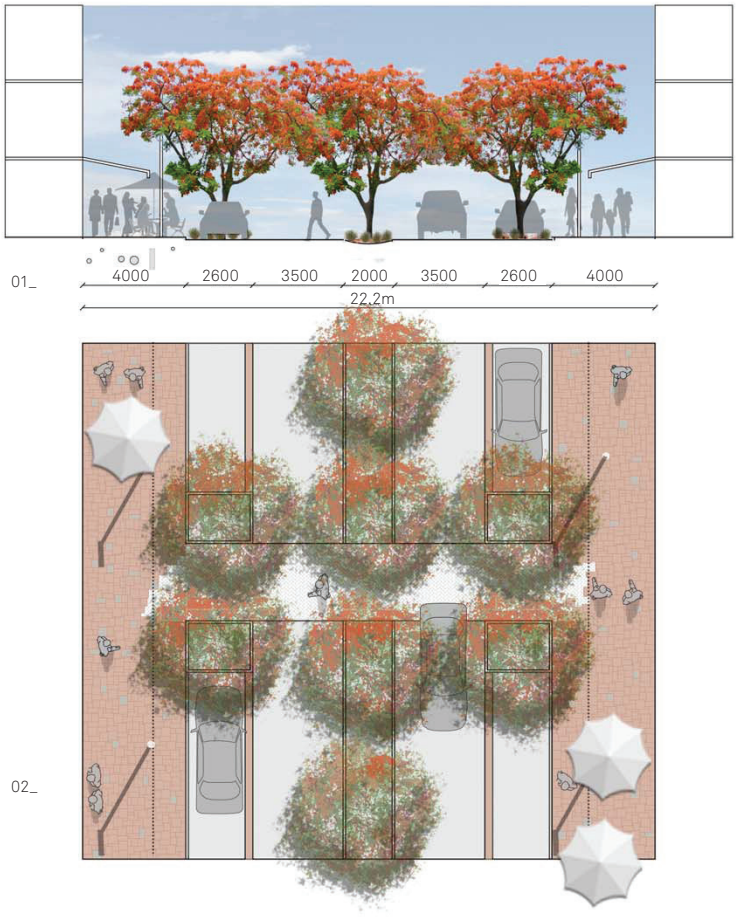
Sharpe Avenue represents a considerable opportunity to create a new city centre which is based upon the creation of a pedestrian focused urban environment. The street can look to significantly reduce the width of its road reserve, which currently stands at over 40 metres. The existing width of the road leads to cars dominating its character with the lack of shade creating a very hot environment in which people are not prepared to walk or contemplate socialising.

The Karratha Vernacular seeks to reduce this width and create a new streetscape based on the quality of the urban environment, encouraging activation, integrated vehicle provision, trees, building scale and architectural features to create a new street which is popular and creates a vibrant heart to the city.

To this end the section and plan on this page suggest a width of 22 metres which includes activated pathways, provision for parallel parking, single lane roads which widen out to allow passing at junctions/intersections, and a median in places that could include wide canopy shade trees. The street should endeavour to be symmetrical in form and allow ease of movement for people to cross the road and feel like the street is for their use and not just for parking or vehicle circulation.

Careful consideration is required for service corridor provision and these can be accommodated within the verge areas. Tree pits should be kept away from service corridors.

The importance of this streetscape layout and scale is a crucial element of the Karratha Vernacular and will provide the foundation for supplementary elements to give character and heart to the city centre.



01_ Typical Sharpe Avenue section
02_ Plan view giving an indication of the ground plane design

Important streets, such as Sharpe Avenue, should ideally have a width of 22 metres from building to building. This is based on the following elements.

_Creates streetscape of a more human scale;
_Facilitates shading through integration of trees, shade structures and buildings;
_Provides feeling of activation, stimulus and a sense of place;
_Encourages pedestrians to cross the road;
_Slows down traffic speeds, especially when integrated with medians, pedestrian crossing points and parallel street parking;
_With the integration of tree planting, provides shelter from winds;
_Creates a streetscape which is more interesting, aesthetically pleasing and a joy to be a part of;
_With increased footfall it provides improved commercial opportunities leading to further activation.

4.0___Public Realm Design

This page illustrates a number of successful WA streetscapes which incorporate a narrower road reserve width helping to create activated and lively streets which are commercially successful and provide a range of amenities.

Karratha should look to emulate these examples in the city centre.

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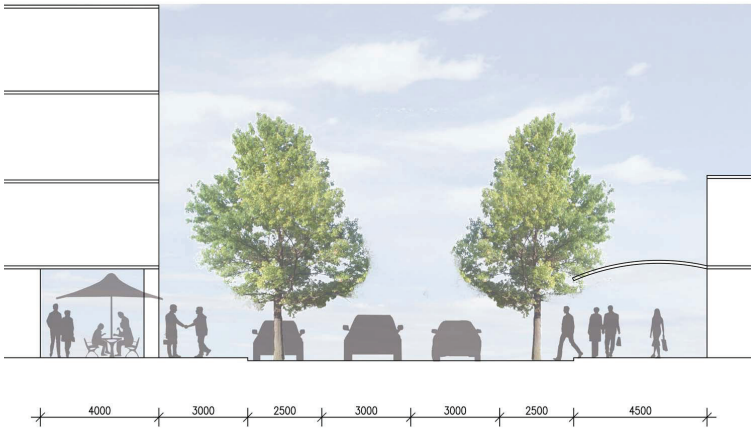

04_Hay Street: 18.5 metre road reserve plus a 4 metre colonnade

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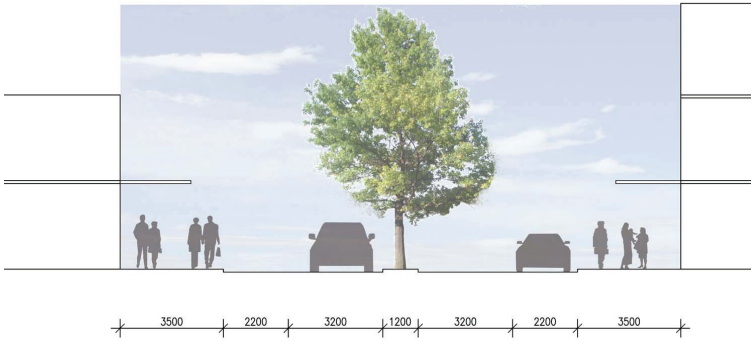


05_Rokeby Road: 19 metre road reserve

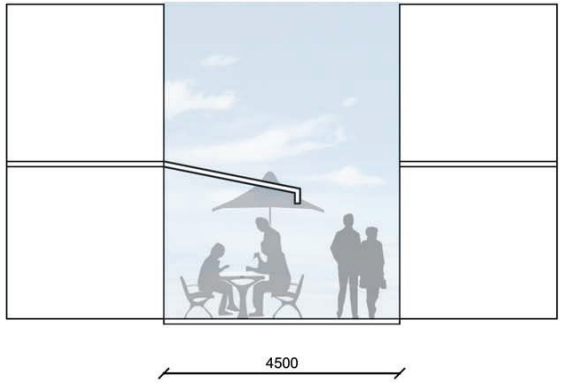
01_ Hay Street, Perth
02_ Margaret River
03_ Rokeby Road, Subiaco
04_ Hay Street section - 22.5m width
05_ Rokeby Road section - 19m width

4.0____Public Realm Design

4.4.2 City Centre Laneways

Opportunities should be sought in the city centre to integrate a pedestrian scale laneway links which can be covered or uncovered, to provide a tight urban grain framework. In hot climates the shade offered from narrow lanes provide interesting opportunities for creating vibrant links which can incorporate shops, cafes, and commercial entry points.

The creation of an interesting network of laneways, which may link also to fully covered internal spaces or the existing/modified street network will combine well with shade from buildings and structures, water features and mechanically cooled environments to provide temperatures which are conducive for external use.



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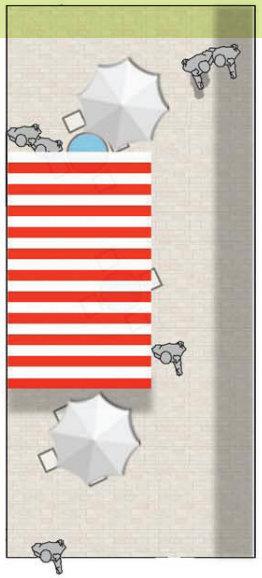

02_

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01_ Section and plan illustrating the type of dimensions for laneways
02_ Melbourne laneways
03_ Perth public space activation through a building
04_ Seville laneway

4.0___Public Realm Design

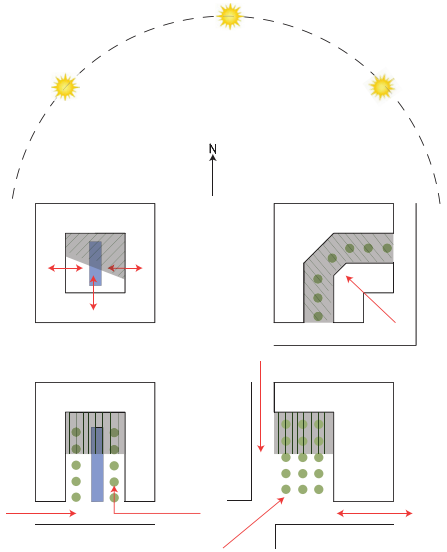
4.4.3 City Centre Plazas, Pocket Parks and Courtyards

The city centre should seek to incorporate a sequence of public realm spaces which are conducive to walking and socialising and link well with the street network to create an interesting cityscape which stimulates the experience of the residents and helps to activate and market commercial properties.

A key consideration is the adoption of principles for scale and form of these spaces, to ensure they provide shade, can include the landscape elements already identified to help reduce temperatures (trees, canopies, water, planting, mist sprays) and ensure the spaces are activated, which will give them life and ensure anti-social behaviour does not occur.

Within commercial areas/ neighbourhood centres in residential estates such as Mulataga these principles can be further developed. In the residential zones public space activation will be more appropriate within pocket parks and larger recreation spaces. Shade again is a key issue and the provision through planting and structures is essential to consider. The channelling of breezes and use of water is also important to consider to give people every opportunity for experiencing the public open spaces in the community.

Provision of lighting is an essential component, with the lower temperatures experienced at night more conducive to external use. The use of lighting should be sympathetic to the landscape, limit light pollution and ensure spaces and pathways feel safe.



01_ Potential open space forms for the city centre utilising building shade and trees
02_ Public open space incorporating shade
03_ Lighting is a key element to draw people into the environment and provide a safe feel

4.0___Public Realm Design

4.4.4 Green Links

The creation of an effective, ecologically rich and interesting green link network is an important consideration for the future development of Karratha. Opportunities exist in established green links such as the Nature Promenade to the west of Sharpe Avenue and the creek lines which cut through residential areas to provide green infrastructure routes which combine amenity use, play areas, storm water retention and infiltration, good opportunities for art work, ground cover and tree planting and provide new pathways and cycle routes to integrate the community away from the road network.

The Nature Promenade is an established green link which needs remediation work to improve its accessibility, aesthetic qualities and landscape structure. Boardwalks, lighting, seating spaces can combine with the improved water retention and infiltration solutions and new planting to boost the quality of the link. The link can potentially form a key part of the character and be a signature part of the Karratha Vernacular with the right treatment and considered long term management.
Within residential areas there are numerous opportunities to combine the road and plot layouts and public open spaces with green links which are formed by the creek network.

By incorporating similar environmental intervention techniques used in the nature Promenade the links can be enlivened and form a rich part of the landscape for community.

It will be important to consider the indigenous community's influence on these spaces. The presence of middens should be respected and through the involvement of the local indigenous community there will be opportunities to enrich and respect these elements within Karratha's community development.

01_ Nature Promenade link which could benefit from improved accessibility, boardwalks, paths, seating, structures, water integration and potentially public art work and natural play areas.
02_ Natural play spaces
03_ Boardwalks
04_ Middens are a sensitive archaeological consideration

4.0___Public Realm Design

4.4.5 Nature Promenade

Concept plan and section for the Nature Promenade integrating boardwalks, shade structures WSUD integration and native planting and landscape forms to create a nature corridor which feels part of the landscape, integrates well with the city centre and provides opportunity for comfortable and stimulating amenity experiences.

4.0___Public Realm Design

4.4.6 Roof Gardens and Community Gardens

The Karratha Vernacular should seek to integrate open spaces that acknowledge the local community's desire for relaxing in elevated open spaces and embrace community input to ensure spaces are well used and create a sense of ownership.

Roof gardens can be included, especially in the city centre mixed use developments to create breezy, communal spaces offering expansive views of the surrounding landscape. The gardens should be provide for shade, adopt rainwater harvesting and xeriscape principles and offer experiences for people of all ages.

Community gardens can be introduced, working with the local community to create a range of public open spaces which reflect their specific needs. The local indigenous community especially should be considered as the external environment is integral to their way of life. Spaces should seek to encourage healthy living (eg. green gyms/ allotments) and reflect the landscape vernacular integrating native planting and xeriscape principles.

Through the design development process opportunities should be sought to acknowledge the importance of embracing local community participation to develop these kind of spaces so they truly become spaces for people of Karratha.

01_ Elevated spaces on roof tops can be used by commercial developments as well as private residences

02_ There are significant opportunities to take in expansive views of the Pilbara landscape

03_ Open spaces need to be designed for all ages, especially the younger generation

04_ Open spaces should look to integrate local people's views as well as reflect the local landscape vernacular.

4.0___Public Realm Design

4.4.7 Residential Streetscapes

The new residential communities should seek to create streetscapes which acknowledge the requirements of the local population for the provision of parking and storage of boats and also seek to create a softened landscape which introduces significant amounts of tree and groundcover planting .

By the introduction of avenues of street trees either side of roadways , positioned in swales, broad canopy trees can create dappled shade to aid cooling. The boundary to the residential properties is a key space to consider introducing a vernacular style which includes shade planting through hedges, trees and permeable fences and gates.. Access is acknowledged for boats and cars but a significantly improved quality to the urban environment will be achieved if the provision of spaces for parking are combined well with the integration of thoughtfully planned landscaping and boundary treatments.

01_

02_

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01_ Section through a typical residential street
02_ Planting providing shade at the front boundary to a dwelling.
03_ Trees providing shade on a residential street

4.0____Public Realm Design

4.5 Shade with Landscapes

To create a townscape which is attractive, softens the built form and most importantly provides cooling through shade, the city centre requires tree planting to provide a major component of the Karratha Vernacular.

There are many trees successfully established in Karratha with a series of mature specimens present within the city centre. Through integrating new street tree planting a new dynamic can be created for the city centre.

Trees should be planted within road medians and verges, alongside footpaths, integrating with parking arrangements and within smaller break out spaces to give landscape structure and heat mediation.

4.5.1 Providing Shade

The benefit of tree shade is well known and appreciated by everyone who experiences the relief from the heat of the sun on a hot day. Karratha's climate ensures that shade is a prerequisite for external activation and therefore all opportunities need to be considered for providing a variety of external spaces which integrate trees with architectural elements.

Cafes, courtyards, plazas and large open spaces will benefit from the careful selection of trees, which give good canopy cover, work well with the creation of seating spaces, pedestrian links and vehicle parking. The images shown here illustrate spaces within hot Mediterranean climates with trees planted to cool the urban spaces. The aerial photograph from Seville shows the classic use of trees in a bosque design creating courtyards which are predominantly in shade and therefore significantly cooler than spaces with no cover.

01_ Semville Bosque
02_ IPalma, Mallorca

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4.5.2 Creating Avenues

It is imperative trees are used in Karratha to give a strong landscape structure and create a softened urban grain which gives a feeling of intimacy and detail to stimulate the local residents and visitors.

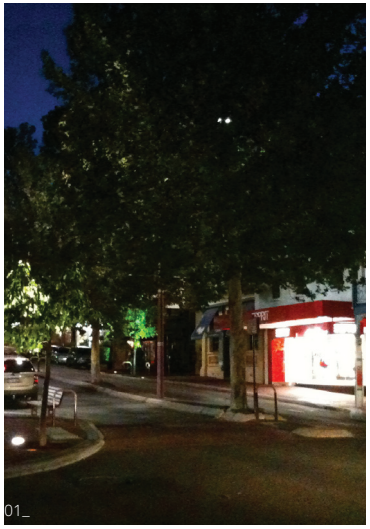
Avenues can be created along all roads and in particular Sharpe Avenue. Multiple rows of trees used at the side of the roads and within medians will cool the streetscape. With the selection of a species such as Poinciana, avenues can be created which create shade through canopy cover and do not impose overbearing maintenance or health and safety considerations. The Poinciana is found to be growing successfully in the city centre and would provide a cooling effect and lushness to the streetscape with the red flowers adding seasonal interest.

4.5.3 Integrating Trees with Architecture

The siting of tree specimens with verandahs, walkways and canopies to create external spaces for comfortable use is an essential part of the Karratha Vernacular. By integrating architecture, urban planning and landscape design components a series of spaces can be created which enrich the experience for the Karratha resident and visitor.

4.5.4 Trees and Seating

As an extension of the integration of trees with the built form it is imperative thought is given to the provision of street furniture in appropriate position which maximises potential for seating, meeting and resting in a shady environment.


01_


02_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01_ Median tree avenue, Perth
02_ Poinciana tree in Karratha
03_ Orchard Road Singapore

4.0____Public Realm Design

4.5.5 Trees and Lighting

The lighting of trees will provide an extra dimension to the streetscape and provide activation during the evening hours when the temperatures have reduced and activity is more attractive to residents and visitors.

4.5.6 Species

The Shire of Roebourne has an approved list of native and ornamental species which can be referred to, however the developer must ensure the suitability of each species. Consideration though should be given to species which will establish successfully, provide canopy cover to give shade, do not require excessive maintenance and through their form and texture give colour, interest and habitat opportunities. The approved list of native species from the Shire include;

_Acacia coriacea - Desert Oak/Wire wood
_Eucalyptus vitrix - Coolibah
_Eucalyptus leucophloia - Snappy Gum
_Lysiphyllum cunninghamii - Native Bauhinia
_Brachychiton acuminatus - Pilbara Kurrajong
_Melaleuca leucadendra - Cadjeput
_Casuarina equisetifolia - Coastal She-Oak
_Hakea iorea - Corkwood
_Livistona alfredii Millsrteam - Fan Palm
_Eremophila maculate - Spotted Emu Bush
_Eremophila glabra - Kalbarri Carpet
_Eremophila longifolia - Weeping Emu Bush
_Eremophila macdonnellii - Splendid Fuchsia
_Callistemon viminalis - Bottlebrush 'Captain Cook'
_Callistemon viminalis - Bottlebrush 'River Dawson'
_Callistemon - Kings Park Special
_Acacia gregorii - Gregory's Wattle
_Gomphrena canescens - Batchelors Buttons
_Grevillea 'Robyn Gordon' - Grevillea Robyn Gordon
_Grevillea 'Honey Gem' - Grevillea Honey Gem


01_


02_


03_

01_ Illumintaed streetscape, Singapore
02_ Trees and seating, Seville
03_ Integrated al fresco, Perth

4.0____Public Realm Design

_*Myoporum parvifolium - Creeping Boobialla*
_*Senna artemisioides - Silver Cassia*
_*Dianella tasmanica variegata - Tasman Flax Lily*
_*Ptilotus exaltatus - Pink Mulla Mulla*

In addition it may be approporiate to consider exotic species which are suitable for the conditions in Karratha. The Shire of Roebourne has approved the following trees;

_Khaya senegalensis - African Mahogany
_Peltophorum pterocarpum - Yellow Flame Tree
_Hibiscus tilaceus 'Rubra' - Cotton Wood
_Stenocarpus sinuatus - Firewheel Tree
_Cassia fistula - Golden Shower Tree
_Cassia javanica - Apple BlossomTree
_Delonix regia - Poinciana
_Ficus hillii - Hill's Fig
_Tabeluia palmeri - Pink Trumpet Tree
_Tipuana tipu - Yellow Jacaranda.

It is also important to consider during design development the importance of striving to retain as many specimens of trees existing within the city centre, as they have taken many years to reach their size and are providing immediate impact.

01_ Retain existing trees where possible
02_ Corymbia flavescens
03_ Tipuana tipu
04_ Casuarina equisetifolia
05_ Brachychiton acuminatus

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4.5.7 Spacing and Positioning

The spatial arrangement of trees should be given careful thought with the dimensions between trees and positioning of specimen trees to provide shade in courtyard spaces considered with the adjacent public realm and architectural elements (refer to the diagram to the right).

01_ This diagram demonstrates how buildings and landscapes may relate together in Karratha's city centre. Narrow lanes receive shade from buildings, whilst courtyards and wider streets contain trees. Fixed shade structures will provide shade and an identity for the city centre.

01_

4.0____Public Realm Design

4.0____Public Realm Design

4.6 Water as Cooling Element

4.6.1 Integrating Water Features

Within the city centre and the commercial and play spaces in residential areas there should be consideration given to providing a range of water elements which seek to integrate with landscape and architecture to aid cooling and stimulate and enliven the public realm.

Avenues, courtyards, gardens and plazas can integrate responsibly designed water features, which will have a psychological cooling effect and will also reduce air temperatures through the evaporation process.


01_


02_


03_


04_


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01_ Shade and water providing cooling
02_ Interaction
03_ A water wall in New York
04_ Water as play
05_ Fountains create movement, air t e and opportunities for touch and feel to give physical and psychological cooling

4.0___Public Realm Design

4.7 Mitigating the Hot Westerly Breeze

4.7.1 Landscape to Cool and Dissipate Warm Airflows

Features within the landscape can be used to mitigate the impact of hot breezes. The use of water, planting and physical screens such as walls and fences can be placed in appropriate positions to provide sheltered spaces.

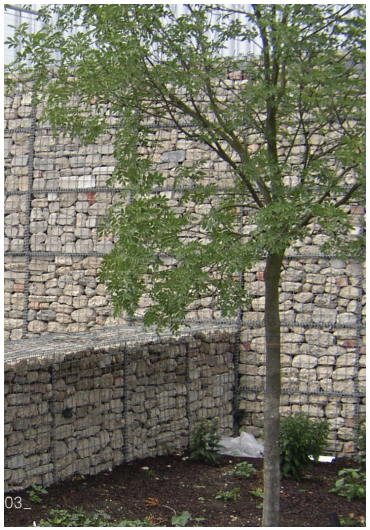
In residential areas it is important to effectively screen the housing plots with planting and perimeter screens to prevent the warm air heating up the elevation of houses.

In the more prestigious city centre public realm spaces water can be used to aid the cooling effect of the wind. Fountains of water will help and placing seating spaces to the east of the water will provide a cooler space for outside enjoyment.

Within residential areas the incorporation of larger water bodies with planting will help to cool air flows within public open spaces and consideration should be given to the creation of areas where water can be retained following storm events.

01_

02_



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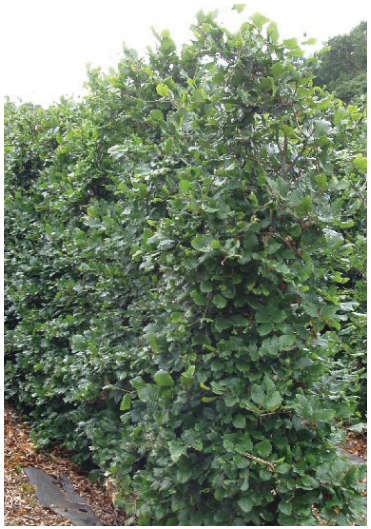

04_

01_ Water combining with planting and screens to aid cooling
02_ Wall of water cooling air flows
03_ Gabion walling used to block hot breezes
04_ Hedges can dissipate air flows

4.0___Public Realm Design

4.8 Soft Landscape Vernacular

4.8.1 Groundcover Planting

Within the new city centre development it is important to utilise a predominantly native planting palette which references the local vernacular, provides colour and interest throughout the year and uses a minimal amount of water.

Xeriscaping, through use of waterwise planting is an essential element of the soft landscape palette and there should be a preference for not incorporating large areas of irrigated lawns.

In addition consideration should be given to utilizing the Spinifex grasses (Spinifex longiflorus, Trioda pungens and Trioda wiseana) which are prevalent within the locality. These species can be effectively used within medians and verges helping to soften the ground plane and reduce the amount of soil/mulch visible.

Within the courtyards and walkways Bougainvillea spp. can be utilised to soften architectural elements and add vibrant colour and further shading.


01_

01_ Spinifex longiflorus
02_ Triodia pungens
03_ Ptilotus exaltus
04_ Eremophila maculate
05_ Acacia gregorii


02_


03_


04_


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4.0___Public Realm Design

4.8.2 Xeriscaping

The principles of Xeriscaping should be the focus of ground cover planting and lawn areas in all areas of Karratha. It is crucial that water is not used irresponsibly to keep water hungry plants or large areas of lawn alive.

Key Xeriscaping principles are as follows:

_Carefully design the landscape to create appropriate proportions of hard landscape versus lawn and groundcover planting.

_Reduced sized or no lawns at all are preferred and it may be appropriate to have larger areas of gravels and hard landscape to minimise extensive groundcover zones.

_Ensure any irrigation included is of the sub-surface leaky pipe variety and avoid mist sprays.

_Use mulch to keep soils moist and limit water loss due to evaporation.

_Use waterwise plants which are native to the locality.

_Integrate soil improvers such as organic matter and slow release moisture ameliorants.

_Integrate the planting areas with surface water run-off movements.

_Ensure irrigation water is from a sustainable resource such as recycled rainwater.

_Consider water use in a precinct wide perspective and integrate the Xeriscape landscape within wider WSUD interventions.

01_ Replace front lawns with xeriscaped landscape
02_ Leaky pipe irrigation emitting large droplets
03_ Native planting - Troda pungens
04_ Mulch

4.9 Fauna

4.9.1 Wildlife as Inspiration and Habitat Provision

It is important to consider the wildlife and native habitat characteristics of the region when developing the Karratha Vernacular. The rich wildlife of the region has given much inspiration, especially to the indigenous community, as the search for food on land and in the sea brought communities to live in the area.

The term Karratha as 'Good Country' has great relevance to the abundance of wildlife and availability for food to support generation after generation. The expansive areas of ancient rock reference this and through further dialogue and workshop work with the local indigenous community many streetscape and public open space elements can be developed with this inspiration in mind.

The continued development of Karratha should look to respect the habitat requirements for native fauna and efforts should be made to integrate ecological management procedures and mitigation programs. This will be most relevant in the residential areas which is undeveloped. Survey work which is timed well with the development process is essential to ensure mitigation programmes are well co-ordinated. The following species, amongst others, will need to be considered through engagement with qualified ecologists and environmental management professionals.

_Euro (stocky kangaroo)
_Red kangaroo
_Red-eared antechinus
_Pilbara ningaui
_Pebble mouse
_Green, loggerhead, flatback and hawksbill turtles
_Gecko
_Python
_Bungarra
_Pink and grey galah
_Bottlenose dolphins
_Humpback whales
_Dugongs
_Hare wallaby
_Golden bandicoot
_Brush tailed possum
_ Dragonflies and damselflies

01_ Burrup Peninsula rock art turtle
02_ Pink and Grey Galah
03_ Bungarra

4.0___Public Realm Design

4.10 Hard Landscape Vernacular

4.10.1 Ground Plane Treatment - Paving

Within the city centre it is crucial that designs are developed which reference the local stone, colours, textures and feel of the landscape and the prevalent Karratha stone. This will help give the city centre a sense of place and ensure a vernacular can be established over time.

Karratha stone can be used in a variety of paving styles in the most prestigious areas. Smaller units can be used for parking zones.

Within vehicular trafficked areas road surface treatments can integrate bound aggregate treatments which use aggregates of the local stone to give a warm colouring.

01_ Local rocks as inspiration
02_ Sett paving for parking zones
03_ High quality design
04_ Karratha stone as paving
05_ Vehicular paving treatment

4.0____Public Realm Design

4.10.2 Ground Plane Treatment - Colour Palette and Features

By adopting a strong colour palette which references the Karratha landscape a strong identity can be given to the public realm. The colour wheel shown here gives a range of colours which draw inspiration from the local environment.

Variety and interest can be added to the ground plane to give a further feel that the town is part of the local geography and history of the Karratha region.

Rock art can be referenced, as can local art work and vegetation. It will be important to involve the local community in the design and efforts should be made to integrate the local indigenous population through workshops.

The ground plane can be further enlivened to give stimulus at night through the use of marker lights.

01_ Karratha colour wheel
02_ Vibrant indigenous painting can be referenced in the ground plane
03_ The texture of Spinifex grass can be referenced.
04_ Burrup Peninsula rock art as inspiration
05_ Directional lighting

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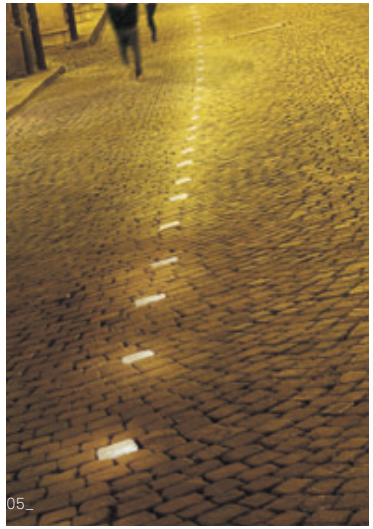

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5.0___Built Form Design

5.1 Design for Climate

Perhaps the most oppressive element of Karratha's climate is its summer heat. Existing buildings in Karratha seek to shut out the heat by being inwardly focused, sealed and dependant on air conditioning.

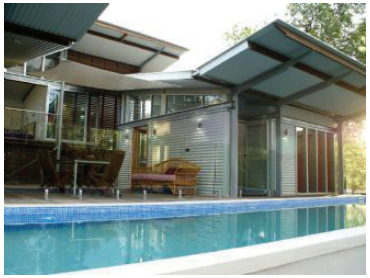
Buildings that are inwardly focused tend to present poorly to the street and detract from a high quality urban realm. This reinforces the perception that buildings in Karratha do not have a sense of permanence or quality. Buildings in Karratha need to be built specifically to respond to local conditions whilst also promoting a high quality urban realm.

The design elements discussed in this chapter relate to all buildings in Karratha, and when employed appropriately, can create a more comfortable and visually appealing vernacular.

5.1.1 Passive Design for Houses

For much of the year, Karratha enjoys a pleasant climate and buildings should apply passive controls to moderate temperature, and resort to active controls (by energy-based cooling systems) only when the passive controls cannot ensure comfort. This approach is suggested for three main reasons:

1. Economic - the installation of mechanical equipment means a capital cost and also the recurrent cost of energy consumed and system maintenance.
2. Ecological/environmental - passive buildings impose the least load on the ecosystem, consume less energy and produce less amount of waste.
3. Aesthetic - passive buildings are more likely to be in sympathy with their environment, and more likely to increase diversity and interest.



Passive Design

Orientation	Day Lighting	Building Shape	Insulation	Wind	Shade
Optimise building orientation	Maximise natural light sources	Minimise heat gain Optimise building structure	Minimise heat gain Control solar radiation	Maximise natural ventilation Block hot westerlies	Minimise solar gain

5.0___Built Form Design

Figure 20: Lot design and orientation for Mulataga needs to facilitate passive design for houses, as shown here, as well as for denser residential development.

5.0____Built Form Design

For Karratha, this means preventing heat gain and maximising heat dissipation. In Karratha, a common construction material for the external face of a building is brick, which has a high thermal mass. Unfortunately, this material performs poorly in hot climates when used externally as it retains heat and decreases the efficiency of buildings to remain cool. The built form in Karratha therefore needs to respond much better to the climate.

In a warm-humid climate, such as Karratha, a building designed for passive cooling would be as open as possible, to ensure the maximum possible cross-ventilation. Buildings in Karratha will require air-conditioning; the design must acknowledge those rooms which are to be mechanically cooled. Building can therefore be closed, sealed and well insulated for the hottest part of the year and opened up for the remainder. This design approach is known as floor plan zoning.

In warm-humid climates, the nights are usually warm and there is very little diurnal variation (often less than 5 deg C). As the humidity is high, evaporation from the skin is restricted. Evaporative cooling will be neither effective nor desirable as it would increase the humidity. The designer should ensure that the indoor temperature does not become higher than the outdoor. Adequate ventilation may ensure this by removing any excess heat input, but this is not enough. Undue increase of ceiling temperature may be prevented by:

_using a reflective roof surface
_having a separate ceiling
_ensuring adequate ventilation of the ceiling space
_using reflective surfaces both for the underside of the roof and for the top of the ceiling
_using some resistive insulation for or on the ceiling

The whole building should be lightweight to allow rapid cooling down at night. East and west walls should have minimum or no windows in order to exclude the low angle east and west sun. They should be reflective and/or well insulated. North and south walls should be as

Key Ingredients of a Sustainable House Design

beauty and comfort

narrow footprints	large eaves and verandahs	street trees	building setbacks	wind barriers	range of lot and house sizes
maximise cross ventilation	minimise solar gain	provide shade	maximise breeze movement	disrupt hot breezes	affordable housing
reduce energy needs	liveable outdoor spaces	improve street appeal	allows solar access	comfort	differing needs of people
		creates micro climates			






5.0___Built Form Design

open as possible, to allow for cross ventilation. This requires that the plan arrangement should avoid double-banked rooms. The spacing of buildings should be carefully considered to avoid obstruction of the wind. The openings require protection from the sun and driving rain but also from mosquitoes and other insects which abound in these climates. In Karratha, shade to walls and windows is paramount.

At times orientation for wind and for sun give conflicting requirements, solar orientation should take precedence, as there are ways of deflecting wind, but no ways of altering the sun's movement. With oblique wind incidence a projecting wing wall at the downwind end of the building would create a positive pressure zone. On the leeward side a similar wing wall at the upwind end would help to create a negative pressure zone. The combined effect of these may ensure a better cross ventilation than that given by wind with normal incidence.

Lot Layout:
Solar orientation should take precedence over wind direction as wind can be shielded or deflected.

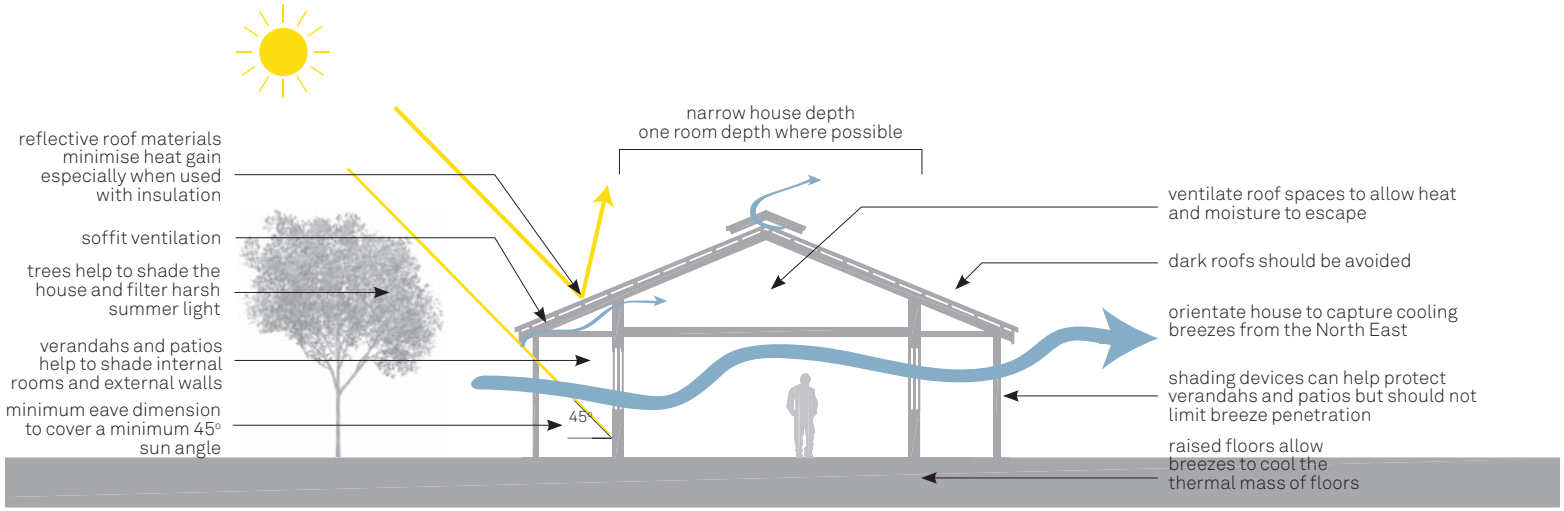


Figure 21: Passive design principles illustrated in section

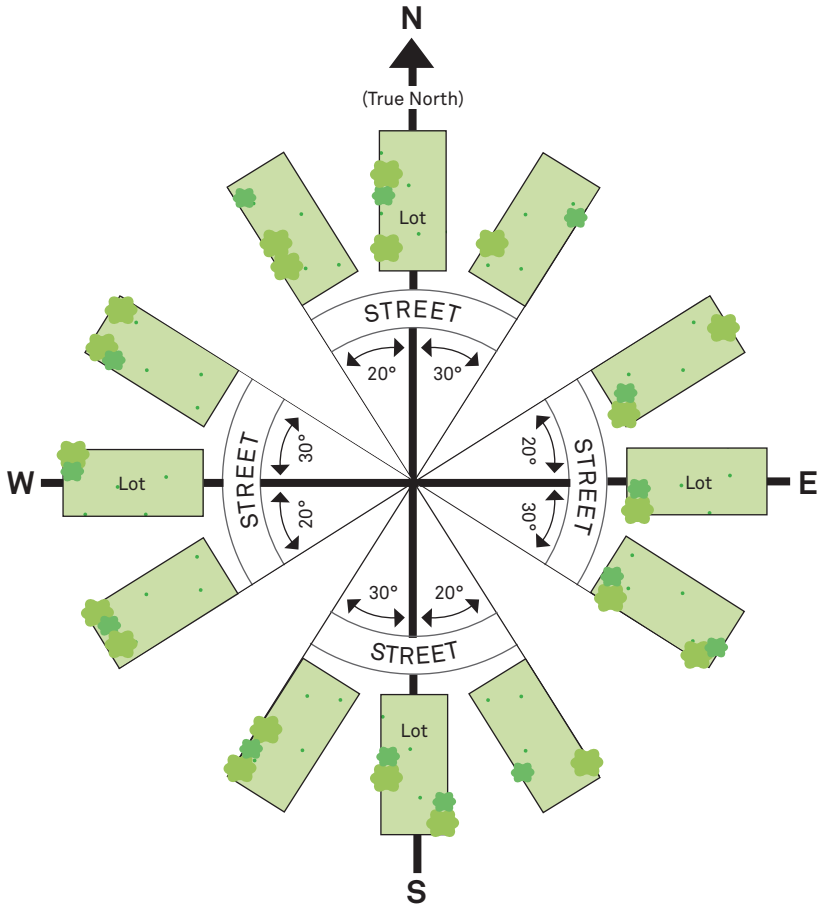
5.0____Built Form Design

Street Layout:
Ideally align streets north - south to minimise access to hot westerly breezes and afternoon sun and maximise solar access for solar energy systems.

Lower Density Lot Orientation:
Where there are north south roads, lots should be narrow at the street interface and wide along side boundaries. This allows all homes to have access to the northern sun.

Higher Density Lot Orientation:
Where dwellings share a boundary wall, such as town houses, north south orientation can ensure all homes have access for day lighting.

Lot Size:
A range of lots sizes can be accommodated, however siting of buildings will determine appropriate protection from afternoon sun and allow northern exposure.

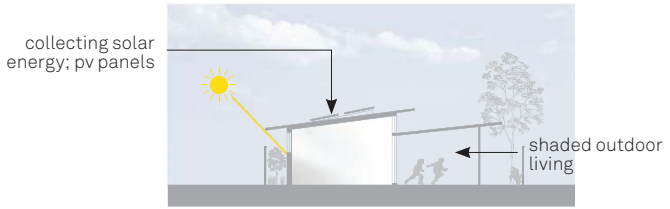


Source AMCORD, 1995

5.0____Built Form Design

Solar Setbacks:
There is more scope for development of house plan configurations that respond to energy efficiency, sustainability and increased visual privacy in north - south streets and east - west blocks. North facing patios (with shade to the west) maximises privacy and provides outlook for living spaces.

Solar Protection:
Lot and house design must protect indoor and outdoor living spaces from heat gain.



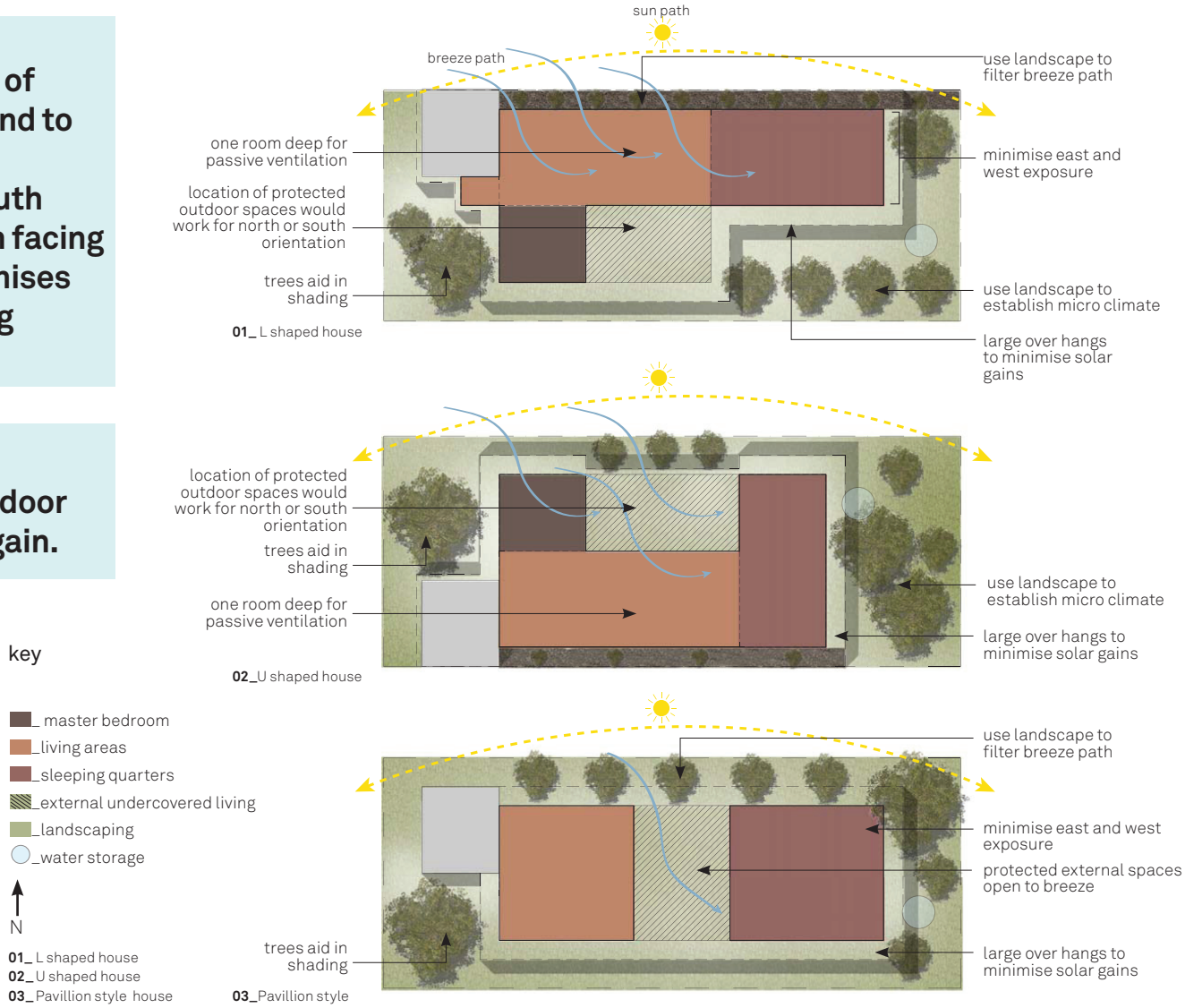
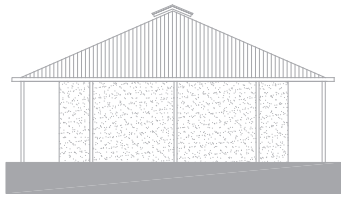


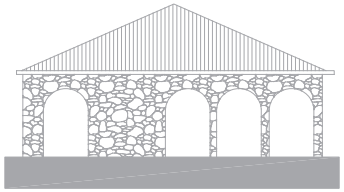
Figure 22: Passive design principles for homes in plan.

5.0___Built Form Design

HISTORICAL

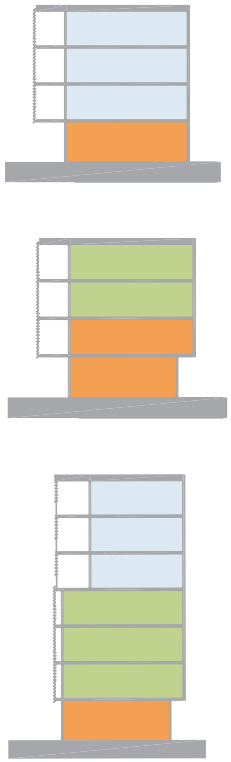


Roebourne
Advantages:
_wide veranda for intergrated outdoor living
_hip roof



Cossack
Advantages:
_colanades provide shaded paths
_local stone - thermal massing
_hip roof

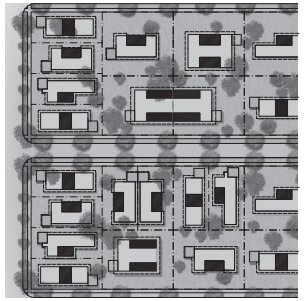
MIXED USE



_residential/short stay/long stay
_commercial
_civic/hospitality/retail

Social Advantages:
_increased density and intergration
_diversity
_activated city centre
_permanence
and civic pride

DENSITY



Residential Area
Advantages:
_mix of lot sizes promotes diversity and intensity
_maximise passive environmental issues at an urban scale
_increased livability
_sense of permanence and neighbourhood pride
_legibility of street and high quality of public space within residential areas such as Mulataga
_establishes and promotes lifestyle and interaction of place
_solar orientation

City Centre
Advantages:
_Establishes sense of legibility and identity that is of Karratha but represents aspirations of a Pilbara City
_creates tourist destinations
_civic and arts opportunities
_establishes a public realm to build a sense of pride and joy for the community
_24/7/365 city centre occupation

5.0___Built Form Design

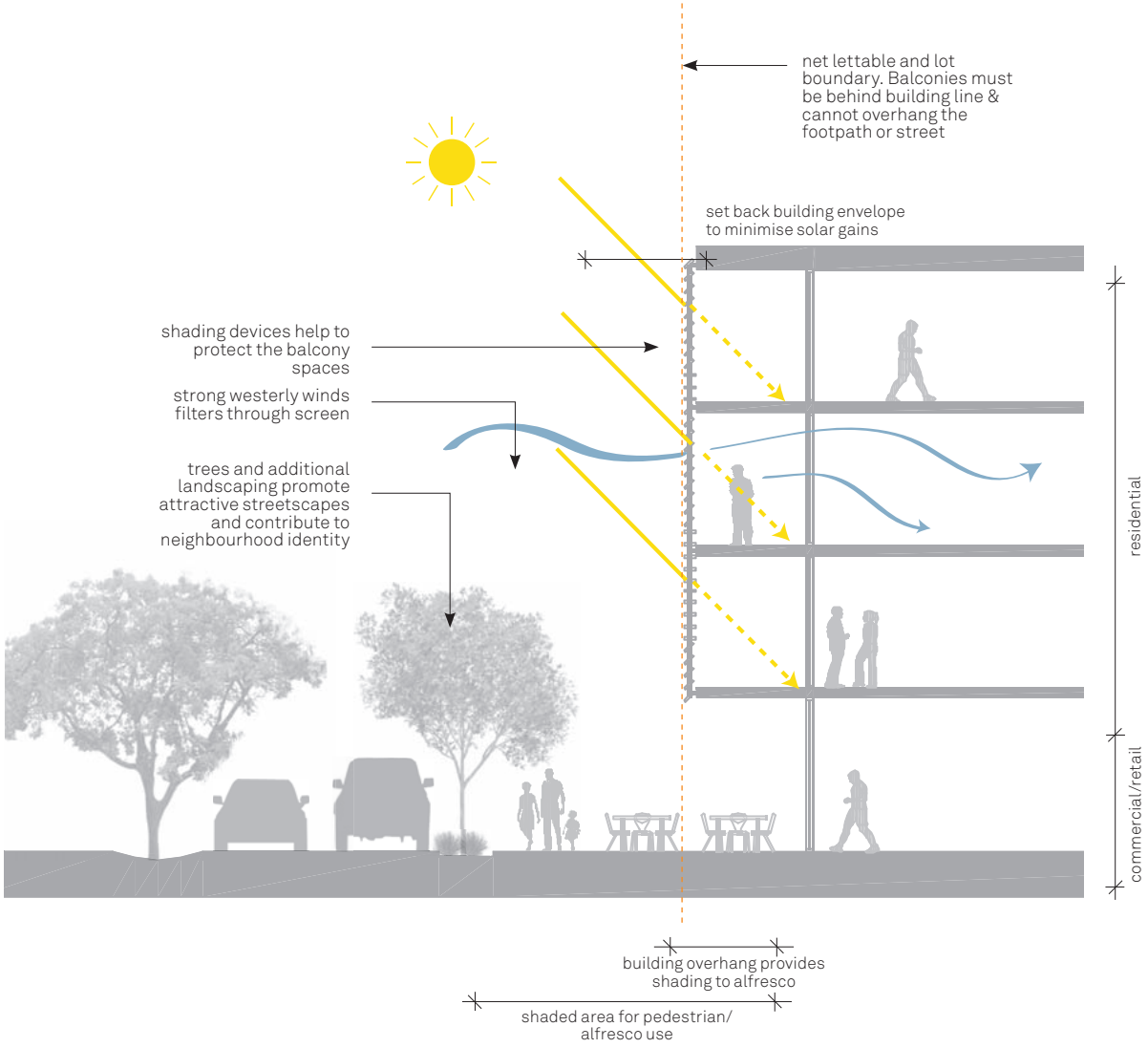


Figure 23: multi-residential/mixed use building types and shading as interstitial space

5.0___Built Form Design

5.2 Shade Devices

In Karratha, shading of a building and in particular, doors and windows, is appropriate year round. This can be achieved with large eaves, fixed shade structures, shutters or pergolas / patios.

In hot climates, simply opting for high performance glass in place of shading devices can lead to heat discomfort for building occupants. As a result, shading of glazed areas is critical.

Designing shading that is both correct and relevant to the aspect and plane (i.e. orientation and whether shading is vertical and horizontal), is the most important issue with external shading.

The appearance of shade devices is also critical. When designed in concert with the building, shade devices can contribute to the appearance of a building and the character of Karratha.

5.2.1 Shade Devices and Cyclones

Care needs to be taken to ensure shade devices are appropriately fixed to buildings and can withstand cyclonic winds within Region D. Moveable shade devices, in particular, may not be designed to withstand cyclonic conditions. Designers need to liaise with suppliers to ensure appropriate shade devices are utilised.

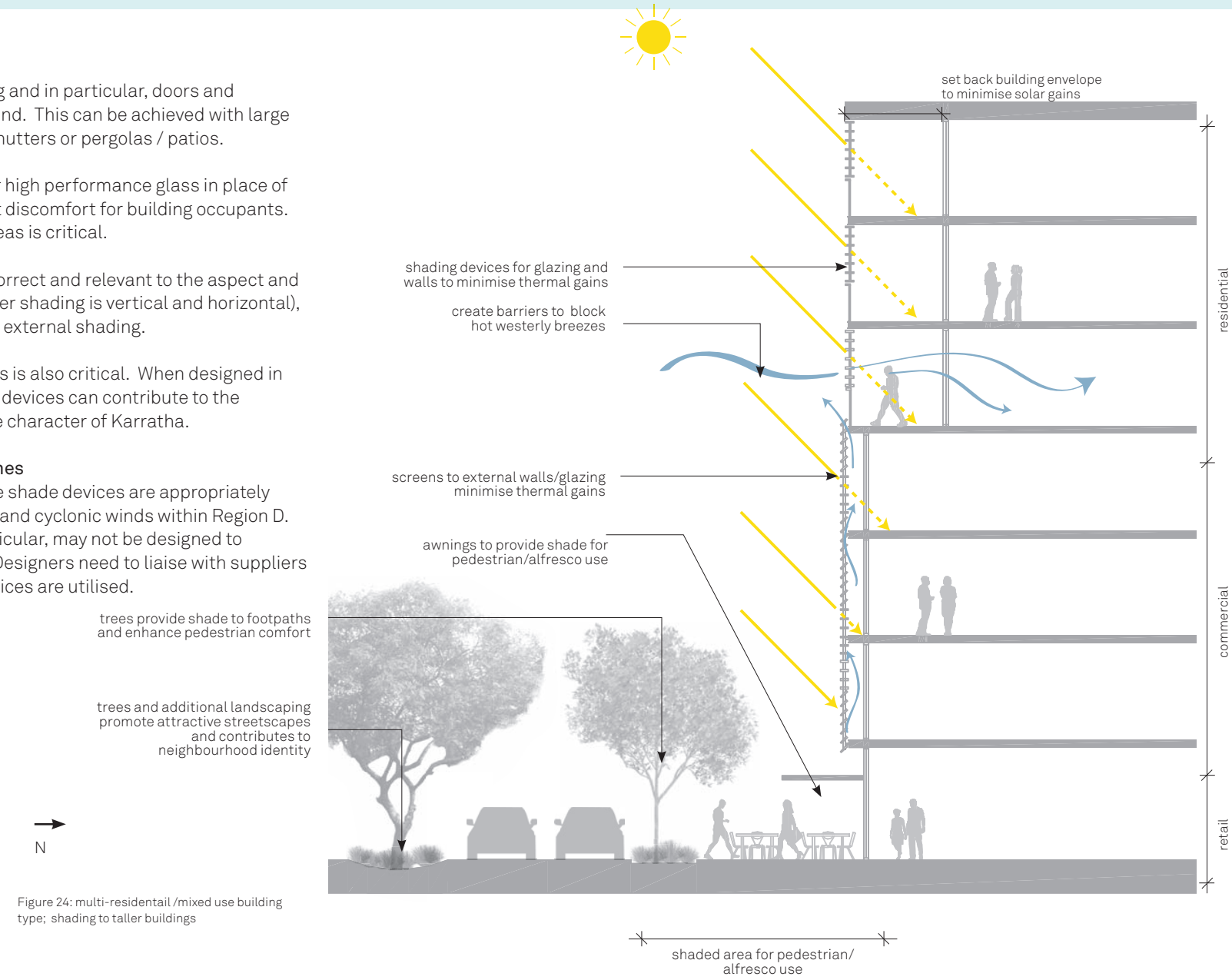


Figure 24: multi-residentail /mixed use building type; shading to taller buildings

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5.3 Daylighting

Daylighting is the controlled admission of natural light into a space through windows to reduce or eliminate electric lighting. By providing a direct link to the dynamic and perpetually evolving patterns of outdoor illumination, daylighting helps create a visually stimulating and productive environment for building occupants, while reducing as much as one-third of total building energy costs.

In large measure, the art and science of proper daylighting design is not so much how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects. It involves more than just adding windows or skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability. For example, successful daylighting designs will invariably pay close attention to the use of shading devices to reduce glare and excess contrast in the workspace. Additionally, window size and spacing, glass selection, the reflectance of interior finishes and the location of any interior partitions must all be evaluated.

A number of design strategies should be understood and explored during the design process. These strategies are briefly described below.

_Increase perimeter daylight zones—extend the perimeter footprint to maximize the usable daylighting area.
_Allow daylight penetration high in a space. Windows located high in a wall or in roof monitors and clerestories will result in deeper light penetration and reduce the likelihood of excessive brightness.
_Reflect daylight within a space to increase room brightness. A light shelf, if properly designed, has the potential to increase room brightness and decrease window brightness.
_Slope ceilings to direct more light into a space. Sloping the ceiling away from the fenestration area will help increase the surface brightness of the ceiling further into a space.

Daylighting:
Daylighting should be explored in house and building designs to minimise artificial light source needs.

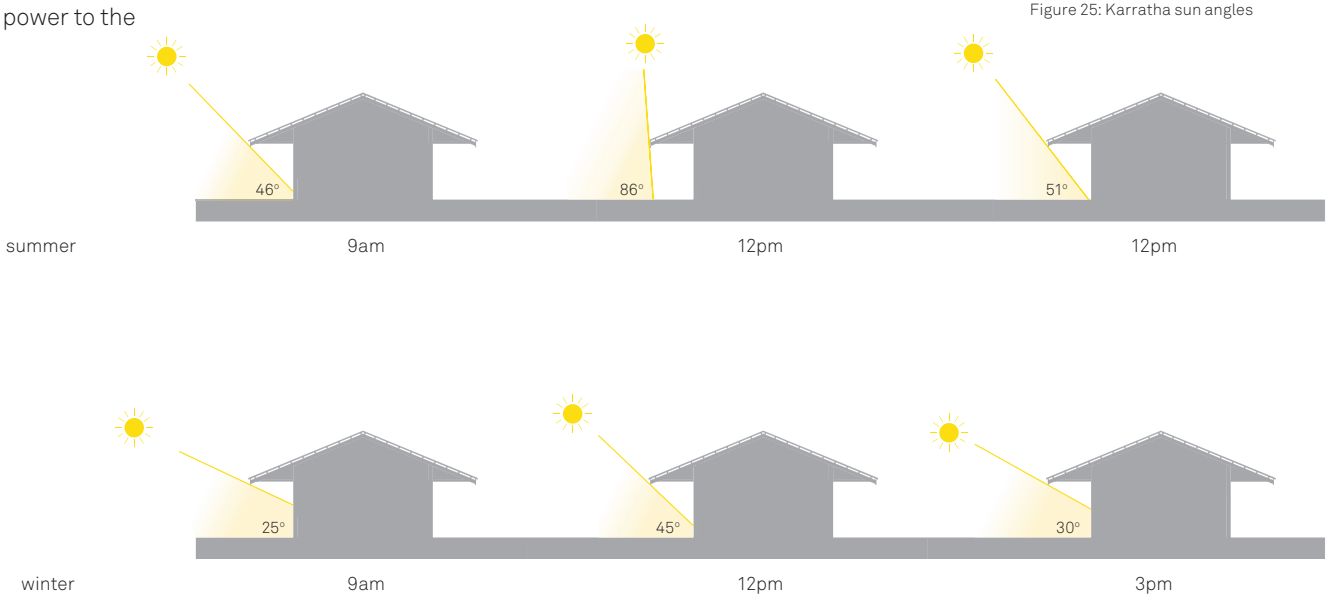
5.0____Built Form Design

_Avoid direct beam daylight on critical visual tasks. Poor visibility and discomfort will result if excessive brightness differences occur in the vicinity of critical visual tasks.
_Filter daylight. The harshness of direct light can be filtered with vegetation, curtains, louvers, or the like, and will help distribute light.
_Understand that different building orientations will benefit from different daylighting strategies; for example light shelves which are effective on south façades are often ineffective on the east or west elevations of buildings.

In hot climates, exterior shading devices often work well to both reduce heat gain and diffuse natural light before entering the work space. Examples of such devices include light shelves, overhangs, horizontal louvers, vertical louvers, and dynamic tracking or reflecting systems.

Emerging concepts for solar shade devices may reduce energy consumption in commercial buildings by up to 30%. The devices are a light weight design that incorporate photovoltaic cells - which power movement of the shade device as well as contributing power to the building.

Figure 25: Karratha sun angles



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5.4 Cool Breeze Penetration

Karratha's coolest breezes come from Nickol Bay to the north east. Whilst prevailing breezes tend to be from the west, house design should not preclude potential to access cooler north east breezes, particularly during winter months.

To catch the prevailing breezes, living areas should always be located on the north or north-eastern side of the home. As many shaded external openings to these areas as possible should ensure that breezes can channel through.

The ideal design solution is a home with single room depths. This provides optimal cross-ventilation as every room has an entry and exit area in the walls for breezes to pass through.

Access to prevailing breezes increases with height. Elevated homes not only receive faster, cooling breezes, they also allow breezes to pass underneath. This helps cool the floor, preventing hot air rising up into the home. In the evening, elevated homes cool down faster as the internal heat can quickly dissipate from the cooling breezes.

Rooms may also be designed with openable walls to promote maximum use and cross ventilation. When combined with adjacent patios and outdoor living areas, the use and enjoyment of dwellings can increase dramatically. Care should be taken though, to ensure openings comply with Building Code of Australia requirements for Region D.

Cool Breeze Penetration:
House and building designs should take benefit of cooling breezes, particularly in winter.

5.5 Noise and Quiet House Design Principles

Karratha will become an active and vibrant place, where activity extends beyond business hours into the evening. Restaurants, bars, shops and cafes will spill onto the city centre streets, enticing people to dwell into the evening. This activity will be complemented by residential dwellings to create a mixed use environment.

In order to maximise the amenity inside residential dwellings within the city centre, quiet house design principles will need to be employed. This includes appropriate insulation, glazing and acoustic treatment to dampen noise intrusion into dwellings. As Karratha's workforce comprises a large amount of shift workers, the need to minimise noise intrusion is intensified. The location of bedrooms also needs to be carefully planned. It is preferable bedrooms are located away from noise sources, however they must still have access to natural light and ventilation.

Quiet House:
Buildings, particularly in the City Centre and along main roads, should be designed according to quiet house principles.

01_ Buildings must be designed to maximise cool breeze penetration
02_ Homes and buildings should be insulated for both noise and heat

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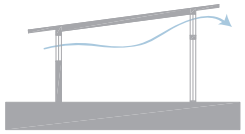
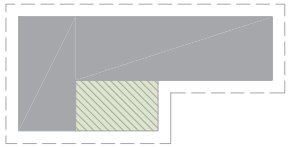
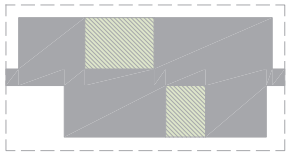
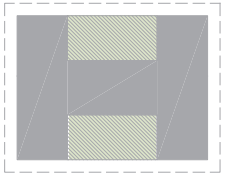
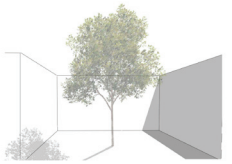
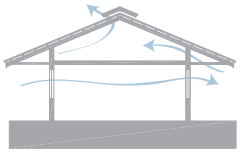
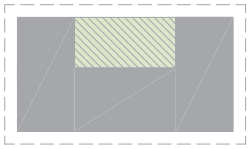
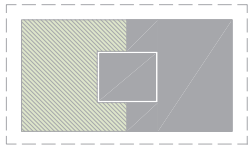
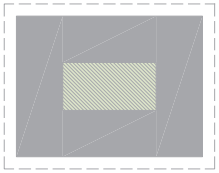
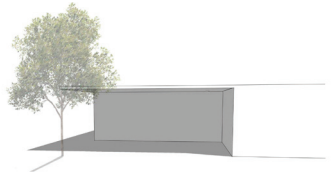
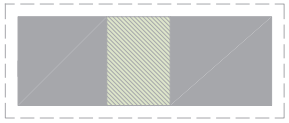
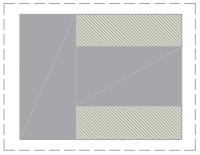
ROOF PITCH	NARROW BLOCKS		WIDE BLOCKS	OUTDOOR LIVING SPACES
				
Skillion Roof Advantages: _ construction methodology _ clerestory windows _contempory design _appication of passive environmental sustainable design principles (ESD)	L Shaped Plan Advantages: _narrow plan improves cross ventilation _protected outdoor living area _maximise landscape outlook and interaction	Spine Plan Advantages: _filters wind through corridor _ creates multiple outdoor living spaces _improves cross ventilation	H Shaped Plan Advantages: _filters wind through corridor _ creates multiple outdoor living spaces _improves cross ventilation _maximises landscape outlook and interaction	Courtyard Advantages: _protected from winds _ access from all directions _improves cross ventilation
				
Hip Roof Advantages: _selfbracing; ideal for cyclone regions _ continuous wide eaves gives protection from harsh climate _passive ESD principles	U Shaped Plan Advantages: _compact _ central external space _maximises landscpae amenity	Prefab Core Advantages: _prefab structural core secures remainder of house _construction methodology _onsite transportation and construction time	Courtyard Plan Advantages: _protected external living space _intergrated outdoor living	Protected Advantages: _shelter from sun, wind and rain _used in any orientation _framed views
				
	Pavillion Style Plan Advantages: _intergrated outdoor living _ filters breeze path to improve cross ventilation		T Shaped Plan Advantages: _improve cross ventilation _multiple external living spaces	Pavillion Advantages: _protected external space _intergrates outdoor living _dual access

_external living
_internal living

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5.6 Light Weight Materials and Thermal Mass

Thermal mass is the ability of a material to absorb heat energy. A lot of heat energy is required to change the temperature of high density materials like concrete, bricks and tiles. They are therefore said to have high thermal mass. Lightweight materials such as timber have low thermal mass.

In Karratha, thermal mass on the exterior of a building, such as brick walls, can store heat from high day time temperatures. Evening temperatures do not reduce sufficiently to allow the heat to escape. Heat from the bricks is transferred to the internal rooms of the house, causing air conditioners to work harder to cool the air.

Materials with a lower thermal mass should therefore be used for external walls, where possible.

Light Weight Materials:
Light weight materials should be used on the exterior of buildings.

Figure 26: Reverse brick veneer is a more appropriate construction methodology for houses in hot climates.

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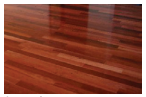
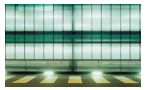
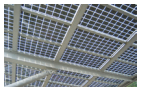
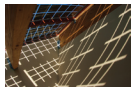
MATERIAL		QUALITATIVE PROPERTIES	APPLICATIONS	AVAILABILITY
Timber	 jarrah  treated pine 	_renewable resource _ common building material _used for construction & finishes _ connection with natural environment	_flooring _framing _cladding _structural _finshes	_Jarrah and treated pine readily available _other timbers can be sourced within 7 days and additional surcharges
Corten	   	_suitable for the harsh climate _designed to weather & age, no need for maintenacnce _colour & industrial vernacular	_cladding _internal and external use _landscaping and sculptural	_corten available for preorder with additional freight charge
Steel	   	_durable _cyclone resistant _lightweight _energy efficient	_framing _structural _roofing	_most products locally available _steel members not available can be pre-ordered and sourced within 7 days
Masonry	 brick & reverse brick veneer  precast concrete  in-situ concrete  rammed earth	_dense and resilliant _high thermal massing qualities _rammed earth soil and be sourced locally	_structural _wall _flooring _paving _landscape	_all products locally available _staff with Pilbarra knowledge and experience _13 000m2 pre cast space
Stone	 diamond cut stonework   natural crazy stone  pindan stone	_abrasion resistant _high silica content creates an anti slip surface _natural colours ideal for features, flooring and walls	_walls _cladding _flooring _landscaping _finishes	_natural crazy cut stonework available from Karratha quarry _additional freight charges form Perth for diamond cut
Colorbond	   	_australian vernacular material _lightweight structure but weather tight and secure _easy to maintain _array of colours available	_cladding _roofing _garages/sheds _patios _structural	_transportable via truck _locally available
Glazing	 double glazing  cyclone resistant  cyclone screen  colour back glass	_must pass AS 1170.2 for cyclonic resistance _connection to the external environment _ ventilation	_openings _framing	_locally available
Danpalon	 	_lightweight glazing alternative _water resistant _suitable for internal and external use	_internal and external use _cladding _roofing	_transported via truck _additional freight charges minimal due to weight of material
Photovoltaic Cells	   	_energy alternative and saver _promotes sustainability	_lighting _electricity _water recycling _solar energy	_needs to be pre ordered and transported on site. _freight charges depends on weight

Figure 27: Materials palette for Karratha Vernacular

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5.7 Cooling

5.7.1 Stack Effect

In natural ventilation mode during winter months, the natural air flows can b e maximised by capturing prevailing breezes, and during still conditions, by using the stack effect.

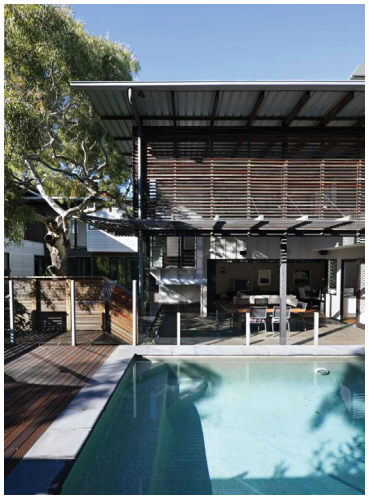
The stack effect is based on the principle that if there is a differential in stack pressure, created via a differential in either temperature or height, or both, air will flow low level to high level. The greater the stack pressure differential, the greater the airflow.

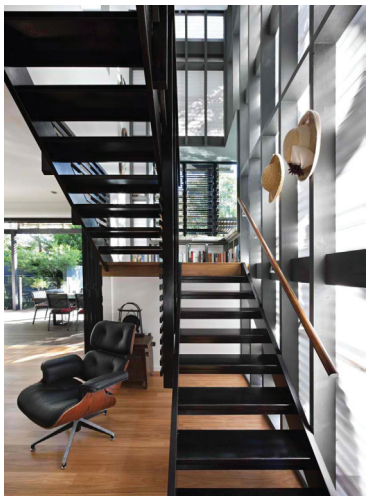
A higher stack pressure differential can be created using:
_low level air intakes and high level relief air vents
_solar chimneys
_trombe walls
_atria
_ground coupled air intakes
_shaded air intakes (cooler air input) and dark coloured solar driven air relief vents
_wind scoops
_creating temperature differentials with microclimates and strategic vegetation planting

Openable systems that provide for the stack effect must be designed to take account of Karrathas cyclonic conditions including appropriate locking mechanisms and seals.

Enthalpy Recovery

Commonly used in all sub tropical climates in Middle East but new to Australia, enthalpy wheels recover both the sensible (dry) heat and latent heat (moisture) from exhaust air streams and transfer the useful energy to incoming fresh air steams to buildings. Sensible heat recovery only results in energy transfer efficiency of ~50% whereas enthalpy recovery can improve this to 75-80%.





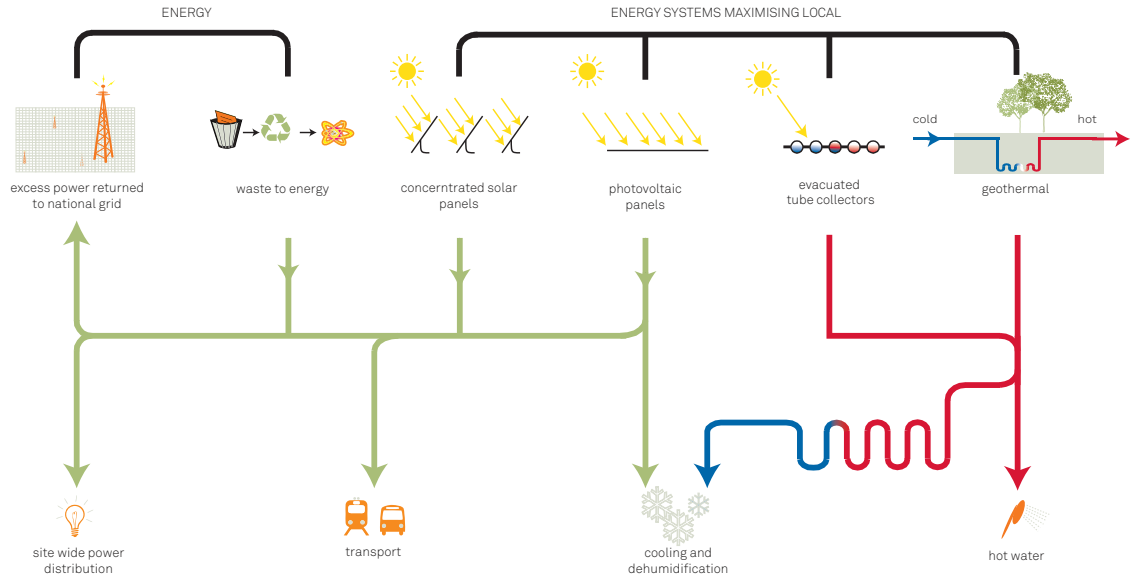


Figure 28: Energy efficeient city model.

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Heat Pipes

In a similar manner, heat pipes are another technology commonly used in Arabic countries and very rarely in Australia, however in "humid" climates, they provide 'free' reheat of the dehumidified air.

Other principles which should be investigated include:

_Opportunities for connection to district energy systems, or at least shared services between multiple buildings.
_Solar thermal cooling
_Ceiling fans to enhance natural cooling
_Solar veils
_Careful colour selection
_Careful placement of thermal mass
_Night sky radiant cooling (black body radiation)
_PV Cells and Wind Microturbines (both more viable in Karratha than Perth) – incentivise PV cells on each house.
_Displacement air conditioning systems (only need to cool the incoming air down to 20°C)
_Package solar thermal for each house – thermosorber etc. Produces hot water and cold water (for a/c) from solar thermal collectors or gas.

5.7.2 District Cooling Systems

A district cooling system (DCS) distributes thermal energy in the form of chilled water or other media from a central source to multiple buildings through a network of underground pipes for use in space and process cooling. The cooling or heat rejection is usually provided from a central cooling plant, thus eliminating the need for separate systems in individual buildings.

A DCS consists of three primary components: the central plant, the distribution network and the consumer system. The central plant may include the cooling equipment, power generation and thermal storage. The distribution or piping network is often the most expensive portion of the DCS and warrants careful design to optimize its use. The consumer system would usually comprise of air handling units and chilled water piping in the building.

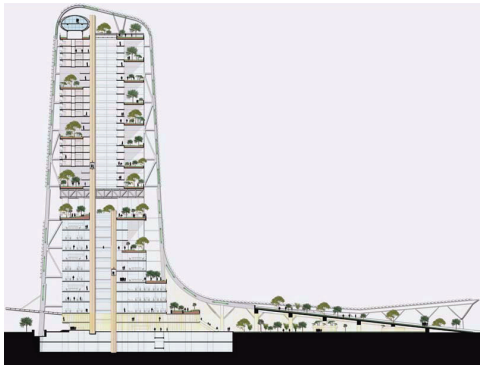

Figure 29: These pictures are courtesy of Ashwin Chaudhari & Tushar Parab in Singapore. The design consists of a mixed-use tower accommodating both office and residential functions. A veil of trackable photovoltaic panels supported on a structural steel frame is draped over the building and orientated east-west to correspond to the Singaporean sunpath. The veil is then extended horizontally at ground level to maximize energy generation and create a covered marketplace. The veil not only acts to generate energy, but also shades the 'hot' sides of the tower from the intense overhead sun, opening up to expose key views when the sun has passed.

Figure 30: District cooling systems (DCS) are frequently used in desert environments, such as Dubai. As the distribution medium is usually chilled water, district cooling plants are often made up of cooling towers or heat rejection equipment.

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5.7.3 Solar Systems

Photo-voltaic cells are ideal for the Pilbara given the intensity of solar irradiation it receives. Approximately 24 square metres or 3kW of cells would be required to power a traditional house with an air-conditioner over a year. This is based on the air conditioner only being run during the 6 month summer period and it being set at 26 degrees.

Installation of photo-voltaic cells needs to take into account cyclonic loading. Intallation, transport and labour costs will be higher within the region, and must be taken into account. To power a standard home, the cells should be based on a minimum quantity of 3kW installed capacity.

Solar Systems:
Solar power systems should be considered for new residential areas in Karratha.

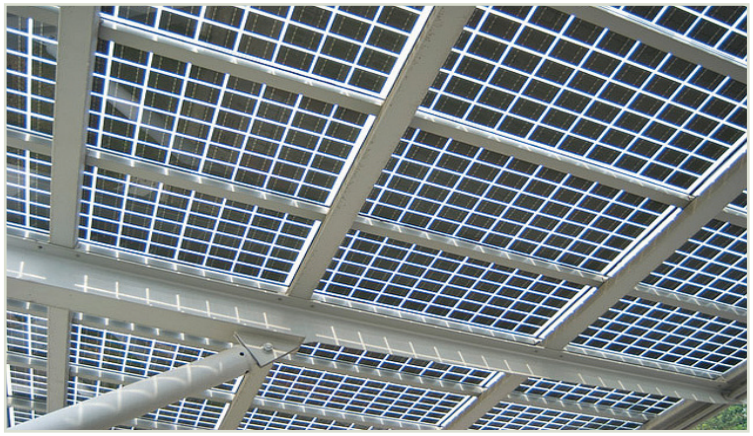

Figure 31: Photovoltaic cells

Based on available solar data for Karratha the anticipated performance of a 3.18kWp system is as follows.

Yield (kWh/kWp)	System Size (kWp)	AC Rating (kWac)	Capacity Factor %	Performance Ratio %
1,918.5	3.18	2.7	21.9%	79.5%

	Daylight Hours	Gh (kWh/m2/day)	Ipoa (kWh/m2/day)	AC Energy (kWh)
January	405.1	7.27	6.68	511
February	354.1	6.54	6.34	440
March	375.1	6.20	6.50	499
April	345.8	5.52	6.29	474
May	342.5	4.70	5.80	463
June	324.2	4.36	5.61	442
July	338.1	4.73	6.02	490
August	350.6	5.87	7.04	564
September	355.4	6.52	7.14	546
October	385.0	7.34	7.38	573
November	387.7	7.77	7.24	541
December	408.9	8.09	7.28	558
Year	4,372.6	6.24	6.61	6,101

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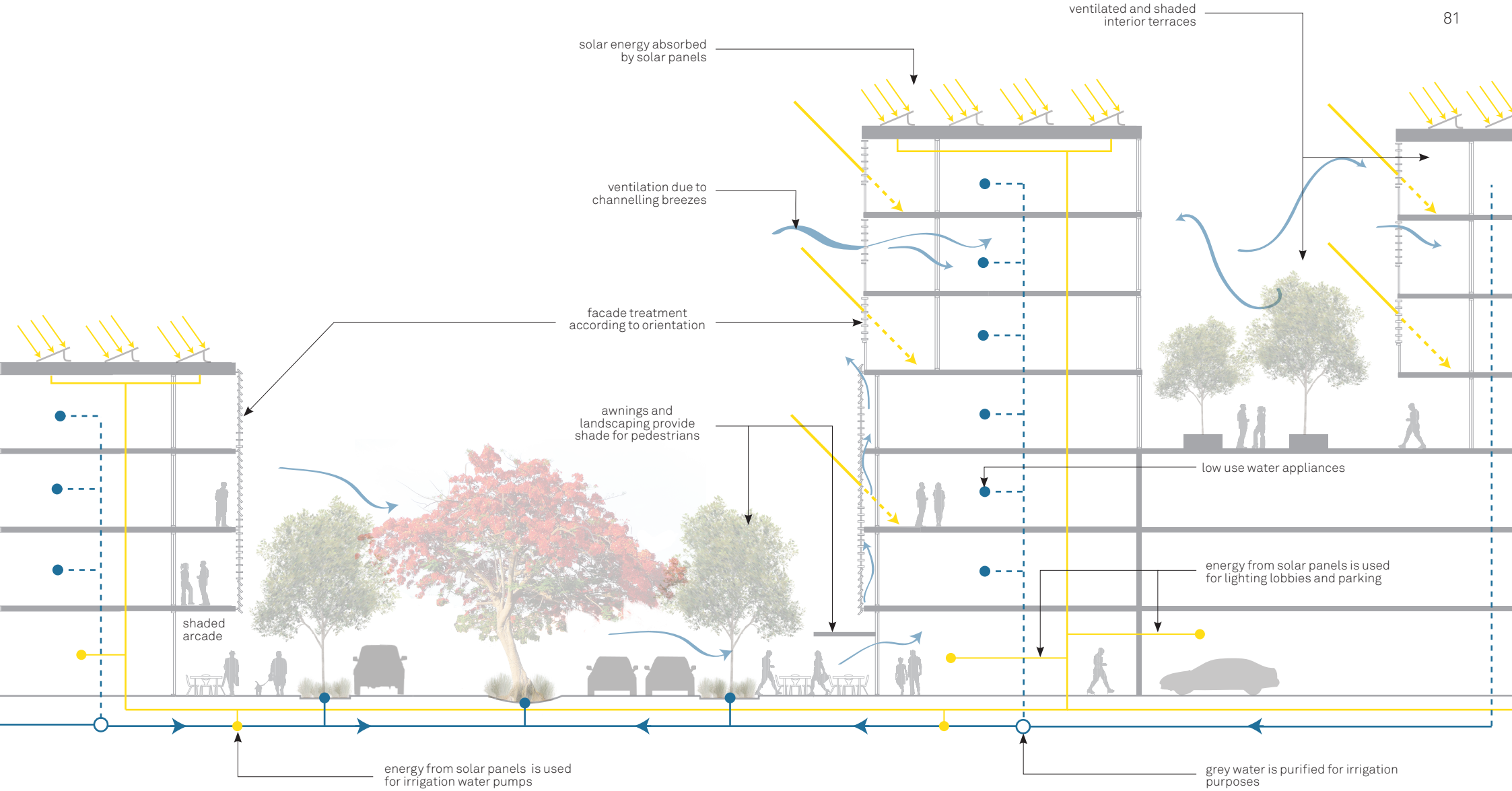

Figure 32: City centre buildings can share solar gain to help provide power

5.0___Built Form Design

5.8 Wind Power

The viability of wind power in Karratha is up to 20% greater than in Perth due to higher wind speeds. When combined with solar photo-voltaic cells, the viability of these sustainable power sources is considered very good because wind power peaks at a different time to solar power.

In terms of noise, any turbine should be at least 500 metres from sensitive land uses, such as residences. Additionally, wind turbines will need to be designed to be shutdown and tied to the ground in the event of cyclones.

For example, to completely power Mulataga's 4,500 homes (over the long term) approximately 60 turbines would be required, in an area of around 9 hectares. If turbines were complemented by 2kW photovoltaic cells on 4,500 rooftops, around 20 turbines would be required to reach carbon neutrality.

Figure 33: Wind turbines at Coral Bay are able to be tilted down during cyclones.

5.0___Built Form Design

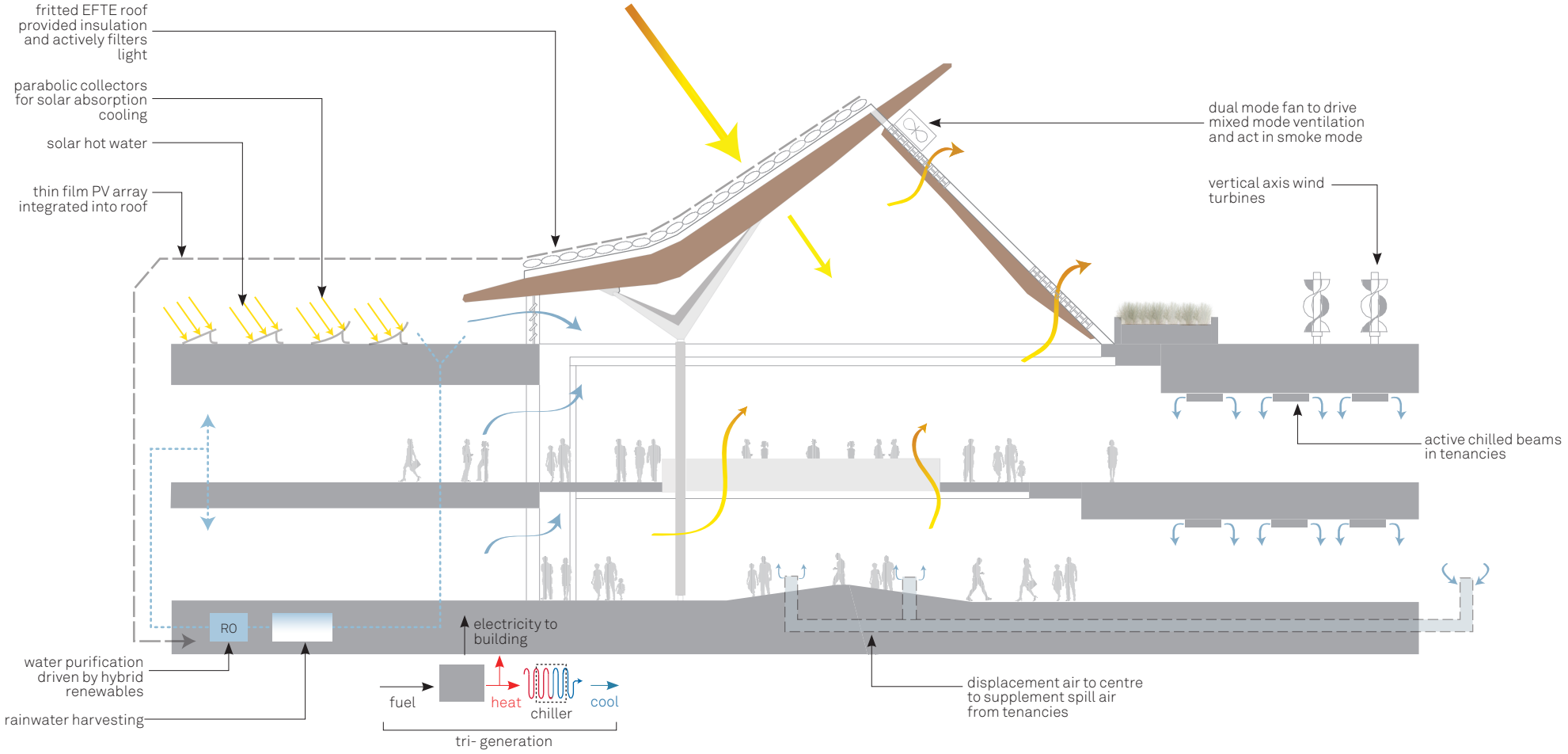

Figure 34: This diagram demonstrates how a combination of systems including solar photovoltaic cells, wind turbines, the stack effect, passive ventilation and district cooling systems can be used to minimise the energy requirements of buildings, particularly within the city core.

5.0___Built Form Design

DESIGN ELEMENT		DESIGN ELEMENT	DESIGN ELEMENT	DESIGN ELEMENT	DESIGN ELEMENT
CONSTRUCTION	General	Lightweight	Combination (Lightweight and Mass; Reverse Brick Veneer)		_Buildings designed to resist a Category 5 Cyclone at 280km/hr
BUILDING FABRIC	External walls	Shading of External Walls		3.12 Energy Efficiency 3.12.1.4 External Walls	_R-Value of 2.8 or 2.4 inclusive of shading device (Table 3.12.1.3a); _Options for each part on an external wall with a surface density of not less than 220kg/m2
	Roof	Roof ventilation (upward ventilation - gable, ridge, eave and roof vents)	Residential- Pitched roof with flat ceiling	3.12 Energy Efficiency 3.12.1.2 Roof	_R-Value as per Table 3.12.1.1a Roof and Ceiling _Minimum total R-Value
	Floor	Raised floors & Suspended floors	Raised concrete slab	3.12 Energy Efficiency 3.12.1.5 Floor	_Suspended floors are preferable for ventilation and airv circulation
	Insulation	Reflective	Bulk/Mass (particularly for airconditioned spaces)	3.12 Energy Efficiency 3.12.1.1 Building Fabric Thermal Insulation	_Insulation in accordance with 3.12.1.1 _Manufacturers Specifications, and AS/NZS 4859.1 _Reflective insulation reduces heat transfe
	Glazing	Shaded, Coated and Tinted		3.12 Energy Efficiency 3.12.2 External Glazing	_Glazing calculators available _There is little or no need for heating at any time of the year in Zone 1; _See table 3.12.2.2b for summer exposure factor in climate zone 1
BUILDING PLAN	Orientation	Lot Orientation East-West	To capture cooler evening/night breezes		_Protect against direct sunlight (predominantly east/west and also north)
	Built Form	Long/Thin or Smaller Individual Buildings	Circulation between buildings (setbacks)		_This buiiding form promotes air circulation _Larger exposed surface area increases opportunities for heat loss at night
EXTERNAL AND INTERSTITIAL SPACES		Balconies, Verandahs, Patios, Internal Courtyards	Covered outdoor living spaces with fans		
AIR MOVEMENT	Ventilation	Two openings per habitable room (breeze path)	Low to high cross ventilation (cooler air drawn in from floor or lower wall vents/louvres and taken out through higher wall/ roof vents/louvres	3.12 Energy Efficiency 3.12.4 Air Movement 3.12.2 External Glazing	_Table 3.12.4.1 Provision for air movement _ 1.5m minimum opening for one of the two openings (per habitable room);
	Heating Cooling	Sealed Building (for heating/cooling other than evaporative)		3.12 Energy Efficiency 3.12.4 Air Movement 3.12.3 Building Ceiling	
SOLAR ACCESS & SHADING		Horizontal Shading and Eaves	Vertical Shading		_Louvres, Shading Screens and fixed angle slatted or perforated shades are beneficial
MATERIALS/COLOURS		Light	Reflective		_The colour of the red earth will impact on the appearance of the façade

01_ Karratha Vernacular Design Principles. Climatic implications and summary of design elements.

5.0____Built Form Design

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