WARM TEMPERATE CLIMATE STUDY & DESIGN GUIDELINES

Phase 2 Report: Architectural Responses to the Warm Temperate Climate

Date	Issue	Authors
30/07/2021	A	Kirsty Volz, Rosemary Kennedy, Liz Brogden, Kieu Pham

Executive Summary

Phase 2 of this project – Defining Warm Temperate Climate Architecture – involves identifying best practice in architectural responses to warm temperate climates. The research for this phase began with a literature review of warm temperate climate responsive design approaches and practices, vernacular principles and contemporary applications, locally, nationally and globally. The next step involved case study research into existing buildings that have been designed to be responsive to the Toowoomba climate (classified as Zone 5, warm temperate climate). The case studies will be selected through consultation with local Architects and Building Designers, via AIA and BDAQ local regional awards databases, through interviews with local residents, as well as drawn from existing knowledge within the research team. Contemporary and heritage buildings will be included and analysed as case studies. Data will be drawn from site visits to these projects. Information collected will include:

- Photographs and sketches created by the research team
- Site plans including analytical data (orientation and neighbouring buildings, setbacks, street scape, built form)
- Drawings/plans (where available)
- Materials application and thermal mass
- Construction methods and systems, insulation and thermal performance
- Ventilation strategies and/or HVAC applications
- Natural lighting strategies
- Building fuel and energy source and any available emissions data

  Anecdotal feedback from building owners and users; and
- Assessment of public space, street quality and the impacts of conditions around buildings on their performance (e.g. shade, ground surface type, adjacencies)
- Alongside gathering this information, the project team will liaise with consultants undertaking the Regional Landscape and Urban Character Study, the TRUFF and the Scenic Amenity Study.

Additionally, exemplars from other Australian states with warm temperate climatic conditions will be investigated as case studies, including: Coastal New South Wales between Port Macquarie and Woollongong; Coastal areas of South Australia west of Adelaide; and Coastal areas of Western Australia (east and west of Esperance and between Margaret River and Geraldton). These case studies will be selected using these same methods; however, site visits to these buildings will not be undertaken as part of this project. Information will be sourced from architects, designers and building owners via email and phone calls. Building types that will be analysed as part of this process will include: traditional housing, small lot housing, duplexes, medium density housing, and multi storey residential and commercial buildings. In addition to this, case studies will also be drawn from institutional, educational, and health buildings, as they may employ design principles and strategies that can be applied to the prescribed list of building types to be in included in the design guidelines.

Table of contents

1. Introduction

This report presents the findings of Phase 2 of the Warm Temperate Climate Study and Guideline Project conducted by the Queensland University of Technology on behalf of the Toowoomba Regional Council.

The Project's purpose is to establish a local rationale for sustainable design for building types that cover housing, commercial and mixed-use classes 1, 2, 5 and 6 in the Toowoomba Region. It is conducted in three phases.

Phase 1 defined the warm temperate climate as it relates to the Toowoomba Regional Council (TRC) area. Phase 2 involves identifying best practice architectural responses to warm temperate climates in general. Phase 3 will draw on the outcomes of Phases 1 and 2 to recommend place-based design principles of good quality climate-responsive architecture that is specific to and for the Toowoomba Region.

The significance of the Project is that it will provide the foundation for design-based provisions to be incorporated in the Council's new planning scheme to achieve more sustainable, regionally appropriate buildings as the region develops.

1.1. Phase 2 Aims and Objectives

The primary aim of Phase 2 is to identify key design principles to enhance liveability and minimise energy requirements for heating, cooling, ventilation, and lighting in warm temperate climate buildings.

The secondary aim is to develop a compendium of warm temperate climate buildings that are demonstratable of the key design principles for traditional housing, small lot housing, duplexes, medium density housing, and multi storey residential and commercial buildings (NCC Class 1,2,5, and 6).

The research objectives of Phase 2 are: 1) to establish fundamental climate-responsive design controls for buildings in comparative warm temperate climate regions in Australia and overseas by identifying proven existing solutions, including novel and innovative responses and, 2) define climate-adaptive design strategies in warm temperate climate zones.

1.2. Key Findings.

The report finds four fundamental controls that are relevant architectural responses for warm temperate climates: responsive massing, form articulation, passive harvesting (natural energies) and mechanical fine-tuning.

Tier 1 Responsive massing: building orientation and street layout

- Produce solar-ready building sites that make it possible to face long sides of lots and buildings north and allow space between buildings in the north-south direction
- Elongate buildings along their east-west axis (exposing the largest surface area toward solar north)
- The ratio between the length and width of a building should be at least 2:1
- Use the (north-east) most habitable part of the site and building for outdoor living areas
- Shade during the hot part of the year and are sunny and protected from cold winds when the weather is cold
- Position the house in relation to cold winds and use a narrow form and layout for cross-ventilation and air movement in summer
- Shelter against the cold south-westerlies blowing during cool to cold months
- Openness to north, north-east year-round

Tier 2 Form articulation

- Shade walls and openings during hot half of the year with deep overhangs
- Ensure the geometry of these overhangs allow winter sun's heat and light onto the interior
- Insulate walls, roof and floor

Tier 3 Passive harvesting: natural energies

- Thermal mass inside, for example, cavity brick not brick-veneer
- Building envelope design for air movement and ventilation – open up in summer, close down in winter

Tier 4 Mechanical: fine tuning

- Add only what is needed, maximise efficiency, monitor performance, and maintain
- Long-life loose-fit principles to integrate emerging technologies

Case study research

The site and surroundings, orientation, shape and internal layout, construction type, (thermal mass and insulation) need to work together as a whole system that combines ordinary building components and uses in ways that best suit local climate, landscape and lifestyle. Case study research revealed:

Traditional passive strategies - orientation, building form and materials to regulate heat and air flow

Contemporary passive strategies taking into account modern spatial aesthetics and function

Future focussed passive and active strategies

Comfort and energy efficiency can be achieved with most housing types and styles.

Ways to resolve the basic contradictions between planning and design for climate are crucial to future climate liveability. The objective is to create warm temperate climate buildings that are warm in winter and cool in summer by design. In the first instance, building sites that allow buildings to open to the north are essential to allow the building's shape and materials to do most of the thermal 'heavy lifting'. Three parameters (orientation, appropriate building shape and construction standards) can create efficiencies and significant energy savings for any auxiliary heating and cooling requirements.

The relationship of the building or dwelling to the block of land in terms of achieving ideal orientation, is the most crucial consideration affecting likely performance. Unfortunately, many subdivision layouts produce building sites that compromise the liveability and potential energy performance of buildings, particularly new stand-alone project homes. Such dwellings are the most popular choice of households, due to perceived affordability. Careful subdivision and precinct design is essential to avoid this and provide sites for buildings with northern orientation and well-insulated and sealed construction standards.

Master planning for infill developments offer ideal opportunities to replace unsuitable urban patterns with streets and opens spaces that are orientated to provide conducive sites for well-oriented buildings.

1.3. Background – Climatic Strategies Phase 1 Report

The consideration of local climate conditions is a key starting point for formulating building principles that aim to minimise building energy consumption. Phase 1 investigated how the warm temperate climate is defined in scientific literature and in regulatory frameworks, and analysed data to determine a comprehensive definition of the Toowoomba Region's warm temperate climate. Phase 1 also established human comfort criteria whereby desired indoor comfort design criteria (physiological) relates to outdoor climate factors.

Current climate

The report comprehensively detailed the macro-climatic characteristics as evidenced by records that indicate a temperate climate with hot summers and no dry season, classified Cfa in the Koppen-Geiger international climate classification system, as is Greater Brisbane on the nearby coastal plain.

Nevertheless, the local conditions place the Toowoomba Regional Council (TRC) area in Climate Zone 5 under the National Construction Code (NCC), requiring winter heating, while Greater Brisbane is in Climate Zone 2. The Phase 1 report described how the TRC area is differentiated from Greater Brisbane by local climate nuances which affect human thermal comfort and potentially the amount of energy required to maintain internal building temperatures in an ‘acceptable’ range.

For example, its elevation above sea level has a marked cooling effect on overnight temperatures in the warming season, and its higher average wind speeds temper the effect of high humidity, particularly on hot summer afternoons. In winter, wind from the south and west exacerbates thermal discomfort when coupled with low temperatures. Though wind from this direction only occurs about 10 percent of the time annually, and mostly during July and August, it is perceived to present a major local design parameter.

In terms of building design requirements indicated by climate parameters and human thermal comfort ranges in the TRC area, the report established that there are very few days that require active cooling systems in buildings and passive cooling can be achieved by thermal mass and natural ventilation. On the other hand, while thermal mass, passive solar gain and active solar gain provides adequate heating, there are comparatively more days when active heating systems are needed in winter, than there are in Brisbane. Thermal mass inside buildings is recommended as the predominant strategy for both passive heating and passive cooling.

Future climate

The Phase 1 report also demonstrated how variable and demanding the climate can be decade on decade in the Toowoomba Region, and that the future climate will bring more challenges. The emerging trends associated with climate change indicate longer and more severe droughts and heatwaves due to decreasing rainfall and increasing temperatures. Such weather conditions exacerbate bushfire risk.

The implications of these trends on human health and well-being, on the efficacy of strategies to increase vegetative cover for cooling and shade, and on the efficacy of energy generation systems to meet increased peak load demands for cooling are predictable, and therefore can be planned for in order to ameliorate the negative impacts of climate change and positively improve local amenity and liveability.

Phase 1 recommended that future urban development in the TRC region must be designed with urban layouts and building design and construction that aid urban ventilation and cooling shade in summer, and wind-protection and solar warming in winter. Phase 1 Appendix 3, Sun Studies for Toowoomba, illustrated the influence of height and horizontal density of built form on shading of outdoor spaces and neighbouring buildings during mid-winter and mid-summer.

1.4. Scope and limitations

Building types that form part of the project scope and were analysed as part of this phase include traditional housing (detached housing), small lot housing, duplexes, medium density housing, multi-storey residential, commercial and mixed-use buildings.

While the focus of Warm Temperate Climate (WTC)research is not on the street, neighbourhood or sub-regional scales, the geometry of subdivision planning and the layout of lots, coupled with topographical characteristics of the terrain, are very influential on the urban microclimate and on subsequent performance of individual buildings for energy, comfort and liveability. In turn, built outcomes, including vegetation or lack thereof, at the individual lot scale can either enhance or worsen local urban climate comfort for residents. Therefore, the methodology we adopt takes into account the physical context of the exemplars identified.

1.5. Methodology

The scope of Phase 2 covers the key strategies for applying WTC design principles for building class 1, 2, 5 and 6 using the following methods:

- Critical review of building design and architectural science literature to identify proven solutions for warm temperate climatic design
- Analysis of design principles documented in the literature using an Analytical Design Framework of climatic design considerations
- Survey of traditional and contemporary architectural practices and principles responding to the warm temperate climate
- Consultation event and panel discussion with local architects and building designers
- Compilation of a database of warm temperate climate architectural typologies relevant to this study
- Local case studies of two contemporary buildings, including site visits and informal interviews with end-users.

Literature review of architecture for warm temperate climates

A critical review of peer-reviewed literature including case studies of notable buildings in warm temperate climates occurring locally, nationally and globally, to identify proven and consistent design approaches and practices, as well as novel and innovative responses, including vernacular principles and contemporary applications.

Climatic Design Analytical Framework analysis

In order to systematically identify the building design strategies employed in warm temperate climates and thus establish the fundamental principles that recur, we selected Lechner's generic three-tier approach as a framework of analysis and adapted it by adding strategies required to respond to the micro-climate surrounding a given building as the first tier of the climatic design approach.[1]

[1] Lechner, N. (2014). *Heating, cooling, lighting: Sustainable design methods for architects*. John Wiley & sons. Page 9.

The adapted framework

Table 1 provides an analytical framework to identify primary design considerations operating at four tiers of influence to attenuate the effects of the external climatic conditions on the indoor thermal comfort and lighting of buildings.

Tier 1 Responsive massing

Micro-climate siting and building form specific to the urban/rural and climate conditions to exploit the natural resources available to the site/building (sun, air movement, rainfall) and minimise the energy required for heating, cooling, and lighting. The building's physical arrangement, orientation and shape, takes account of the effects of the building's surroundings at different levels of granularity - the city or neighbourhood, street, and site scale - and brings urban interfacing and local council requirements into focus.

Tier 2 Form articulation

Building form articulated by materiality, colour finishes, spatial zoning, openings and structural integrity to minimise heat loss in winter, heat gain in summer. Location and orientation of openings should maximise daylight availability for visual comfort (including exposure for circadian stimulation and task acuity).

Tier 3 Passive harvesting

Natural energy systems. Passive and/or active (e.g., solar) energy systems for heat modulation, dissipation and passive lighting using thermal and/or non-thermal energy sources.

Tier 4 Mechanical fine-tuning

Auxiliary technology, mechanical systems, plant and equipment for heating, cooling, and lighting added to meet remaining energy load and offset seasonal variations aimed at achieving 'acceptable' indoor conditions. Provisions for managing, monitoring and maintaining performance, and ways of integrating emerging technologies with least disruption to existing building.

Table 1 Analytical Design Framework for sustainable and climate-responsive building design (adapted from Lechner's three-tier framework[2]).

		Heating	Cooling	Lighting
Responsive massing	**Tier 1** **Micro-climate siting** Basic building arrangement (form, shape, height, and orientation) to urban/rural context and climatic conditions for heating, cooling, lighting, and urban interfacing.	**Blending** 1. Solar gains (form orientation) 2. Thermal gains (urban interface: common walls, urban activities)	**Protection from heat gains** 3. Solar shading (existing deciduous trees) 4. Natural ventilation (building layout)	**Solar Access** 1. Daylight exposure Sky view Angle (form orientation and layout)
Form articulation	**Tier 2** **Basic building articulation** Articulation of the building form (openings, materiality, colour finishes and zoning) and structure to minimise heat loss in winter and heat gain in summer	**Conservation** 1. Solar infiltration (openings) 2. Heat conservation (window-to-wall ratio) 3. Solar absorption (exterior finishes) 4. Heat transfer (exterior materials)	**Heat avoidance** 1. Reflectance (exterior and interior finishes) 2. Cool and/or lightweight materials 3. Heat ventilation (surface-to-volume ratio) 4. Cross-ventilation (openings) 5. Separating heat generating activities (spatial zoning)	**Natural Light** 1. Daylight access (apertures) 2. Daylight distribution (opening width and height)
Passive harvesting	**Tier 3** **Natural energy systems** Passive and active systems for heating, cooling, and lighting	**Passive heating** 1. Direct gains (apertures) 2. Isolated gains (e.g., sunroom) 3. Indirect gains (e.g., thermal mass) 4. Heat conservation (insulation) 5. Draught sealing (insulation, sealants) 6. Active heating (solar power)	**Passive cooling** 1. Evaporative cooling (e.g., porous materials, cool roofs) 2. Night-flushing (stack ventilation) 3. Radiant barriers (insulation) 4. Heat sinks (earth-coupled slabs or roofs) 5. Low thermal mass (lightweight materials) 6. Cross-ventilation (apertures) 7. Operable shading (thermal comfort) 8. Active cooling (solar power) 9. Natural shading (deciduous trees) 10. Evapotranspiration (green landscaping)	**Daylighting** 1. Colour rendering and exposure (daylight permeation and distribution) 2. Visible transmittance (e.g. low-e glazing or diffused) 3. Glare control (operable shading) 4. Indirect illumination (wall and ceiling reflectance) 5. Solar generated electrical lighting
Mechanical fine-tuning	**Tier 4** **Mechanical systems** Auxiliary systems and technologies for heating, cooling, and lighting. Management, monitoring and maintenance systems	**Mechanical heating** 1. Gas heaters 2. Central heating (ducts/pipes) 3. Space heating (e.g., gas, wood, electric) 4. Smart home technologies (energy management)	**Mechanical cooling** 1. Central cooling (ducts/pipes) 2. Geo-exchange 3. De-humidification 4. Ceiling fans 5. Smart home technologies (energy management)	**Electrical lighting** 1. Energy efficient lamps (low input power and high distribution W/m²) 2. Colour rendering (lamp CCT) 3. Energy offsetting (e.g., dimming) 4. Other smart home technologies (energy management)

[2] Lechner, N. (2014). *Heating, cooling, lighting: Sustainable design methods for architects*. John Wiley & sons. Page 9.

2. Warm Temperate Climate Architecture

2.1. Literature Review using climatic design analytical framework

The review of existing literature on architecture for warm temperate climates found generalisable strategies to create climatically comfortable dwellings and other habitable buildings in the warm temperate climate zone. All design solutions require integrated decision-making to find the best fit for a particular set of macro- and micro-climatic conditions and building use.

2.1.1. Tier 1 Responsive Massing: Micro-climate siting

Securing access to solar gains during winter and cooling breezes during summer are key objectives in warm temperate climates. Key architectural science and urban design researchers[3] [4] draw attention to the importance of the microclimate and its influence on buildings' comfort and energy performance. External sources of overshadowing, glare, air pollution, waste heat, noise, and so on, also contribute to the micro-climatic context within which a given building sits.

The key planning controls that can attenuate the effects of the micro-climate and leverage positive climatic attributes at the local scale are the three-dimensional urban form, material properties of surroundings including facades, landscape and vegetation.[5] Similarly, the determinant features of 'building form' are the building elements, materials and associated landscaping.[6]

At the urban scale, important determinants of microclimates are:

- Street layout and geometry (orientation and aspect ratio - building height: street width) and the configuration of buildings and relationship to one another in the urban arrangement (horizontal

[3] Emmanuel, R 2021, 'Urban microclimate in temperate climates: a summary for practitioners', *Buildings and Cities*.
[4] Koenigsberger, O H, Ingersoll TG, Mayhew, A & Szokolay S V 1974 *Manual of Tropical Housing and Building Part 1 Climatic Design* London, Longman Group Ltd
[5] Emmanuel, R. (2021). Urban microclimate in temperate climates: a summary for practitioners. Buildings and Cities, 2(1), pp. 1–9. DOI: https:// doi.org/10.5334/bc.109
[6] Hyde, R (2000) Climate Responsive Design: A Study of Building in Moderate and Hot Humid Climates. E & FN Spon. London. p31

density - openness or compactness; and / or vertical density - building heights and access to sky view).

- Choice of building envelope materials related to street orientation (surface texture and colour affect materials' reflectivity and emittance and how readily solar radiation is emitted to surroundings)
- Size, spread, distribution and geometry of urban trees and vegetation in combination with buildings. (Gunawardena et al. 2017 in Emmanuel, 2021)

The responses to these determinants can potentially add to or ameliorate the urban heat island (UHI) effect.

A study[7] comprising detailed climatic analyses of three Australian capital cities belonging to NCC Climate Zone 5 Warm Temperate produced design recommendations for climatically suitable and energy efficient planning and building design options for Sydney, Adelaide and Perth. The study confirmed the climatic variation of locations designated Zone 5. Though similar requirements exist for winter heating and thermal mass across all three cities, locality-specific strategies are needed for street and building orientation due to differences in humidity, sky conditions, wind intensity and directions. The study generally recommended to organise streets, open spaces and buildings for solar utilisation and urban ventilation by facing buildings north with elongated east-west axes to collect sun in winter and spacing them far enough apart in the north-south direction not to shade each other. Moreover, the study also recommended considering summer wind movement by angling streets approximately 20 - 30 degrees in either direction to prevailing afternoon and evening wind directions in each city.

The *Your Home Technical Manual*, Australia's guide to environmentally sustainable homes[8] concurs that NCC Climate Zone 5 has "widely variable solar access and cooling breeze directions and patterns" and that…northern orientation (east-west long axis) is desirable in climates requiring winter heating.[9] The single most important design strategy for domestic scale building form in temperate climates is to face the building 'towards the sun'. In the Southern Hemisphere, this means buildings are oriented so long sides face north for solar access in winter; shortest sides face east and west to minimise solar gains. Furthermore, the recommended house shape has a length-to-depth ratio of approximately 2:1. *Your Home* also notes that deviations of 20 degrees off true north, either to the west or east, are acceptable without loss of performance.

When ideal orientation is not achievable, building design and responses to the micro-climate conditions become even more crucial. The 12-

[7] Upadhyay,A. 2008 *Climatic Design Strategies for Sydney, Adelaide and Perth: A Study of Building Code of Australia's Climate Zone 5*. Proceedings of the World Conference SB08. p.7
[8] Your Home Technical Manual
[9] Cole, G, (2011) *Residential passive design for temperate climates,* EDG66, Environment Design Guide, February. Environmentdesignguide.com.au; Your Home; Hyde, R (2000)

storey office building National Association of Realtors Building in Washington, D.C (Cfa, warm temperate climate) has a full glass facade on its long western street side, utilising low-emissivity double-glazing with a high shading coefficient. The intention was to shade its western facade and reduce the need for "extreme solar control" by utilising overshadowing by existing buildings.[10] While 'self-shading' buildings and streets are found in historic centres of temperate climate cities with drier climates, for example Barcelona, this strategy is not advisable in contemporary cities, where developers have little control over whether an adjacent building will actually be built, stay built or even provide expected protection due to street aspect ratio. Furthermore, in this case, while the shiny low-emissivity glass envelope material may have been chosen for energy savings to the individual building, solar radiation falling on the west-facing street facade is reflected and re-radiated back into the urban microclimate. It is likely this strategy also has adverse impacts on pedestrian thermal comfort at street level during the overheated part of the year. On the positive side, this building's light coloured roof pavers reduce urban heat island effect. The paved roof also captures rainwater.

Another office building, the Winrock International Global Headquarters in Little Rock, Arkansas (warm temperate (Cfa) climate) resolved site constraint conditions which resulted in a north-south long axis building orientation, with an oversized roof and large trees on the west to provide solar shading.[11]

Vegetation and green cover in urban, suburban areas, and rural areas have the greatest potential to improve the microclimate through evapotranspiration and physical shading. Trees on public and private land provide additional benefits including visual amenity and air quality improvement.[12]

Other generic Tier 1 warm temperate climate-matching strategies for domestic scale buildings found in the literature [13]include:

- Vegetation and landscape - tree canopy for summer shade and winter solar access; heat and glare reduction
- External sun-shading devices - summer sun control and winter sun ingress; diffuse daylighting and glare reduction

[10] Emerald Architecture, Case Studies in Green Building. 2008. P.88
[11] Case Studies in Green Building. *Emerald Architecture,* 2008
[12] Yuan, J., Emura, K., & Farnham, C. (2017) cited in Emmanuel 2021) Is urban albedo or urban green covering more effective for urban microclimate improvement? A simulation for Osaka. *Sustainable Cities and Society*, 32, 78–86. DOI: 10.1016/j.scs.2017.03.021
[13] Hyde, R, 2000. pp30-31

2.1.2. Tier 2 Basic Building Articulation

The Santorini townhouse and Roman atrium house[14] are examples of traditional architecture of warm temperate moderately dry climates (Csa) which embody basic building articulation elements: heavy stone wall construction has a long lag time and stabilises indoor climate [heat transfer], whitewashed externally [heat reflectance], small windows [heat conservation], and the use of buffer zones such as loggia, balconies, terraces, porticos, patios, enclosed courtyards and gardens [spatial zoning].

Architectural strategies are generally combined to minimise heat loss in winter and heat gain in summer. In Marseille, France, [Csb, Warm temperate, dry summer] the Unite d' Habitation – a multi-storey residential apartment building; spatial zoning is combined with shading, ventilation and daylighting. In this exemplar, dwellings in the building have a double-height living room located off a balcony which has openable double-height windows and a reflective shelf to screen out the heat of high angle summer sun, whilst allowing access to controlled daylight. With each dwelling having access to openings on each of the long sides of the building, the cross-section facilitates cross-ventilation. Le Corbusier's *Brise-Soleil* facade system provides a pleasant indoor climate and a varied façade expression. This three-part system consists of fixed shading to prevent direct sun during summer months [solar infiltration], a glass area to facilitate view and allow daylighting, and an aperture for ventilation for every dwelling.[15]

Cross ventilation is recommended in Cfa climates within Australia[16] and Japan[17]. Post-occupancy evaluations of commercial and institutional buildings within warm-temperate climates revealed occupants were both becoming more accepting of a wider temperature band for comfort, and natural ventilation openings in which occupants had control over the system were mentioned as being appreciated.[18] Summer over-heating was noted in some naturally ventilated and mixed-mode temperate zoned buildings.[19] Ventilation must be provided with fine control to allow occupants to find their own level of ventilation for economy, comfort and condensation control.[20]

---

14 Climate and Architecture; Torben Dahl, 2010, p.18
15 Climate and Architecture; Torben Dahl, 2010 p.134
16 Upadhyay, A. 2008
17 Hyde, R, Bioclimatic Housing, Innovative Design for Warm Climates p.198
18 Sustainable Buildings in Practice. George Baird; 2010. P.21
19 Sustainable Buildings in Practice. George Baird; 2010. P.20
20 Energy Efficient Building; Susan Roaf and Mary Hancock; p.204

Design recommendations for NCC Zone 5 also include the protection of openings to avoid direct sunlight [solar infiltration][21]

Generic Tier 2 warm temperate climate-matching strategies for domestic scale buildings also include[22]:

- Verandas provide shaded space outside.
- Open cross-section to maximise stack ventilation whereby openable clerestory windows at the highest part of the roof facilitate cross ventilation especially if a double-loaded plan with living areas to the north and bedrooms to the south.

A preliminary concept sketch (dated Jan/Feb 94) for a house in the Adelaide Hills[23], warm temperate climate Csb (NCC Zone 5) illustrates the essential combination of Tier 1 'orientation' strategy and Tier 2 spatial zoning strategy. The sketch notes the winter winds to avoid, direction of summer winds and location of a major shade tree. It shows a linear north-facing plan fortuitously running along the contours of the rural site, locates an outdoor space in the more habitable part of the site to the north east, shielded from October and November hot winds, and the carport at the western end acting as a buffer against expected adverse environmental conditions such as summer afternoon heat and winter cold winds.

Spatial zoning also drives heat avoidance and heat conservation strategies in a Zone 5 warm temperate climate case study design.[24] Living areas are zoned to the north with openings for solar infiltration and indirect gains in winter; the kitchen may be separated to avoid internal heat gain; bedrooms are zoned to the cooler south side; the garage is zoned in the south western side of the house to protect habitable areas from cold winter wind and summer afternoon sun. Cross-ventilation of both living areas and bedrooms is facilitated by stack ventilation with openable windows at the highest point of the roof. Cellular room layouts also facilitate efficient winter heating.

Within Cool Temperate climates (Cfb) the need for a well-sealed insulated envelope, avoiding cold bridges, is required to minimise infiltration heat loss. Insulation is best evenly distributed around the building rather than concentrated to one element. For example, a well-insulated roof without floor insulation is not recommended.[25] Similarly, a simulation and case study in Japan- a warm temperate Cfa climate, recommended the same envelope strategy of high insulation and air

[21] Climatic Design Strategies for Sydney, Adelaide and Perth: A Study of Building Code of Australia's Climate Zone 5. Upadhyay,A. 2008
[22] Hyde, R (2008)
[23] Murcutt, G (1998) *House in the Adelaide Hills South Australia*, UME 7 pp2-9.
[24] Cement Concrete and Aggregates Australia, (2007) *Climate-responsive house design with concrete,* ZONE 5 Warm temperate: Sydney, Adelaide, Perth pp20-24
[25] Energy Efficient Building; Susan Roaf and Mary Hancock; p.207

tightness, as well as utilising eaves for shading.[26] Australian NCC Zone 5 design recommendations also include protecting openings with external shading to avoid direct sunlight in summer.

2.1.3. Tier 3 Natural Energy Systems

Traditional buildings are whitewashed internally to aid indirect illumination. Operable shading provided by shutters and louvres controls glare, and earth-coupled heavy construction promotes passive cooling by providing heat sinks.

Passive solar heating favours climates with clear winter skies within Zone 5, such as Sydney, rather than climates with prolonged overcast conditions in winter.[27] The simulation and case study within Cfa climates of Japan also recommended passive heating by direct solar gains through south-east to south-west windows. The converse equatorial orientation would be true for Southern Hemisphere locations.[28] Whilst passive heating strategies such as trombe walls, roof space collectors and atria work well they are expensive; whereas direct gain and conservatory systems (isolated gains) are noted as cost effective. Three techniques for direct gain were shown to provide 24% of the house 's energy needs without increasing capital costs: facing the house south [equiv north] and avoid overshadowing, concentrate glazing on the south [equiv north], ensure windows are not covered with internal blinds or curtains.[29]

Thermal mass recommendations within Australian Zone 5 vary depending on the localised Koppen-Geiger climate subtypes - from walls and roofs with short time lags in Cfa/Cfb climates, to heavy external and internal walls and heavy roofs with over 8-hour time lag in Csa/Csb climates; as the requirement for thermal mass becomes significant when the diurnal temperature range is more than 10degC. However, it should be noted that this particular study utilises Mahoney tables (Koenigsberger, et al., 1978) to extrapolate pre-design guidelines which do not consider night-time wind movement to cool thermal mass.[30]

Over-heating is a concern in warm temperate climates therefore design strategies that promote airflow (night flushing), heat sinks, and evaporative cooling are recommended. Comparatively the strategies to avoid under-heating are indirect heat gain (thermal mass) and direct solar gains and isolated gains.[31]

[26] Bioclimatic Housing, Innovative Design for Warm Climates; Richard Hyde, p.198
[27] Climatic Design Strategies for Sydney, Adelaide and Perth: A Study of Building Code of Australia's Climate Zone 5. Upadhyay,A. 2008
[28] Bioclimatic Housing, Innovative Design for Warm Climates; Richard Hyde. P.198
[29] Energy Efficient Building; Susan Roaf and Mary Hancock; p.209
[30] Climatic Design Strategies for Sydney, Adelaide and Perth: A Study of Building Code of Australia's Climate Zone 5. Upadhyay,A. 2008
[31] Climate Responsive Design: A Study of Building in Moderate and Hot Humid Climates; Richard Hyde

Whilst a well-sealed building is advantageous to minimise infiltration heat loss, ventilation must be provided with fine control to allow occupants to find their own level of ventilation for economy, comfort and condensation control.[32] Cross ventilation is a recommendation in Cfa climates within Australia[33] and Japan.[34] Post-occupancy evaluations of commercial and institutional buildings within warm-temperate climates revealed occupants were both becoming more accepting of a wider temperature band for comfort, and natural ventilation openings in which occupants had control over the system were mentioned as being appreciated.[35] Summer over-heating was noted in some naturally ventilated and mixed-mode temperate zoned buildings.[36]

Passive systems for lighting are achievable for both residential and office buildings if openings and/or glazing are designed correctly in terms of quantity and direction. Office buildings can utilize daylighting for most occupied hours without the use of artificial lighting, if the building floor plan is narrow to allow permeation, as seen in Winrock International Global Headquarters in Arkansas, a Cfa climate.[37]

2.1.4. Tier 4 Mechanical Systems

Csb temperate, dry summer climates require heating during winter, even in traditional architecture with high thermal mass.[38] Within Cfa warm temperate climates, post occupancy reports of fully air-conditioned, commercial and institutional buildings were found to be too cool to cold during winter.[39] Occupant satisfaction with mechanical heating and cooling can be attributed to extent of occupant control. In commercial buildings, systems which incorporate raised floors with under-floor air distribution and separate diffusers at each workstation provide individual control over temperature and airflow.[40] Post-occupancy feedback on an Office building with an air handling system fitted with variable-frequency drives noted that it was not utilised, thus

[32] Energy Efficient Building; Susan Roaf and Mary Hancock; p.204
[33] Climatic Design Strategies for Sydney, Adelaide and Perth: A Study of Building Code of Australia's Climate Zone 5. Upadhyay,A. 2008
[34] (Bioclimatic Housing, Innovative Design for Warm Climates; Richard Hyde) p.198
[35] Sustainable Buildings in Practice. George Baird; 2010. P.21
[36] Sustainable Buildings in Practice. George Baird; 2010. P.20
[37] Emerald Architecture, Case Studies in Green Building. 2008
[38] Climate and Architecture; Torben Dahl, 2010. P.18
[39] Sustainable Buildings in Practice. George Baird. 2010. P.20
[40] Emerald Architecture, Case Studies in Green Building. 2008 p.107

did not save a lot of energy, due to the small floor plates only requiring uniform air demand.[41]

Electrical lighting expectations can be adjusted utilising both task lighting and lower levels of ambient lighting - as noted in a post occupancy evaluation that saw a reduction in staff use of task lighting after becoming accustomed to the new buildings lighting system which automatically dims with sufficient daylighting.42 Daylight hours within Cfa climates allow PV systems to be successfully integrated mechanical systems.43

2.1.5. Summary and synthesis

Commonalities across the literature for architectural responses in warm temperate climates are:

Site: response is micro-climate specific, orientation long axis east-west

Building Envelope: to be well sealed and insulated; thermal resistance over thermal mass. Surface area to volume ratio through interventions such as courtyards.

Heating: use of glazing and thermal resistance (mass) to the north;

Cooling: cross ventilation and shading (eaves and adjustable shading)

2.2 Consultation and Survey Findings

To understand Toowoomba's climate and architecture from a local perspective, the research team conducted a public lunchtime event at the Toowoomba City Library attended by local building designers, architects, builders and general public. This event served as an opportunity to present Phase 1 findings, conduct a panel discussion with local building industry and development experts, and recruit audience participants for a follow-up survey.

The objective of the facilitated panel discussion was to elicit local insights, shared approaches to successful design, and observations on local climatic attributes. Detailed notes taken during the event were included as data along with the nine responses to the follow-up survey.

The ideas that emerged from the initial community consultation stage have been grouped according to three main themes: (1) social and political factors, (2) building context and (3) building form. 'Social and political factors' include people's values and beliefs about Toowoomba, what makes Toowoomba and its architecture unique, as well as priorities about what should be preserved or improved. This theme also

[41] Emerald Architecture, Case Studies in Green Building. 2008. P.91
[42] Emerald Architecture, Case Studies in Green Building. 2008. P.91
[43] Bioclimatic Housing, Innovative Design for Warm Climates; Richard Hyde

includes ideas relating to policy and planning regulations that impact on built environment design. ‘Building context’ includes observations on climate, siting of buildings as well as site conditions and urban form. Local insights on ‘building form’ include architectural character, ideas about aspects of the building envelope that are effective or do not work and building performance.

2.2.1 Social and political factors

Values and Perceptions

Local perceptions of Toowoomba, and how the location shapes a specific architectural character, reflects the sense that Toowoomba is unique compared to other Australian locations. Further, that this point of difference should be both protected and celebrated and resist the norm of *“mean-spirited, treeless developments”* seen elsewhere. Toowoomba is seen as a location that should be safeguarded from mass produced project homes and standardised development approaches and, rather, design that considers climate and local character is valued. There is a collective resistance to *“4-bedroom cookie-cutter homes”*, *“4 x 2 mass-produced project homes”* and *“standard plans”* that can be *“dropped on to any block, anywhere, facing any which way”*. The desire for architectural diversity extends to a call for greater block size variety *“to allow for a more inclusive social mix of people”* and in turn, *“a more representative mix of people from the wider community”*. The notion of diversity refers to multigenerational communities and household size/type.

The data suggest that people in the community value architecture that is *modern*, however it is unclear if this is a stylistic or aesthetic priority or if this relates to lifestyle/liveability and comfort priorities. Locals enjoy buildings that are sized adequately for modern living with generous outdoor areas and flexible spaces and comfortable *“liveable temperatures during heatwaves and also cold winters”.* Outdoor and flexible space came out as overlapping concepts, where people like *“flexible spaces that can be opened up or closed down depending on the time of the year”.* The notion of flexible spaces also connected to positive views on houses with an *open plan* as well as commercial buildings that can be refitted for future change.

Policy and Planning

Community members are vocal about how national and local planning policies impact on Toowoomba’s architectural character. The Queensland Development Code was critiqued for *“giving people outs, resulting in poor outcomes”*. There was a strong call for better mandatory minimum efficiency ratings and siting/orientation requirements. The example of outdoor ceiling fans was mentioned as a *“cheat’s way of getting the star rating”*, which doesn’t help in a Toowoomba climate. Financing obstacles were also cited, where bank lending requires a certain profit margin but evaluations are made against similar buildings regardless of “green initiatives” that would raise the value of a building.

Respondents also mentioned local planning policy and Council approval processes as levers for sustainable design outcomes. Community members mentioned the need for both progressive and flexible approval processes as well as mandatory design standards. It is seen as the Council's responsibility to *"create positive design and planning outcomes"* as well as provide *"advice for poorly considered or environmentally (problematic) proposals".* People want the Council to *"have a leading sustainable designer involved"* early on in the planning process who is supported by formal sustainable design principles to guide a design review process between the Council and the application.

2.2.2 Building Context

Climate

When asked to nominate the defining features that best characterise local climate, all nine survey respondents agreed that the *"cold winter wind"* is a key feature of the Toowoomba climate. Five people noted the "*long summer*", four answered *"seasonal rainfall"* and there was one respondent for *"clear sunny skies"*, *"short winters"* and other: *"climate change"*, respectively (see Figure 1).

There was also mention of the need to acknowledge microclimates in the region while designing for both extremes of summer and winter. This is seen as an important consideration for both the precinct scale but also site scale due to effects such as transpiration from vegetation.

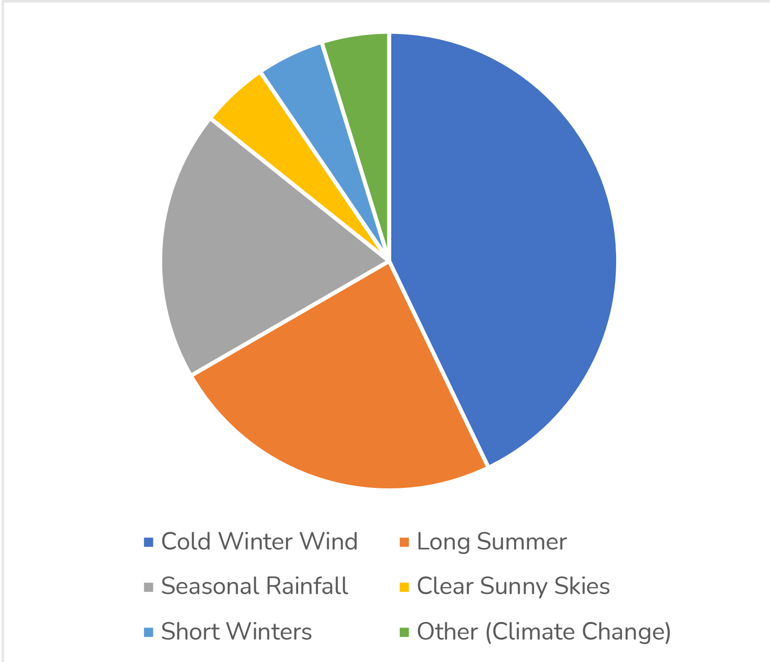


Figure 1 Defining features of the Toowoomba Climate.

Site and Siting

The lot orientation was perhaps the strongest theme emerging from the community consultation data, where both sun access and control opportunities can either be allowed or obstructed. There is the sense that building design often has to *"fight a poorly arranged block"* or that standardised building plans are placed onto sites without consideration of resulting energy requirements. Lots that allow for north-facing orientation are favoured.

Community priorities about site planning mainly included notions of size and outdoor space requirements. People want *"suitable sized blocks that allow a modern sized home with more generous outdoor space"* and *"outdoor spaces where the house does not consume the whole block".* The relationship between block size, outdoor space and house size presents a balancing act of priorities resulting in houses that are *"built to boundary with no eaves, landscaping or consideration for siting".* The problem of impervious surfaces, adequate storm water management and the desire for *"good quality vegetation"* and *"deciduous trees to the north"* were also mentioned.

Urban Form

Community feedback on climate-responsive design for Toowoomba frequently referred to factors beyond the design of individual buildings, or even site conditions, highlighting a connection between architectural design principles that operate at multiple scales. Town Planning is seen to *"hardwire a place"* where the layout of roads and loads can create good climatic design outcomes while also responding to views, aspect and topography. There is the sense that these are poorly considered priorities and that solar access and optimal orientation are hindered by lot divisions. Some participants mentioned a preference for gridded roadways, no cul-de-sacs, buildings that increase urban density and decrease sprawl and rear laneway access to residential parking to improve streetscape character and safety.

The nature of surrounding development and building types was also mentioned as a factor in protecting or enhancing local architectural character. People want to be connected to community facilities such as parks and community centres and adjacent to a diverse mix of development types. The desire for "*large, interconnected public spaces"* was mentioned as well as apartment developments that leave sufficient space *"to foster green spines".* Local residents note the importance of avoiding an urban heat island effect by minimising bitumen and paved surfaces and through deciduous street trees on verges that will also benefit private residences.

2.2.3 Built Form

Character

A locally specific architectural character was implied through the community consultation data rather than explicitly defined. Responses mostly referred to climate-responsive design principles rather than architectural character but did tend to mention "modern" architectural responses – both in terms of size and materiality – and did not mention features of the heritage architecture that Toowoomba is renowned for.

The use of dark colour schemes as problematic with regard to heat gain in summer was noted.

Building Envelope

Ideas about how building envelope features such as materiality choice, windows/fenestration and shading or shelter devices reveal some locally specific approaches to design for Toowoomba's climate. Perceptions about the benefit of thermal mass appear to be connected to Toowoomba's inland location, which is an idea that is sometimes in tension with the desirable "modern" home that utilises lightweight materials. In contrast, other respondents critiqued lightweight building practices as being more suited to hot coastal climates. It is possible that this due to associating masonry/brick architecture with heritage buildings. The need for insulation to walls and ceilings is also deemed very important, "*unlike a classic Queenslander"*.

Locals have a sound understanding of optimal window location and orientation in line with conventional passive solar design principles where north-facing is to be maximised and western exposure avoided. While summer sun should be excluded, locals want natural light and winter sun. There is also a strong emphasis on *protection* where shading devices serve a dual purpose of both sun protection and also shelter from wind. "Short" or missing eaves is seen as a problem (also referred to as overhangs) especially in new builds. Various devices for sunshade and wind shelter were mentioned including balconies, verandas, courtyards, decks, pergolas and awnings. Of note is that window dressings are seen as "the mark of poor design and energy inefficiency".

Building Performance: Natural Energy Systems and Mechanical Systems

Knowledge and values about building performance indicate a greater emphasis on passive strategies and not technological solutions (with only passing mention of photovoltaic solar and heat pump hot water systems, the move away from gas and value of wiring houses for batteries). There was a strong emphasis on the performance enhancing potential of indoor-outdoor threshold spaces such as balconies, verandas, courtyards, decks and pergolas. As mentioned earlier, this includes sub and wind protection through mediated lights and a veranda or outside covered area as a protected circulation space. These physical structures serve to *"deflect, block and moderate wind movement"*, a function that is especially valued in winter. Whereas they also provide much-needed sun protection in summer. North-facing is deemed optimal. Another performance enhancing trend in Toowoomba is enclosing these sheltered outdoor spaces to achieve passive solar heating, or "greenhouse" effect. There is the desire to *"trap as much winter sun as possible"* and *"even though people want a deck, they are enclosing them as a nice glass area that can be used all year round"*. The adaptability of these spaces is highly valued, as *"sheltered and shaded spaces; flexible spaces that can be opened up or closed down depending on the time of the year".*

People prefer natural ventilation and note the effectiveness of courtyard spaces to achieve this in a way that ensures protection from the wind.

Similarly, verandas achieve this outcome as an *“efficient, active cooling”* device. While natural ventilation is an important feature of climate responsive design, Toowoomba locals also mention the importance of good draught-proofing.

2.2.4 Summary and Synthesis

The community consultation findings indicate that local perceptions of climate and climatically responsive architecture for the Toowoomba regions lend themselves well to Lechner’s framing of architectural design. While social and political factors did reveal another layer of culturally constructed values and perceptions, as well as the political influence of council policy and planning instruments, local ideas about ‘building context’ and ‘building form’ align well with Lechner’s tiers of micro-climate siting, basic building articulation, natural energy systems and the first tier added by us, mechanical systems. Beyond these relatively conventional design considerations that prevail in any region, five locally specific themes emerged that have the potential to inform design guidelines that are specific to Toowoomba’s unique climate: (1) Local perceptions on climate and climate change; (2) Winter-Summer Seasonal Transitions; (3) Architecture as connected-in with an urban framework; (4) The problem of the ‘suboptimal lot’; and, (5) Indoor-outdoor threshold spaces.

Local Perceptions on Climate and Climate Change

For messaging about climate change to be relevant and accessible to the local community in Toowoomba, it must be communicated in terms that are meaningful to everyday life. Examples given included cost savings on power bills if sustainable design principles are implemented, and impacts described in terms of how the local area will be affected. Explaining a transition of the Toowoomba climate to be more like that of Kingaroy’s was observed to be a particularly compelling way to explain climate change in “real terms” with an emphasis on awareness building and education that would serve as a source of reassurance.

Even though there is some “pushback” on climate change that is freely acknowledged in the community, the survey data showed a wide range of ideas that serve to both mitigate and adapt to climate change. These include motivation for zero emissions buildings, zero waste, passive design principles and the use of renewable products. Terms like “sustainable”, “regenerative”, “biophylic” and “climate-friendly” were used as well as the desire to plan for RCP8.5 climate scenarios through planning and architectural design.

Winter – Summer Seasonal Transitions

Toowoomba’s warm-temperate climate results in summer-winter extremes, which feature strongly in local priorities for human comfort. But the cold windy winters and hot summers call for distinctly different architectural design strategies that must be addressed carefully to achieve optimal outcomes year-round. Community perspectives revealed a desire for buildings that provide shade from the summer sun, while allowing winter sun to penetrate and heat thermal mass. The winter wind featured heavily in local perceptions of climate – at times intolerable – and therefore requiring shelter. However, locals also want buildings that allow for desirable summer breezes to pass through and ventilate spaces. Of significance to this requirement is evidence that the local community are uncertain as to the direction of prevailing winds year-round and therefore effective control of cold winter winds and access to summer breezes is possibly hindered.

Architecture as connected-in with an Urban Framework

While the urban form framework of Toowoomba sits outside the scope of this study, it is important to note the strong emphasis on the greater surrounds to a building from the local community. Locals see the street layouts, site orientation, urban form and access to local facilities, shade and adjacent development as a fundamental component to successful architectural design in the area. These issues came out as strongly as architectural building-scale ideas about climate-responsive design for the region.

The Problem of the 'Suboptimal Lot'

Perhaps the most significant limitation to climate-responsive design in Toowoomba was attributed to suboptimal lot orientations that do not allow for maximisation of northern aspect. Locals believe that *"the design must literally start from the ground up. If the basics of good block size, solar orientation and amenities are in place at town planning stage, then things bode well for the potential house design."* There is a sense that good architecture is at the mercy of Town Planning, which highlights an opportunity to educate the Toowoomba community about the many ways in which successful climate-responsive outcomes can be achieved despite lot orientation.

Indoor-Outdoor Threshold Spaces

The idea of indoor-outdoor threshold spaces is interesting because it emerged as a theme that simultaneously supported both building performance but also local culture and lifestyle patterns. Verandas, balconies, decks and courtyards are a highly valued spaces, both for their ability to provide cooler ventilated spaces in summer, but also as adaptable spaces able to be enclosed in winter as a sort of "greenhouse". The idea of such indoor-outdoor threshold spaces lends itself to other notions of flexibility and adaptable living spaces that are also valued by locals as well as the need for Summer-Winter seasonal transitions.

2.3 Warm Temperate Climate Architecture Database

Building projects were retrieved using a semi-structured approach (see Figure 2) from a list of well-known and reputable databases listed in Table 2. Building classification number (NCC Class 1, 2, 5 and 6) and climate zones initiated the search criteria to retrieve residential, commercial, retail and mixed-class building projects in climate relevant regions. Buildings were filtered to obtain a cross section of contexts (e.g. urban or rural), site configurations (e.g. zero lot, narrow and standard), build type (e.g. lightweight and high mass) and build conditions (e.g. new, renovation, extension, and adaptive reuse). Features were reviewed and separated using the four tiers of the analytical design framework and then rated against each for its overall relevance to Toowoomba's climate.

In total, 91 were collated into a building database compendium (see Appendix One). Figure 3 is step 4 and 5 of the search and filter framework to review building design features and relevance to warm temperate climates using the analytical design framework.

Table 2 Translation of Building Types to NCC Classifications.

Building Description in Brief	NCC Building Classification
Traditional housing (1 and 2 storey detached dwellings on lots of 500 – 1000m²)	Class 1 and 1a
Small lot housing (1 and 2 storey detached and semi-detached dwellings on lots less than 450m²)	Class 1 and 1a
Duplex (Two, 1 and 2 storey, attached or detached dwellings on a single lot)	Class 1 and 1a
Medium density (3 or more 1 and 2 storey dwellings on a single lot)	Class 2
Built Works	Australian blog and database of building projects.
Multi-storey residential (3 or more storeys of single or mixed use)	Class 2
Commercial (3 or more storeys of single or mixed use)	Class 5 and 6 (and can include Class 2)

Table 3 Summary of databases used for identifying WTC building exemplars.

Database	Description
Architecture and Design	Australian database and design media network for builders, architects, and design professionals.
Arch Daily	International database and design media network for builders, architects, and design professionals.
The Design Files	Australian design blog and database of interior and building projects.
UME The International Architecture Magazine	Independent publication and database of architects' design ideas, projects, and architectural trends.
Built Works	Australian blog and database of building projects.
Green Building Council of Australia	Directory of local and national GreenStar accredited buildings.
Australian Institute of Architects (AIA)	Local and international architectural, design, travel and landscape database and publication, focused on sustainable residential design.
Sustainable House Day	Australian residential database and design media network.

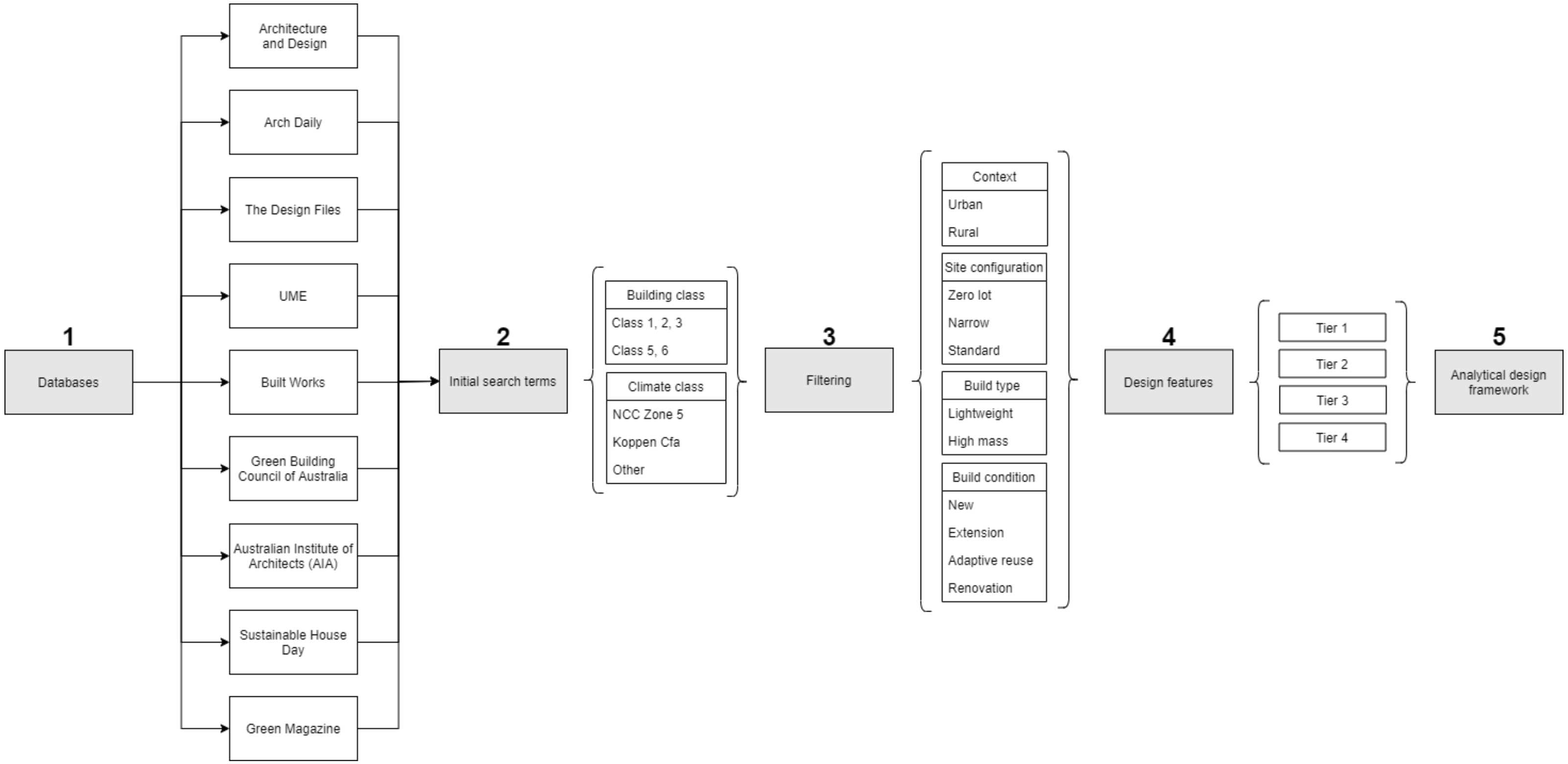


Figure 2 Flow diagram of searching and filtering related building projects from well-known and reputable online databases using a semi-structured approach.

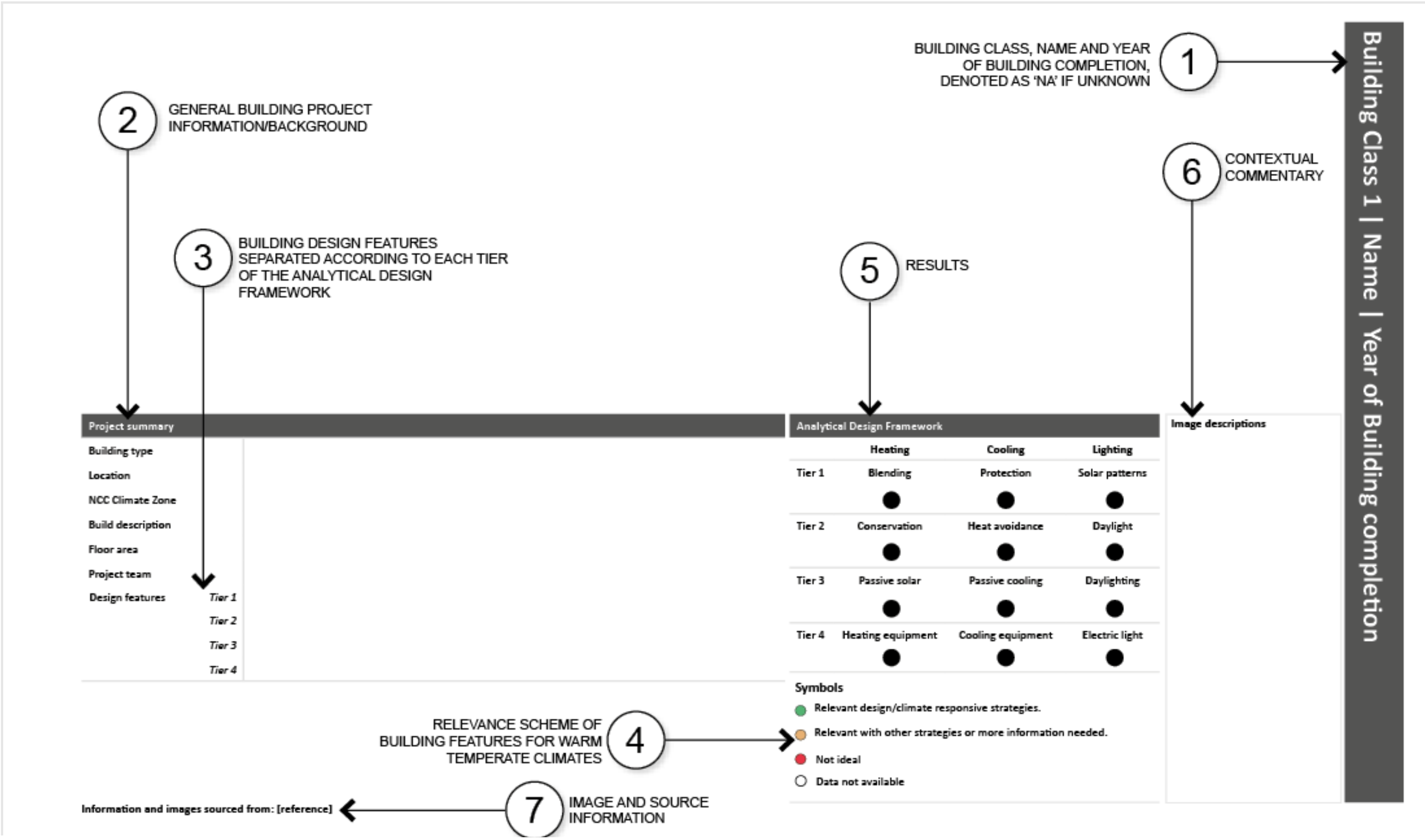


Figure 3 Procedure for step 4 and 5 of the search and filter framework to review design features and relevance according to the analytical design framework.

2.4 National and International Examples

2.4.1 Key Design Strategies Relevant to Toowoomba

Appendix One for this report presents a compendium of example projects responding to warm temperate climates. The following provides a summary of the key strategies that these buildings employed.

Tier 1 Responsive Massing: micro-climate Siting

- Prioritise optimal orientation with consideration to the existing context (lot configuration, set-backs, proximity to neighbouring boundaries)
- Work with existing vegetation for shading and protection, this includes reinstating native deciduous trees
- Build close to the ground (earth coupling/slab on ground) to use ground temperature to stabilize indoor temperature
- Articulate building form and facades to increase surface area to mass ratio.

Tier 2 Basic Building Articulation

- Break-up the building form to reduce the total volume for indoor heating and cooling where possible (courtyard configurations, narrow and long or stacking the building and using setbacks on different floor levels)
- Combine lightweight and high mass materials; specifically locating high thermal mass in extensive shaded areas (where it is an external wall) and or indoors as a heat sink for only winter sun
- High performing thermal resistant wall, floor and roofing systems that are adequately sealed.
- Fenestrations open to optimal orientation for daylighting, passive solar heat gain and natural ventilation
- Arrange living spaces to optimal orientation, such that habitable rooms are located towards solar north or north-east with adequate operable shading for controllability
- Shading from roof eaves and shading devices to be calculated so as to allow for solar heat gain in winter and provide shade to surfaces in summer
- Light colour cladding to avoid excessive heat gain including indoors
- Provide vegetation or other built forms to protects spaces from cool wind in winter

Tier 3 Natural Energy Systems

- Provide operable fenestrations, for indoor thermal comfort control preferably to areas where people actively interact with openings, such as verandas, courtyards, entry points and circulation
- Stacked ventilation systems to promote indoor air movement and respiratory comfort
- Glazing located along optimal orientation for solar heat gain to internal spaces

Tier 4 Mechanical Systems

- Ceiling fans generally provide adequate cooling for warm temperate climates
- Heating systems to be designed in combination with adequately insulated and sealed building envelopes.
- Smart technologies are increasing in application to improve offsetting opportunities from mechanical systems.

2.5 Local Vernacular Buildings

Much of what is understood as “vernacular” housing in Queensland was built during the interwar period (1920s and 1930s) as part of the Queensland Government State Advances Corporation, Workers’ Dwelling Board (WDB) program. The WDB issued government loans to build houses for low- and middle-income Queensland residents. There is some misconception that these homes were simply chosen from a standard pattern book of houses due to the proliferation of “Queenslander” (timber clad, asymmetrical fronted, raised on stumps bungalows) style of houses produced via the scheme. While there were standard style books issued by the WDB, many of the houses were individually designed by architects and all the houses had to meet design guidelines requirements to receive funding. The WDB guidelines were mostly concerned with suitable responses to climate and included the following guidance:

> When about to set out the plan of your home, carefully consider the site in its relation to the dwelling proposed to be erected. If possible, place the sleeping veranda on the eastern side of the building and thus gain the benefit of the morning sun. Avoid a common practice of wrongly planning the position of the bathroom and thus blocking the cool evening breeze from your sleeping veranda. Plan the kitchen away from the western side of the building if at all possible.[44]

These guidelines emphasised the general arrangement of rooms but were not prescriptive in terms of architectural responses. As such there are various regional adaptations of WDB, “vernacular” in Queensland in response to local climatic conditions.

In Peter Bell’s book on the *A History of the Queensland House* (2002), he described the houses of Toowoomba as being characterised by “a prosperous regional centre at fairly high altitude, Toowoomba has another concentration of relatively large and elaborate houses. Its cool climate means that open verandas with their characteristic forms of embellishment are relatively rare, while masonry construction, fireplaces and brick chimneys are prevalent.”[45] Bell’s description reinforces that

[44] Queensland Government State Advances Corporation, Workers Dwelling Board, Residential Design Guidelines (1908).
[45] Bell, P. (2002). *A History of the Queensland House*. Historical Research.

the warm temperate climate has informed regional variation and local adaptions of Queensland residential architecture in the Toowoomba region. The description also reinforces many of the findings from the consultation undertaken for Warm Temperate Climate architecture, including the need for materials that provide thermal resistance (such as masonry construction, when employed correctly). As well as creating outdoor spaces, such as internal courtyards or conservatories with operable fenestrations, which can be used for solar heat gain in for internal spaces in winter or as shade for cooling interiors during summer.

The purpose of investigating vernacular housing, or early 20th century housing, aims to better understand the design for buildings that were built before air conditioning or mechanical heating was common and readily available. The house chosen as a case study for this section of the report was selected because of its exemplary climatic responsive design. It is the house, Morocco built in 1963 on a farm just outside of Dalby and designed by John Dalton. The architect was well known for his climatically responsive architecture in the subtropics, and he applied this same knowledge to the design for a warm temperate climate.[46] The following outlines these climatic responses under the four tiers.

Tier 1: It is important to note that houses in the Toowoomba region and surrounds built on large acreages have the freedom to site a building in an optimal location. By comparison, a house in a suburban lot must work within limitations of lot orientation. The Morocco house was positioned in a new location away from the existing homestead. The siting of the house was informed by "the application of sun path data for summer and winter and the control of insects and wildlife rather than the imposition of any predetermined form."[47] The resulting house is a long, narrow form with an axis that runs from east to went to maximise access to the north and provide protection from prevailing south-west winter wind.

Tier 2: Unlike the original homestead, Morocco is "nestled" into the site, built slab on ground to take advantage of the thermal mass within the ground as well as the thermal resistance provided by the floor itself. The construction system is double brick (sourced from Wyamba), providing further thermal mass through the walls. The low-pitched roof has eaves that extend to provide shade for the walls in summer but still allow for solar heat gain in winter. The house has a long narrow floor plan with "Twelve foot deep, flyscreened, north facing verandas run the length of the living space on the north."[48] The narrow floor plate

[46] Musgrave, E. (2020). The Distance between Myth and Reality: Constructing a Modern Architectural Identity in Rural Queensland.
[47] Musgrave, E. (2020). The Distance between Myth and Reality: Constructing a Modern Architectural Identity in Rural Queensland.
[48] Musgrave, E. (2020). The Distance between Myth and Reality: Constructing a Modern Architectural Identity in Rural Queensland.

allows for cross ventilation, which is further promoted by internal courtyards, which articulate the façade and maximises the location for fenestrations that can be opened or closed as required.

Tier 3: One of the significant architectural features of this house are the brick walls that run along the east and western (shorter) façades of the house. Both walls extend beyond the eaves line of the house to provide protection from the prevailing winds.

Tier 4: The eastern and western walls of the house have fireplaces, which provide further thermal mass and active heating as required. There are also ceiling fans for cooling as required in living and sleeping areas.

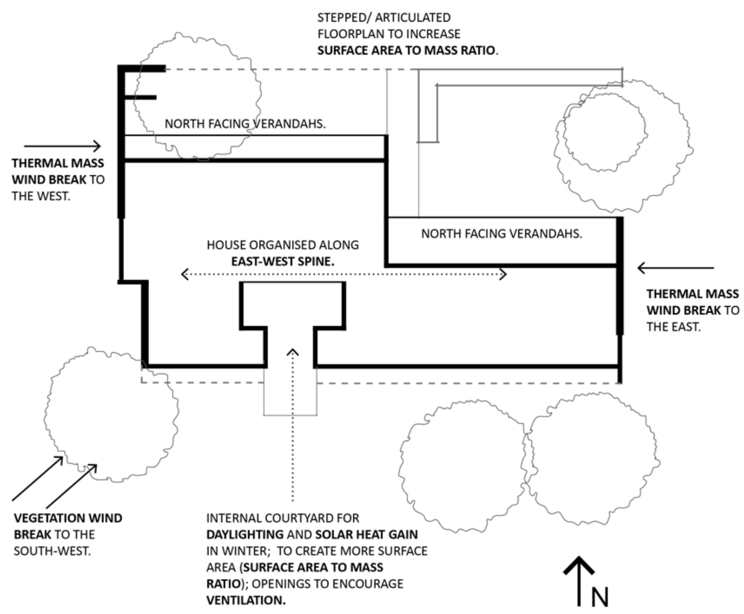


Figure 4: Diagram of climatic strategies employed in the design of the Morocco House

Toowoomba's City Hall is a heritage listed building in the Central Business District. It was built in 1901 and designed by Willoughby Powell, who the architect for other heritage listed buildings in Toowoomba including the Toowoomba Grammar School, Gabbinar

Homestead and the Wesley United Church. The building and its subsequent renovations in 1937 and 2016, provide an interesting case study of various adaptations to climate. The original building is an example of what is described as part of the "European Fashioning" of Toowoomba where the response to the cooler climate was motivated by appearance more so than an empirical response to climatic conditions.[49]

> Tier 1: Although the building was designed with a square footprint and no specific orientation or aspect, the location of the Ruthven Street Park to the northern side of the building is a notable strategy. By providing open space to the north of the building it mitigates overshadowing from neighbouring buildings. While City Hall utilises this space for a public park, this same strategy could be applied via a car park or other open area service and ancillary spaces along the northern side of buildings. However, this strategy also funnels wind and air movement, especially as it is along and east-west axis, which exacerbates cold south-westerly winds in winter. This approach could be optimised by operable structures or vegetation that would obstruct the wind in winter but still encourage air movement in summer.

Tier 2: City Hall was constructed from local clay bricks and although this material provides thermal mass for passive temperature control, this construction system does not provide adequate thermal resistance without insulation. In the 2016 refurbishment of City Hall insulation was added to the roof and walls to improve the thermal performance of the building envelope.[50]

Tier 3: There are no specific passive heating or cooling strategies to discuss and this is most likely due to the multipurpose nature of the building, which has resulted in a building with small door and window opening and a deep, square floor plan.

Tier 4: There are a few mechanical interventions that were required, especially for cooling the building. In the 1937 refurbishment of the building ceiling fans were installed after theatre groups using the building complained about the lack of ventilation. Then, in the 2016 refurbishment air conditioning was included, which was a driving reason for adding insulation to the building's walls and roof.[51]

---

[49] Lee, Christopher. "Spirit of Place: The European Fashioning of Toowoomba." *Queensland Review* 3, no. 1 (April 1996): 24–30
[50] Mehr, S. Y., & Wilkinson, S. (2018). Technical issues and energy efficient adaptive reuse of heritage listed city halls in Queensland Australia. *International Journal of Building Pathology and Adaptation*.
[51] Mehr, S. Y., & Wilkinson, S. (2018). Technical issues and energy efficient adaptive reuse of heritage listed city halls in Queensland Australia.

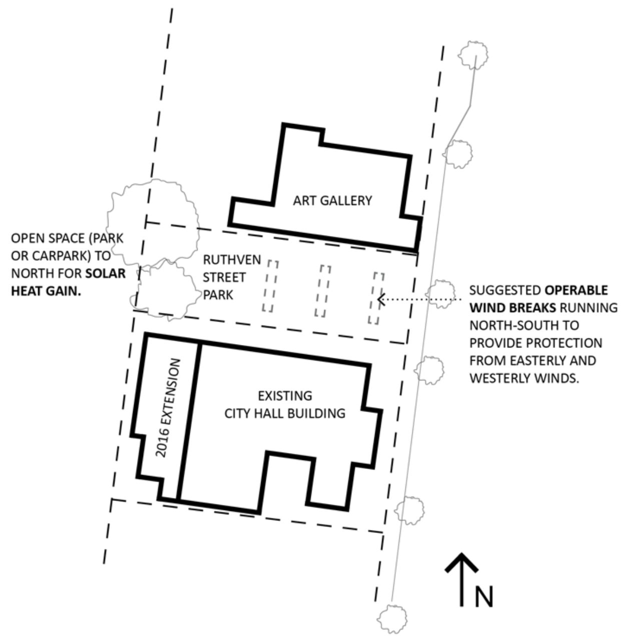


Figure 5: Diagram of climatic strategies employed in the design of City Hall

2.5 Local Contemporary Buildings

This section looks at three contemporary examples of climate responsive architecture in Toowoomba. It looks at two houses, one in the CBD and one on a suburban plot. It also looks at a mixed use commercial building that accommodates a combination of Class 5 and Class 6 tenancies. Of the typologies listed in the brief, the only missing typology in these case studies is a Class 2 or multi-residential project. There were no examples of climatically responsive Class 2 buildings in Toowoomba identified, and this is an aspect of the report that should be revisited at a future date. Each of the examples has been analysed using the four tiers and a diagram for each building has also been provided to showcase the strategies applied.

The first contemporary house is the Wilson house, which was completed in 2021. The house is a great example of compact housing built on an infill lot (formerly the backyard of an existing house) in the Toowoomba CBD. The house was built by clients who were motivated to achieve an energy efficient home, the design was driven by a very skilled architect and the builder specialises in energy efficient housing. The house has achieved 8.3 NatHERS rating and employs several strategies that are worth studying.

Tier 1: The house is built on slab of ground, which provides an opportunity to work with the thermal mass of the site as well as ensuring accuracy in sealing the building between slab and wall frame. Working with a small, square site, the house demonstrates one method for organising spaces on this type of site. The footprint for the house occupies most of the site, except for required setbacks from the boundary. Setbacks assist in providing access to solar heat gain (prevent excessive overshadowing) and encourage natural ventilation between dwellings. To enhance opportunities for solar heat gain and winter and cooling breezes in summer, living spaces are arranged towards the North of the block and organised around a courtyard.

Tier 2: The planning maximises surface area to the north, north-east, north-west through the courtyard. Wall insulation was built to R2.7, with 150mm wall framing that was double wrapped, and all joins were taped for both layers of wrapping. This included sealing under the bottom plate to prevent any thermal bridging between slab and frame. Corners were sealed using “California Corners” to prevent thermal bridging from external wall joins and corners. Doors and windows are double glazed, with seals between door and window framing and wall framing.

Tier 3: Large operable openings (glass sliding doors) define the threshold between the courtyard and the living areas of the house. These doors can be opened to encourage access breezes and natural ventilation on a hot, humid day or closed to seal in warm air. The sliding doors are glazed which promotes passive solar heat gain deep into the plan as well as natural daylighting. There are very few fenestrations to the Southern façade of the house and this helps to protect internal spaces from prevailing winter winds. South facing clerestory over the central circulation space in the house provides natural daylight deep into the floor plan as well as natural ventilation via convection or “stack ventilation” for passive cooling. Good thermal resistance in the walls creates a constant temperature throughout seasonal variation.

Tier 4: Additional cooling is provided by ceiling fans as required in the kitchen and living spaces. The house is heated using an energy efficient reverse cycle system. There is also a recycled heat pump for both heating and hot water. The high performance of the thermal resistance in the wall construction system and the seals for doors and windows help to minimise the energy requirements of the heating system.

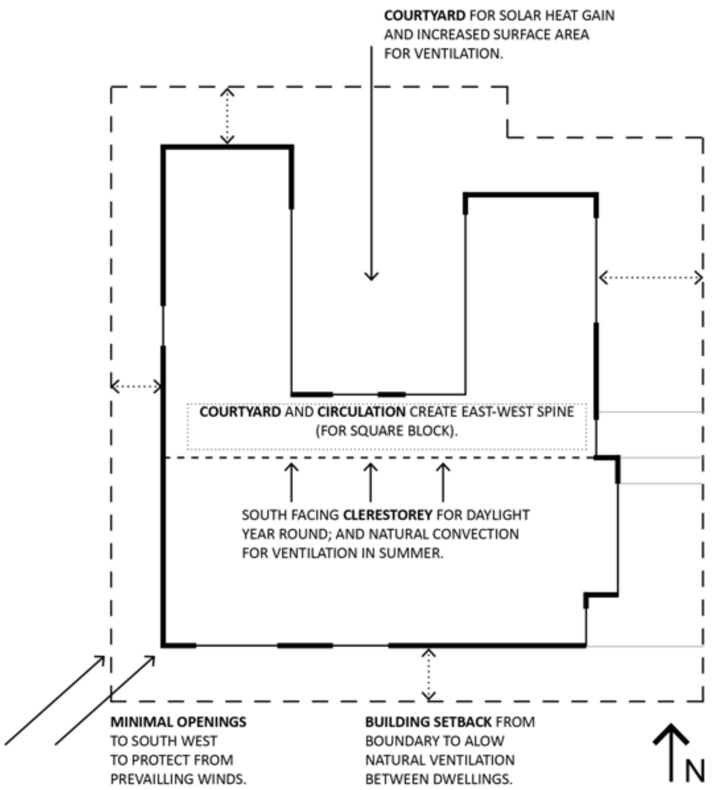


Figure 6: Diagram of climatic strategies employed in the design of Wilson House

The second contemporary house is the Curnow or "Esky" House which was built in 2016 on a typical Toowoomba suburban block. The house employs several similar strategies to the Wilson house, which are briefly summarised below. There are also strategies that differ from the Wilson house and these are discussed in more detail under each of the four tiers.

Tier 1: The response is much the same as the Wilson house.

Tier 2: The Curnow house was built using a pre-fabricated panel wall system, called Structural Insulated Panels (or SIPs). Similar to the Wilson house, a great level of care was taken to ensure the building envelope was sealed. The building envelope sealing was tested using a 'blower door test' and the result showed a higher-than-average performance. Additionally, a lighter colour cladding was chosen, which can assist with thermal resistance, especially in the reflection of heat for passive cooling.

Tier 3: The passive heating, cooling and lighting strategies are similar to the Wilson house, however the clerestory for the Curnow house is north facing and it's recommended that clerestory be south facing to avoid excessive heat gain in warmer months.

Tier 4: Similar active heating and cooling mechanical systems are provided in the Curnow House and the Wilson house. The thermal resistance and sealed envelope of both houses assists with the efficient running of mechanical heating and cooling systems.

The last contemporary building to be discussed is a mixed-use commercial building located in Toowoomba's CBD. The building was designed by Sims White architects and completed in 2020. It was the recipient of the Commercial Architecture award from the AIA for the Darling Downs region in 2021.

Tier 1: Similar to City Hall, 111 Campbell Street has organised open space to the North of the building to provide access to daylight for passive solar heat gain. The building is organised along an east-west axis and a long façade that opens toward the north. The entry sequences are flexible and address the street facing southern façade, which is an amenable access point on hotter, summer days.

Tier 2: The amenities are co-located in a separate block to the north-west corner of the building. This provides shade from hot Westerly afternoon sun in the afternoon and blocks predominate Winter winds. There are similar issues of wind funnelling that need to avoided especially with external walls running parallel along an east-west axis. External stairs are located on the eastern and western edges of the building and provide shade from heat of the afternoon sun and protection prevailing winter winds. The building envelope includes insulated wall systems, with the application of thermal mass through brick work to south and east facades. Otherwise, the walls are lightweight, sheet metal cladding with appropriate insulation. Internal floors are panelled concrete system.

Tier 3: The north facing verandas of the building facilitate circulation in the building as well as entry points and break out spaces for each of the tenancies. This method for the functional organisation of the building encourages occupants to utilise the operable openings (glass sliding doors) along the northern façade, which promotes either passive heating or cooling through opening or closing the doors as required. The southern façade of the building also has operable openings behind the screening and these can be opened to access cooler air in summer.

Tier 4: Good building thermal performance assists with efficient HVAC systems for heating and cooling. PV cells power mechanical systems.

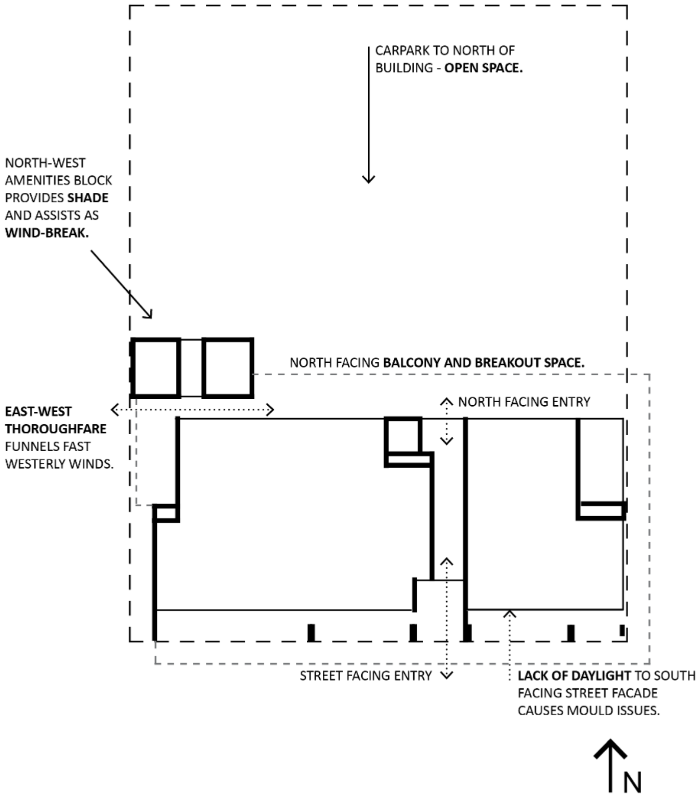


Figure 7: Diagram of climatic strategies employed in the design of 111 Campbell Street

2.6 Key design strategies

Tier 1 Strategies:

- Ensure buildings are set back from each other enough to promote access to solar heat gain (prevent excessive overshadowing) and air movement for natural ventilation
- Place open spaces such as car parks, landscaping, and open public space to the north to promote access to solar heat gain.
- Use vegetation or operable permeable structures to prevent wind tunnelling in outdoor spaces that are organised along an east-west axis
- Make use of thermal mass heat gains from the ground
- Utilise the topography (when available) to protect buildings from prevalent Westerly winds in winter.
- Set subdivisions and lots to promote the arrangement of buildings along and east-west axis with the longest side of the building facing North.

Tier 2 Strategies:

- Articulate facades to increase surface area to mass ratio.
- Shading to walls from roof eaves and shading devices should be optimally calculated to provide shade in summer and passive solar heat gain in winter.
- Courtyards are an effective device for increasing surface area-mass ratio. They also draw natural daylight, passive heating

through solar heat gain and passive cooling through natural ventilation deep into the floor plan.

- Minimise fenestrations to the west and southwest to provide protection from prevalent winter winds. Building walls can extend beyond the western side of a building (where possible) to provide vertical shade from the sun and protection from winter winds (such as those used in the Morocco House). Alternatively, vegetation can also provide shade and protection.
- Thermal resistance is more important than thermal mass. All the contemporary examples (Wilson House, Curnow House and 111 Campbell Street) achieved high performing building envelopes with lightweight cladding by utilising appropriate thermal insulation and sealing the building to prevent thermal bridging. As seen with the case of City Hall, masonry construction is not an adequate solution by itself, it must be insulated to work effectively.

Tier 3 Strategies:

- South facing clerestory provides access to natural daylighting and promotes passive cooling through stack ventilation.
- Arrange spaces in such a way to encourage occupants to open and close fenestrations. For example, arrange fenestrations around a courtyard space (such as Wilson House), or around main circulation/veranda spaces (such as 111 Campbell Street).
- North, north-east and north-west facing sides of the façade should have operable fenestrations to allow occupants to passively control internal temperatures (open to allow breezes and close to keep warm air inside)

Tier 4 Strategies:

- Ceiling fans are advised for bedrooms and living areas
- Mechanical heating is required during Toowoomba’s winters. The efficient running of these systems is greatly assisted by well-sealed and insulated building envelopes that are correctly orientated.

3. Key Design Strategies for warm temperate climate architecture

3.1. Analytical Design Framework for Warm Temperate Climate

Synthesis of findings of lit review, consultation and case studies – looping back to the framework. Insert table from methodology – with specific details for Warm Temperate Climate

Table 2 Analytical design framework WTC specific.

		Heating	Cooling	Lighting
Responsive massing	**Tier 1**	**Blending**	**Protection from heat gains**	**Solar Access**
	Micro-climate siting Basic building arrangement (form, shape, height, and orientation) to urban/rural context and climatic conditions for heating, cooling, lighting, and urban interfacing.	1. Solar gains from north facing openings 2. Set-backs from other buildings to prevent overshadowing and access to solar heat gains 3. Thermal gains from building close to the ground 4. Protect building from prevalent winter winds through vegetation and built form 5. Promote open space to the North of buildings to promote access to thermal heat gains.	1. Solar shading from existing deciduous trees 2. Natural ventilation through building orientation	1. Daylight exposure Sky view Angle through south facing clerestory
Form articulation	**Tier 2**	**Conservation**	**Heat avoidance**	**Natural Light**
	Basic building articulation Articulation of the building form (openings, materiality, colour finishes and zoning) and structure to minimise heat loss in winter and heat gain in summer	1. Solar infiltration through openings and façade articulations such as courtyards 2. Heat conservation through window-to-wall ratio 3. High thermal resistance through appropriate insulation and sealing of the building envelope	1. Reflectance (exterior and interior finishes) 2. Cool and/or lightweight materials 3. Heat ventilation (surface-to-volume ratio) 4. Cross-ventilation (openings) 5. Separating heat generating activities (spatial zoning)	1. Daylight access (apertures) 2. Daylight distribution (opening width and height)
Passive harvesting	**Tier 3**	**Passive heating**	**Passive cooling**	**Daylighting**
	Natural energy systems Passive and active systems for heating, cooling, and lighting	1. Direct gains (apertures) 2. Isolated gains especially through courtyard or verandas with sliding doors that convert into conservatory type spaces 3. Indirect gains (e.g., thermal resistance) 4. Heat conservation (insulation) 5. Drought sealing (insulation, sealants) 6. Active heating (solar power)	1. Stack ventilation 2. Radiant barriers (insulation) 3. Heat sinks (earth-coupled slabs or roofs) 4. Cross-ventilation (apertures) 5. Operable and optimal shading (thermal comfort) 6. Active cooling (solar power) 7. Natural shading (deciduous trees)	1. Colour rendering and exposure (daylight permeation and distribution) 2. Visible transmittance (e.g. low-e glazing or diffused) 3. Glare control (operable shading) 4. Indirect illumination (wall and ceiling reflectance) 5. Solar generated electrical lighting
Mechanical fine-tuning	**Tier 4**	**Mechanical heating**	**Mechanical cooling**	**Electrical lighting**
	Mechanical systems Auxiliary systems and technologies for heating, cooling, and lighting. Management, monitoring and maintenance systems	1. Energy efficient reverse cycle heating 2. Smart home technologies (energy management)	1. Ceiling fans 2. Smart home technologies (energy management)	1. Energy efficient lamps (low input power and high distribution W/m²) 2. Colour rendering (lamp CCT) 3. Energy offsetting (e.g., dimming) 4. Other smart home technologies (energy management)

3.2 Beyond the Building: external factors influencing climatically responsive design

In warm temperate climates the objective is to design buildings that are warm in winter and cool in summer by design. The results of this report show that in the first instance, building sites that allow buildings to open to the north are essential to allow the building's shape and materials to do most of the thermal 'heavy lifting' (Tier 1 controls). Then, three parameters (orientation, appropriate building shape and construction standards) can create efficiencies and significant energy savings for any auxiliary heating and cooling requirements (Tiers, 2,3, and 4).

These findings are unsurprising as architects and building designers have long sought to ameliorate negative impacts of climate on people and the places and buildings they inhabit. However, basic contradictions between urban planning and urban design and architecture for climate-responsiveness have meant that these attempts are not as successful as they could be. Over the past 160 years of Queensland architectural history, ways to resolve these contradictions have been beset by perennial problems that are common throughout Australia:

Short term financial models prevail over longer-term value investment. In this model developers require a fast return on investment to minimise development loan repayments and do the least necessary to satisfy regulations and minimise risk.

The economics of subdivision configurations favour yield (the production of the most lots possible) over climate-driven urban design.

Proven passive design strategies for buildings have been ignored or neglected and replaced by active energy-driven technology to compensate for deficient performance.

These barriers to climatically responsive design persist, but there is scope in the Queensland regulatory regime, to apply controls in planning schemes that can consider the relationship of buildings to surrounding context (Tier 1 controls) and improve on the amenity that can be obtained by developers' yield. For example, a planning scheme can encourage sustainable subdivision layout that helps lot orientation to maximise potential for future dwellings to take advantage of climate responsive design.

New neighbourhoods and communities in greenfield areas can optimise solar access and beneficial breezeways for buildings and open spaces through subdivision arrangements, street layouts and lot dimensions that maximise northern orientation. Local terrain conditions, that is, the shape, slope, and aspect of hills, ridges, and gullies, have a noticeable influence on site micro-climate and must be considered in combination with orientation. Boundary setbacks and the intended mix of vertical and horizontal building densities must also be considered at the earliest stage of subdivision design.

Brownfield, redevelopment, or urban renewal areas also offer ideal opportunities to replace unsuitable urban patterns with master planned streets and opens spaces that are orientated to provide conducive sites for well-oriented buildings.

Many existing and contemporary subdivisions produce building sites that compromise the liveability and potential energy performance of buildings. Yet the case study house, Wilson House, demonstrated that it is possible to develop a design that delivers thermal comfort efficiently in a highly liveable residence on a less than optimal site. The courtyard house type gives a good northern aspect to the living spaces, achieves shaded and protected sunny northern outdoor living area and thin plan and tall cross-section for cross ventilation and air movement, as well as high quality construction practices to optimise air tightness and efficient thermal performance.

The Wilson house project shows how the site and landscape, orientation, shape and internal layout, construction type, (thermal mass and insulation) and natural energy systems, work together as a complete system. In general, these Tier 2, 3 and 4 controls are building provisions and may not be dealt with in planning schemes.

Australia introduced the Nationwide Housing Energy Rating Scheme (NatHERS) to encourage improvement in energy performance for heating and cooling and has regulated minimum energy standards since the early 2000s. The current minimum standard is a 6-star energy efficiency rating is currently the minimum standard. But a recent survey[52] found that most new dwellings have not achieved even 6-star energy efficiency and that current legislative requirements do not make it imperative to reduce either operational or embodied energy. The authors called this a market failure particularly as housing built today to NCC requirements will continue to underperform in decades to come.

The blanket regulatory approach to energy efficiency is concerned with the amount of energy required to maintain internal temperatures in an acceptable range. Such an approach misses significant differences between places and communities, and usually relies on technology to produce homogeneous results. For example, coastal southwest Western Australia and the Toowoomba Region are both in Zone 5, yet regional differences in vegetation type, rainfall, humidity, wind speed and direction, and so on, are quite particular to each place. These differences quite rightly provoke different lifestyle responses and expectations in how people interact with their local built environment.

People extend their comfort zones by adjusting their clothing and behaviour. It has never been the local perception that the whole building must be heated or cooled all year round rather than at a time of occupants' choosing such as on the coldest winter days or summer extremes. However, current legislation may be leading towards thermal

[52] Moore, T., Berry, S and Ambrose, M (2019) Aiming for mediocrity: The case of Australian housing thermal performance, in *Energy Policy* Vol 132, pp 602-610.

monotony, where the same indoor conditions are maintained year-round regardless of external conditions.

As standard project homes are the most popular choice for new stand-alone dwellings in Australian cities, it will be important to find ways that comfort and energy efficiency can be achieved with most housing types and styles and communicate these to consumers and builders. The challenge is to make well-insulated and sealed buildings with northern orientation, standard construction.

Design guidance can elevate consumer and builder knowledge of ways to make the most of the relationship of the house to the block of land combine ordinary building components and uses that best suit the climate, landscape and lifestyle that are particular to the TRC locality.

3.3 Future proofing and responding to climate change

Where Phase 1 of the WTC study focused on climate; outlining climate change projections for the Toowoomba region, as well as providing a review of key reports and documents informing climate change adaptation nationally and regionally, this Phase 2 report explores WTC approaches architectural design, which must also be future proofed according to climate change projections.

The Phase 1 report outlined that the Toowoomba Region will experience:

- Decreased rainfall
- Increased temperatures in summer
- Decreased frosts in winter
- Longer and more frequent heatwaves
- Loss of vegetation

The Climate Council (2021) asserts that “no developed country has more to lose from climate change-fuelled extreme weather”[53] - a fact that must translate to resilient built environment design or lives are at risk. Turrent (2007) states that “designers need to start using future projected temperatures as a basis for design rather than the historic weather data currently in use[54] a sentiment that is reinforced by contemporary initiatives such as the Global Resiliency Dialogue[55] discussed in detail in the Phase 1 report. Current minimum building standards according to the NCC will not adequately support the need for

[53] Steffen, W. and Bradshaw, S. Hitting Home: The Compounding Costs of Climate Inaction. 2021. Climate Council. Available from: https://www.climatecouncil.org.au/wp-content/uploads/2021/01/hitting-home-report-V7-210122.pdf p. iii
[54] Sustainable Architecture; David Turrent, 2007.p152
[55] https://www.iccsafe.org/advocacy/global-resiliency/

increased cooling loads into the future, nor provide the required level of resilience to natural hazards such as wildfire, flood and cyclone.

This limitation is becoming increasingly acknowledged as evidenced in Australia's most widely accessed guide to environmentally sustainable homes *Your Home*, which makes the point under *Design for Climate*:

> *New homes built now will be in service in future times when we expect to see significant changes in the climate. Designing for today's climate is important; ensuring that those designs can be just as efficient after 30 years of climate change would certainly be desirable.*[56]

The *Your Home* resource points out that affordability is frequently cited as a significant barrier to integrating energy efficient and climate-responsive design measures; a sentiment that was also echoed during the TRC community consultation process. Further, that consultation process revealed that this barrier is bound up in bank lending according to valuations that do not account for sustainability measures that may increase the market value of the final building product. While sources like *Your Home do* acknowledge the need for homes that are responsive to future climate change, it is still positioned as a resource that uses NCC climate data. This disproportionately impacts regional areas, such as Toowoomba, where available weather data are limited (see Phase 1 Report Section 2.6, which notes NCC climate data is from BOM, which is accessed from the Oakey weather station).

3.4 Forward-Thinking Strategies

In the coming years, consideration of climate change predictions - and forward-thinking strategies as embedded within design processes - will be a necessary norm in architectural design. For example, if we are to expect increased temperatures and associated decreased humidity the Toowoomba region will become drier and more arid in nature, requiring drought-resistant planting, a greater emphasis on efficient appliances, rainwater harvesting and grey water recycling. Heavier winter rain and "flash flooding" events will require oversized guttering and careful management of overland flow on sites. Higher average wind speeds will require increased wind loading of structures.

In recent years, a series of *Resilient Building Guides* have been released by the Queensland Reconstruction Authority to "improve how we prepare for, respond to and recover from disasters"[57]. It is important to acknowledge that a disaster event is the result of the coincidence of a hazard with a vulnerability. Therefore, good design that is resilient has

[56] https://www.yourhome.gov.au/passive-design/design-climate para. 5
[57] https://www.qra.qld.gov.au/resilient-homes

the potential to prevent disaster events entirely.[58] The ramifications of this paradigm shift for architecture and design cannot be understated given that disaster events are projected to cost Australians $39 billion per year by 2050.[59]

Bushfire Resilience

The *Bushfire Resilient Building Guidance for Queensland Homes*[60] by CSIRO and the Queensland State Government encourages residents to first understand their individual bushfire risk and outlines a series of resilient design principles depending on building category. The document focuses on reducing the vulnerabilities that result in the loss of a building or lives (a disaster) as a result of bushfire (a hazard). They provide a minimum set of requirements to increase the likelihood that a building and its occupants will survive a bushfire using building design and landscaping principles.

Queensland's building and planning regulations seek to ensure that new developments are designed and constructed with bushfire protection in mind.[61]

Given the recommendation in this report for the consideration of "climate-safe rooms", it is interesting to note that the Bushfire Resilient Building Guidance suggests to "design the defendable space with aesthetic values in mind" considering "how to make the space both functional and practical."[62]The Guide outlines 4 levels of protection and associated building design principles to be considered as the last layer of bushfire defence after siting considerations (p.43).

Flood Resilience

The *Flood Resilient Building Guidance for Queensland Homes*[63] by the Queensland Government in conjunction with a number of LGAs is a targeted response for Queenslanders who live in the most disaster-impacted state in Australia, with flood presenting the highest risk. Similarly to the *Bushfire Resilient Building Guidance for Queensland Homes,* it first asks residents to consider their flood risk as well as the

[58] Twigg, J. (2017). Chapter 9 - Disaster Risk Reduction. Good Practice Review. Retrieved from https://goodpracticereview.org/9/introduction/disastersexplained/
[59] Deloitte (2017). Building Resilience to Natural Disasters. Source: https://www2.deloitte.com/au/en/pages/economics/articles/building-australias-natural-disaster-resilience.html
[60] CSIRO, Queensland Government (2021). Bushfire Resilient Building Guidance for Queensland Homes. Accessed from: https://www.qra.qld.gov.au/resilient-homes/bushfire-building-guidance-queensland-homes
[61] p. 33
[62] p. 42
[63] Queensland Government (2019). Flood Resilient Building Guidance for Queensland Homes. Accessed from: https://www.qra.qld.gov.au/sites/default/files/2019-04/flood_resilient_building_guidance_for_queensland_homes_-_april_2019.pdf

economic return on investment in flood-resilient design. As a non-mandatory guide that is aligned with the QDC, flood resilient design is defined as:

> *"The use of materials, construction systems and design types that can withstand substantial and multiple inundations by actively mitigating the effects of, and minimising the cost of flooding. Flood resilient design enables occupants to safely store belongings prior to flood and easily clean, repair and quickly move back in with minimal long-term disruption to family and finances." (p.9)*

The guide is structured around three main design strategies: elevating the finished floor level, wet-proofing (surfaces that are resistant to water) and dry-proofing (prevention of water penetration) depending on the type of flood event a property is most likely to experience. The guide also contains a combination of building design and landscaping recommendations.

Cyclone Resilience

The *Cyclone and Storm Tide Resilient Building Guidance for Queensland Homes*[64] is a non-mandatory guide by the Queensland Government aims to enhance household resilience to wind and cyclones. It offers design requirements to address issues of external wind pressure, wind loads and damage from debris by recommending a combination of material use and structural design methods.

Table ? outlines a series of design strategies that can be considered in combination and applied to concurrently address multiple aspects of climate-responsive design. These include heat, cold, drought, winter winds, passive solar design principles, as well as natural hazards of bushfire, flood and cyclone. The table demonstrates a potential range of core approaches to the design of buildings that will enhance the general resilience according to a number of outcomes or objectives. Limitations are discussed in the next section, however the table illustrates the need for further research that can inform a robust and evidence-based range of future-thinking strategies in response to climate change.

[64] https://www.qra.qld.gov.au/resilient-homes/cyclone-and-storm-tide-resilient-building-guidance-queensland-homes

Table 3 Overlapping Principles: Resilient Design and WTC-responsive Design Principles.

Strategy	Hazard/s Addressed	Description of Benefit
Building Siting	Bushfire Radiant Heat	Maximising distance between siting of buildings away from neighbouring buildings to prevent fire spread. Maximising distance between siting of buildings away from neighbouring buildings to prevent radiant heat.
Materiality	Bushfire Winter Cold	Concrete/masonry as non-combustible materials. Thermal mass potential.
Screening	Bushfire Winter Winds	Minimising wind exposure / ember attack. Screening and shielding of winter winds.
Building Form / Roof Line	Bushfire Heat	Simple house shape and simple roof lines. Maximised northern frontage and minimal heat gain from roof.
Building Seal	Bushfire Heat / Cold	Airtight housing to prevent smoke penetration. Draughtproofing for thermal performance.
Priority Space	Bushfire Heatwave Flood	Defendable space or asset protection zone. Air-conditioned “climate safe room”. Elevated storage spaces / defendable space.
Window Screens	Bushfire Heat Cyclone	Window screens and shutters. Solar protection. Debris and external wind pressure.
Materiality	Bushfire Heat Cold	Thick non-combustible wall cladding. Insulation properties. Thermal mass.
Floor construction	Bushfire Cold	Slab on ground. Thermal mass.

Strategy	Hazard/s Addressed	Description of Benefit
Rainwater collection	Bushfire Flood Drought	On-site rainwater tank supply for bushfire defending. On-site rainwater tank for reduction of water runoff and overland flow. On-site rainwater tank as water supply for garden.
Stairs	Bushfire Flood	Ensure under-stair cavities do not have accumulated debris. Design without cavities under stairs.
Ground Surfaces	Flood Radiant Heat	Reduce impervious ground surfaces. Cooler site and surrounds.
Perimeter fencing	Flood Heat	Permeable fencing. Breezes and cross-flow.
Landform	Flood Drought Winter winds	Bioswales / rain garden systems / berms Drought-proof vegetation and provision of shade. Wind shielding/shelter
Doors	Flood Fire Cyclone	Solid core doors. Non-combustible solid-core doors. Solid doors with drop bolts and heavy duty hinges.
Water absorbtion	Flood Cyclone	Construction methods and materials that quickly dry out after a flood. Materials that dry out without deteriorating
Window shutters	Fire Cyclone Heat load Cold Wind	Shutters for ember attack resistance. Shutters for debris resistance. Shade Shelter / shielding

Climate-Responsive Design Limitations

While a number of architectural design approaches reinforce resilience, some can result in counterproductive outcomes where a building is subjected to multiple hazard types, for example:

- Siting buildings away from vegetation to prevent fire spread reduces shading benefits.
- Verandas, decks and covered outdoor spaces provide passive solar benefits and shading but can exacerbate bushfire vulnerability unless design is carefully considered.
- Wide gutters for heavy rainfall events are harder to provide effective gutter guards required for bushfire resilience.
- Vents for air circulation can serve as ember entry points in bushfire events.
- Weep holes required for flood resilience undermine bushfire resilience unless carefully designed and maintained
- Drainage and ventilation to subfloor area is desirable for flood but problematic for bushfire resilience
- Solid fences and barrier walls protect from ember attack but obstruct air flow and water movement required to minimise flood impacts.
- Some of the most flood resilient materials are not particularly fire resilient.
- Cross-bracing of stumps for high set homes enhances cyclone resilience but presents problems during flood events in that they can catch debris.

These examples point to current limitations in knowledge when it comes to climate-responsive design where there is a coincidence of hazard types. Additionally, they highlight the need to ensure resilient building design principles that reduce vulnerability in certain circumstances do not unintentionally increase exposure other risks. There is a need for future research that integrates climate responsive design principles in a way that: (1) is responsive to future climate change trends; (2) addresses risks of multiple hazard types, (3) not compromising on design quality or creating new vulnerabilities; and (4) is responsive to a locally specific understanding of hazard and risk types.

Carbon Considerations

Approaches to climate-responsive building design that integrates data about carbon impact is still in a pilot stage at the time of publication of this report [65] [66] [67], particularly at a legislative level that is aligned with the

[65] https://www.energy.gov.au/publications/reports-national-pilots-residential-efficiency-scorecard
[66] https://www.energy.gov.au/publications/achieving-low-energy-existing-commercial-buildings-australia-report
[67] https://www.energy.gov.au/publications/trajectory-for-low-energy-buildings-addendum

Paris Climate Agreement. Therefore, this is beyond scope of this project, however, there are well-known and established principles regarding sustainability and passive design addressed in the report that are within the jurisdictional control of LGAs. These work in line with federal planning toward net/carbon zero buildings, but requires local, state and national coordination.

4. Key findings and recommendations

Recommendations and next steps.

4.1. Recommendation 1

The design of the overall built form is the first level of intervention in climate-responsive design. When it comes to designing future subdivisions in the TRC area, key principles are needed to establish lots that allow individual dwellings to make the most of 'design for warm temperate climate'.

A future planning scheme can use knowledge of orientation and prevailing breeze to encourage well-planned precincts and sites that support buildings designed with natural light, solar passive heating and cooling.

Local authorities may look at developing new design and assessment tools such as:

- ventilation analysis at the master planning level
- shading analysis of street design and building interface to enhance thermal comfort
- attenuating the effects of climatic conditions on a building's performance.

Future urban design guidelines can facilitate and measure climate-responsive design outcomes in the language of resident amenity, using more accessible and meaningful ways than developers' yield. For example, a metric such as Green Plot Ratio would indicate the expected amount of landscaped surface area compared to development's site area.

4.2. Recommendation 2

Local climate variability and rapidly emerging climate change trends require design for future conditions. The Phase One report provided the starting point for understanding the effect of future climate on the future building design and building performance.

This Phase Two report identified the key design strategies for warm temperate climates: responsive massing, form articulation, passive harvesting (natural energies) and mechanical fine-tuning. These will remain relevant. It will be more important than ever to apply them to develop resilient designs for future warmer drier climate, and enable adaptation to changing climate conditions and mitigate the effects of extreme heat and decreasing rainfall.

It will also be essential to lobby the Australian Building Codes Board to seek amended climate files to take into account the warmer drier future climate based on worst case business-as-usual RCP8.5 scenarios.

4.3. Next Steps (Phase 3)

The next phase of the Warm Temperate Climate Study and Guideline project will integrate the climate design framework and findings for warm temperate climate in specific design guidance for the Toowoomba Region's current and projected climate.

It is proposed to develop tailored design guidance aimed at two main stakeholder groups.

(1) User–centred guidelines aimed at home buyers for Class 1a buildings regulated by NCC Volume 2.

- Traditional housing (1 and 2 storey detached dwellings on lots of 500 – 1000m²)

- Small lot housing (1 and 2 storey detached and semi-detached dwellings on lots less than 450m²)
- Duplex (Two, 1 and 2 storey, attached or detached dwellings on a single lot)

(2) Consultant-oriented guidelines aimed at building design, construction and planning professionals for Class 2, 3, 5 and 6 buildings regulated by BCA Volume1.

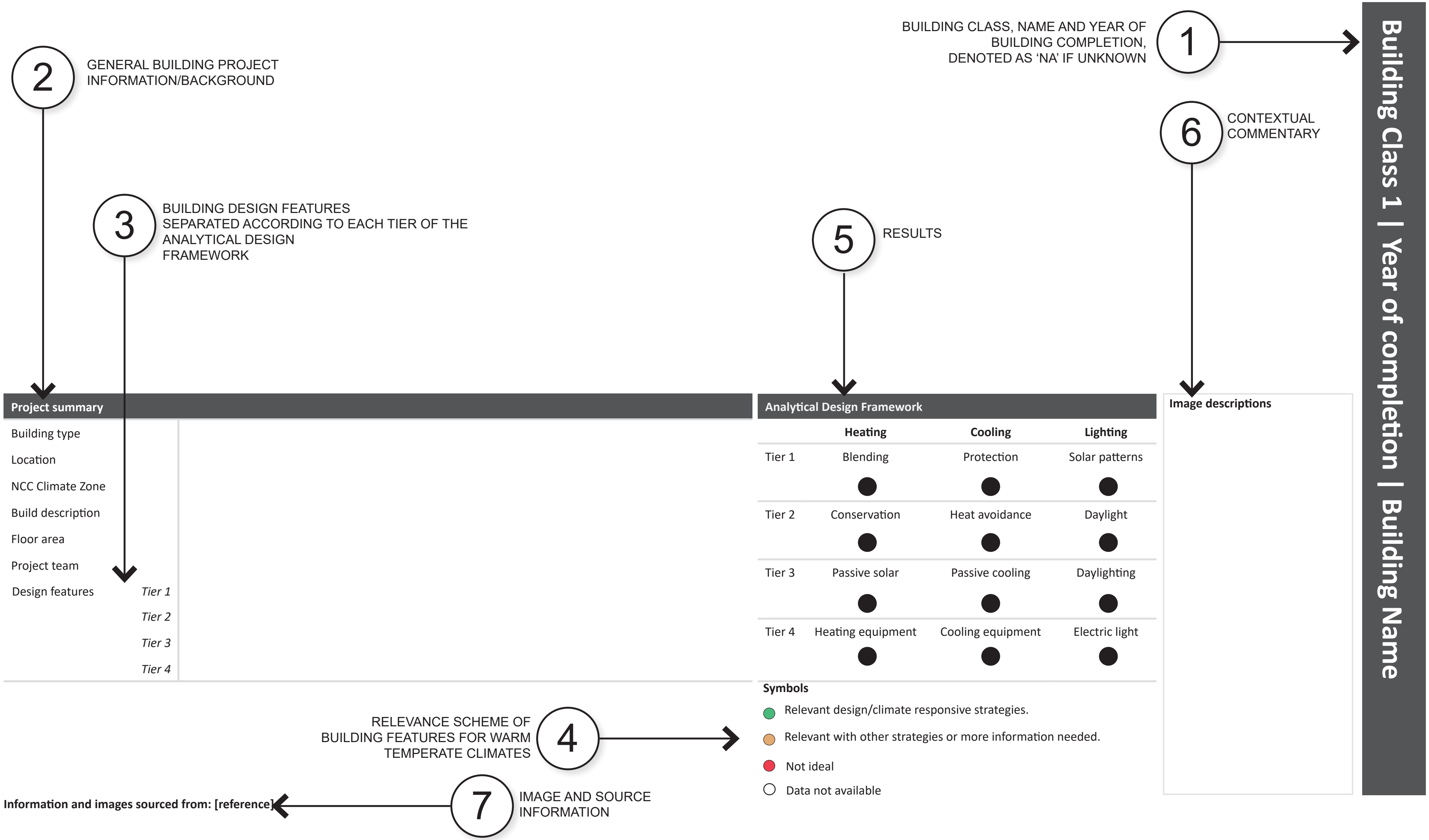
- Medium density (3 or more 1 and 2 storey dwellings on a single lot)
- Multi-storey residential (3 or more storeys of single or mixed use)
- Commercial (3 or more storeys of single or mixed us

Appendix One

Building Database

Table of Contents

Table of Contents


Building Class 1 | Year of completion | Building Name
1
BUILDING CLASS, NAME AND YEAR OF BUILDING COMPLETION, DENOTED AS 'NA' IF UNKNOWN
2
GENERAL BUILDING PROJECT INFORMATION/BACKGROUND
3
BUILDING DESIGN FEATURES SEPARATED ACCORDING TO EACH TIER OF THE ANALYTICAL DESIGN FRAMEWORK
4
RELEVANCE SCHEME OF BUILDING FEATURES FOR WARM TEMPERATE CLIMATES
5
RESULTS
6
CONTEXTUAL COMMENTARY
7
IMAGE AND SOURCE INFORMATION
Project summary
Building type
Location
NCC Climate Zone
Build description
Floor area
Project team
Design features
Tier 1
Tier 2
Tier 3
Tier 4
Analytical Design Framework
Heating
Cooling
Lighting
Tier 1
Blending
Protection
Solar patterns
Tier 2
Conservation
Heat avoidance
Daylight
Tier 3
Passive solar
Passive cooling
Daylighting
Tier 4
Heating equipment
Cooling equipment
Electric light
Symbols
Relevant design/climate responsive strategies.
Relevant with other strategies or more information needed.
Not ideal
Data not available
Image descriptions
Information and images sourced from: [reference]

Detached Dwellings
Class 1

NCC Classification One

Class 1 | NA | Rob and Bobbie's House

Project summary

Building type		Detached dwelling (Traditional, Urban), Class 1
Location		Mount Lofty, Toowoomba QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey slab on ground lightweight with timber cladding and zincalume sheeting (hip/valley)
Floor area		271m²
Project team		Eco Blueprints (designer), Ross Hogno Construction (builder)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltation (openings), reflectances (exterior/interior finishes), cool materials , lightweight materials, cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), outdoor living
	Tier 3	Active heating (solar power), draught sealing, heat sinks (slab on ground), lightweight materials, cross-ventilation (aperturess), operable shading (thermal comfort), active cooling (solar power), natural shading (deciduous trees), glare control (operable shading), reflective illumination (wall and ceiling finishes), electric
	Tier 4	Air-conditioning, ceiling fans, energy efficient lamps, smart home technologies (energy management)

Information and images sourced from: **https://sustainablehouseday.com/listing/rob-bobbies-house/**

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending	Protection	Solar patterns
Tier 2	Conservation	Heat avoidance	Daylight
Tier 3	Passive solar	Passive cooling	Daylighting
Tier 4	Heating equipment	Cooling equipment	Electric light

Symbols

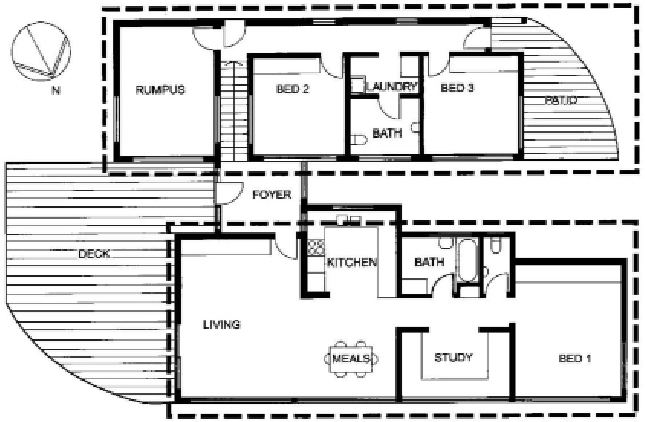
- Relevant design/climate responsive strategies.
- Relevant with other strategies or more information needed.
- Not ideal
- Data not available

Commentary:

Orientation of the building form is unknown. However, lightweight construction is well suited for warm temperate climates when it is combined with insulation.

Location of outdoor living with ceramic flooring as cooling material in summer and light reflective colours to reflect solar gains and provide reflective illumination indoors.

Class 1 | 2001 | Pemberton House



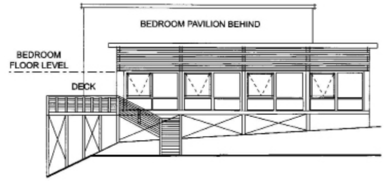


Figure 2. Section drawing

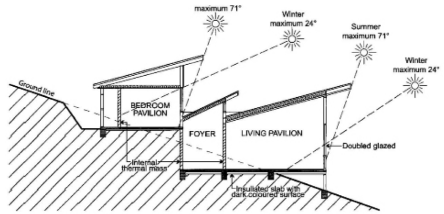


Figure 3. North elevation to living pavilion on lower ground level

Project summary

Building type		Detached dwelling (Compact, Rural), Class 1
Location		Mount Wellington, Tasmania
NCC Climate Zone		Zone 7 - Cool Temperate
Build description		1-storey slab on ground, reverse block veneer, corrugated sheeting (skillion roof)
Floor area		210m²
Project team		Detlev Geard (Architect), Robert & Gandy (Consultants), Denis Young (Contractor)
Design features	*Tier 1*	Solar gains (form orientation), daylight exposure (form orientation and layout), compact form, thermal gains (topography blending)
	Tier 2	Solar infiltation (openings), heat conservation (WWR), reflectances (exterior/interior finishes), spatial zoning, daylight access (apertures), daylight distribution (width and height), heat transfer (exterior materials)
	Tier 3	Direct gains (apertures), indirect gains, heat conservation (insulation), draught sealing, colour rendering and exposure (daylighting), reflective illumination (wall and ceiling finishes), thermal mass
	Tier 4	Ceiling fans, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🔴	Solar patterns 🟠
Tier 2	Conservation 🔴	Heat avoidance 🟠	Daylight 🟠
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟠
Tier 4	Heating equipment ⚪	Cooling equipment 🟠	Electric light ⚪

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

⚪ Data not available

Commentary:

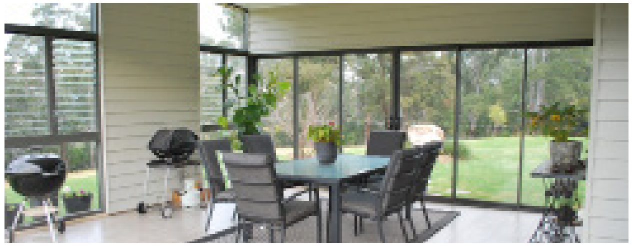
Cool temperate climates have more focus on partially or fully sealed envelopes. However, a key takeaway is form blending to utilise natural features of the topography for daylighting (levelling) and earth coupling to stabilize indoor temperature.

The building form is narrow and separated, with living areas located along solar north, but with extended overhangs to mitigate solar gains in summer.

However other adaptations are needed to suit warm temperate climates, such as shading along the west facade and removing west facing windows to the south (or reduce window size area).

Information and images sourced from: https://acumen.architecture.com.au/globalassets/asset-import/files/environment-notes/cas49.pdf

Class 1 | 2018 | Wakarara House



Project summary

Building type		Detached dwelling (Courtyard, Rural), Class 1
Location		Grapetree, Toowoomba QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey slab on ground, lightweight, masonary, aluminum sheeting (skillion roof)
Floor area		320m²
Project team		Ross Campbell (Building Designer), Tim Emmert - Emmert Homes (Contractor)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), lightweight materials, heat ventilation (SVR), cross-ventilation (openings), open-plan layout, daylight access (apertures), daylight distribution (width and height), outdoor living
	Tier 3	Direct gains (apertures), indirect gains, active heating (solar power), lightweight materials, cross-ventilation (aperturess), operable shading (thermal comfort), active cooling (solar power), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), reflective illumination (wall and ceiling finishes)
	Tier 4	Gas heaters, ceiling fans, electrical lighting

Information and images sourced from: https://sustainablehouseday.com/listing/wakarara/

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ●	Cooling equipment ●	Electric light ●

Symbols

- ● Relevant design/climate responsive strategies.
- ● Relevant with other strategies or more information needed.
- ● Not ideal
- ○ Data not available

Commentary:

An example of lightweight construction with high mass features located in well-shaded areas to mitigate overheating in summer. Courtyard forms are an ideal building configuration to cross-ventilate rooms and making use of vegetation (or water features) for evapotranspiration.

Earth coupling high thermal mass stabilizes indoor temperature, but can be used as an external wall feature to act as a heat sink in winter.

Class 1 | 2016 | House on Guido

Project summary

Building type		Detached dwelling (Narrow), Class 1
Location		Blue Mountain Heights, Toowoomba QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey slab on ground, concrete render, cladding, stone veneer with basement parking (flat roof)
Floor area		Data not available
Project team		Shane Denman Architects
Design features	*Tier 1*	Solar gains (form orientation), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form, thermal gains (topography blending)
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Draught sealing, cross-ventilation (aperturess), operable shading (thermal comfort), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes)
	Tier 4	Ceiling fans, electrical lighting

Information and images sourced from: https://www.shanedenmanarchitects.com/house-on-guido

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟢	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟠
Tier 4	Heating equipment ⚪	Cooling equipment 🟠	Electric light 🟠

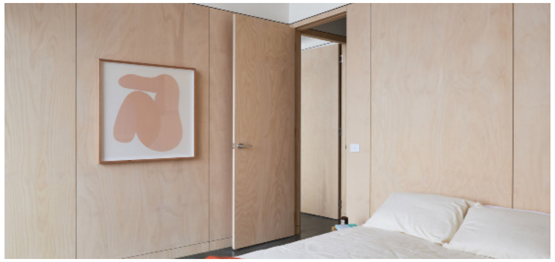
Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ⚪ Data not available

Commentary:

An example of narrow but long building form for cross-ventilation and air-flow. The orientation of the building is unknown, however habitiable areas north and north-east will maximise natural lighting. Sufficient protection from summar solar gains is provided with deep shading, whilst articulating outdoor and indoor living zones. Green landscaping increases evapotranspiration. A high ratio of hard surfaces (e.g. bitumen) can create hot outdoor environments that can also affect neighbouring buildings.

A consideration is under-utilising the roof slope for passive energy. Sloping towards north would maximise solar harvesting.

Class 1 | 2017 | Carbon Positive

Project summary

Building type		Detached dwelling (Compact, Bayside), Class 1
Location		Cape Paterson, Victoria
NCC Climate Zone		Zone 6 - Mild Temperate
Build description		1-storey slab on ground, reverse brick veneer, vertical timber cladding (butterfly roof)
Floor area		160m^2
Project team		The Sociable Weaver (Designer), Claire Cousin Architects
Design features	*Tier 1*	Solar gains (form orientation), natural ventilation (building layout), daylight exposure (form orientation and layout), compact form, thermal gains (topography blending)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Direct gains (apertures), heat conservation (insulation), draught sealing, active heating (solar power), heat sinks (slab on ground), cross-ventilation (aperturess), operable shading (thermal comfort), active cooling (solar power), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes), electric lighting (solar power)
	Tier 4	Smart home technologies (energy management), ceiling fan, electrical lighting

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending (green)	Protection (green)	Solar patterns (green)
Tier 2	Conservation (green)	Heat avoidance (green)	Daylight (green)
Tier 3	Passive solar (orange)	Passive cooling (orange)	Daylighting (orange)
Tier 4	Heating equipment (orange)	Cooling equipment (orange)	Electric light (green)

Symbols

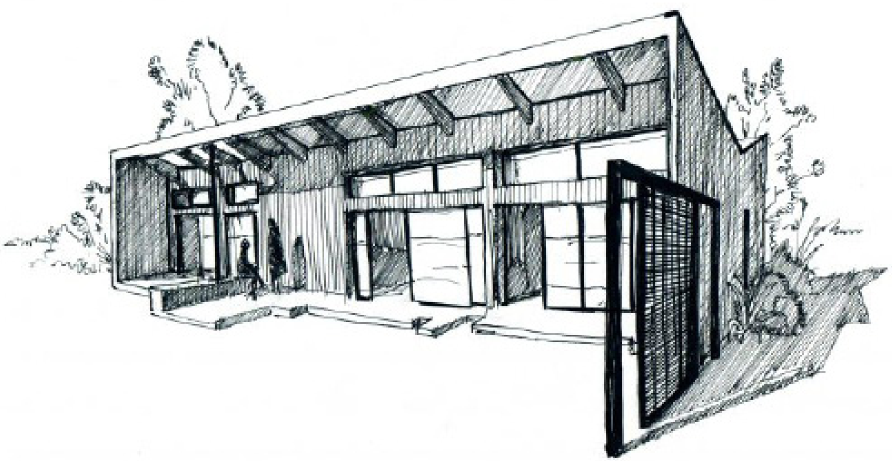
- (green) Relevant design/climate responsive strategies.
- (orange) Relevant with other strategies or more information needed.
- (red) Not ideal
- (empty) Data not available

Commentary:

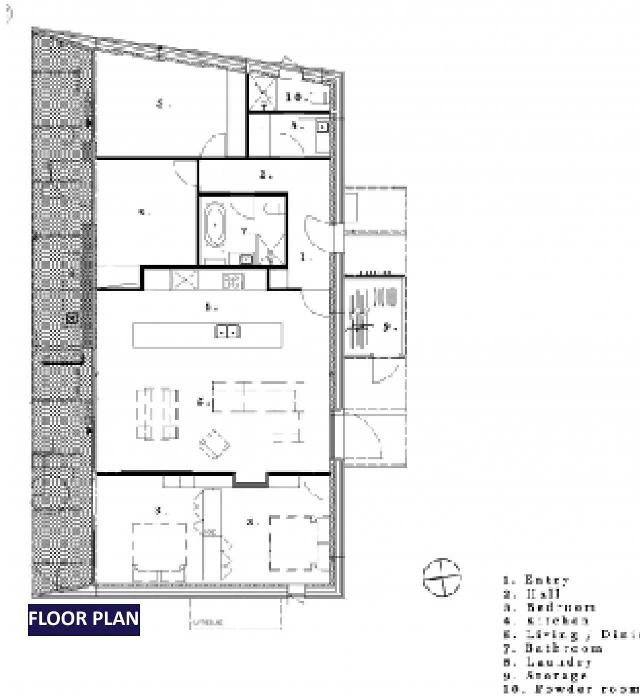
Compact homes are economical and energy sufficient. It reduces carbon footprint by prioritising the utility of space over spatiousness. Reverse brick veneer can turn high thermal mass into cool materials (with insulation and reflective colours). Increasing ceiling height activates night purging via operable clerestories. Smart technologies can increase energy efficiency, by switching off electrical appliances and lighting when solar energy is not needed. It can be prone to overheating - kitchens quickly generate heat in small spaces. Adaptations require zoning off kitchen to the south (away from habitable areas). Operable shading is needed to provide more control of prevailing winds, air-flow and daylighting.

Information and images sourced from: https://www.dezeen.com/2017/09/10/10-star-home-the-sociable-weaver-clare-cousins-architects-victoria-australia/
https://thesocialbleweaver.com.au/houses/10-star-home/

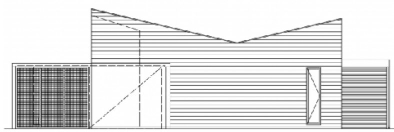
Class 1 |2017 | Carbon Positive



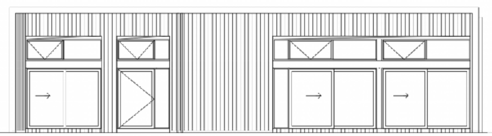
SCHEMATIC



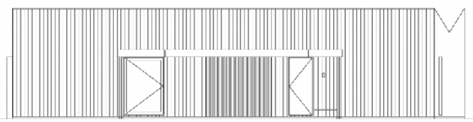
FLOOR PLAN



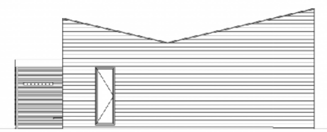
EAST ELEVA-



NORTH ELEVATION



SOUTH ELEVATION



WEST ELEVATION

Class 1 | 2018 | Helensvale

Project summary

Building type		Detached dwelling (Courtyard, Urban), Class 1
Location		Gold Coast, QLD
NCC Climate Zone		Zone 2 - Warm Humid Summer, Mild Winter
Build description		2-storey slab on ground, fibre cement cladding (flat roof) and carport
Floor area		350m^2
Project team		Happy Haus (Architects)
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form
	Tier 2	Solar infiltration (openings), solar absorption (exterior finishes), reflectances (exterior/interior finishes), cool materials , lightweight materials, spatial zoning, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Indirect gains, active heating (solar power), lightweight materials, cross-ventilation (aperturess), operable shading (thermal comfort), active cooling (solar power), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), cool materials, reflective illumination
	Tier 4	Ceiling fans, electrical lighting, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending	Protection	Solar patterns
Tier 2	Conservation	Heat avoidance	Daylight
Tier 3	Passive solar	Passive cooling	Daylighting
Tier 4	Heating equipment	Cooling equipment	Electric light

Symbols

- Relevant design/climate responsive strategies.
- Relevant with other strategies or more information needed.
- Not ideal
- Data not available

Commentary:

Example of courtyard home in urban suburbs. Long narrow form, with fixed and operable shading for cooling and air-flow. Earth coupling to stabilise indoor temperature in combination with cool flooring materials (tiling).

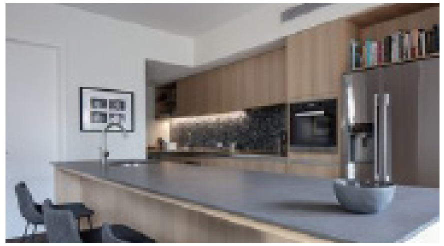
Setbacks are utilised for fixed shading, with vegetable and green landscaping for evapotranspiration. Reducing window area on the west facade minimises overheating in combination with reflective cladding.

Information and images sourced from: https://happyhaus.com.au/gallery-helensvale-haus/
https://homeworlddesign.com/helensvale-haus-in-south-east-queensland-happy-haus/

Class 1 | 2017 | Hampton House







Project summary

Building type		Detached dwelling (Narrow, Bayside Urban), Class 1
Location		Hamptons, Victoria
NCC Climate Zone		Zone 7 - Cool Temperate
Build description		2-storey slab on ground, groove cladding with metal sheeting (gable roof) and carport
Floor area		299m²
Project team		Habitech Systems (Architects)
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), lightweight materials, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Heat conservation (insulation), draught sealing, operable shading (thermal comfort), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes), electric lighting (solar power), solar power (for all electrical services including hydronic slab heating and hot water), combustion stove with masonry walls (heat sink)
	Tier 4	Energy supplied by solar panels

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending	Protection	Solar patterns
Tier 2	Conservation	Heat avoidance	Daylight
Tier 3	Passive solar	Passive cooling	Daylighting
Tier 4	Heating equipment	Cooling equipment	Electric light

Symbols

- Relevant design/climate responsive strategies.
- Relevant with other strategies or more information needed.
- Not ideal
- Data not available

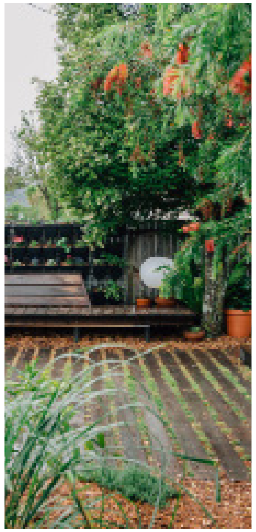
Commentary:

Energy efficient solution for long narrow building forms in urban environments. Setbacks on lower floors for shading (in this scenario high mass materials can be utilised as a cooling on lower floor) with reflective materials (roof and external wall) to minimise heat gain. Balance of natural and built areas for evaporative cooling and activing frontage using locally sourced and recycled materials. Adaptations to openings required for cross-ventilation and air-flow for warm temperate climates. Double hung windows are not

Information and images sourced from: https://www.architectureanddesign.com.au/projects/houses/ultra-sustainable-intelligent-family-home
https://www.habitechsystems.com.au/new-houses#/hampton-house/

Class 1 | 2017 | Yeronga House




Project summary

Building type		Detached dwelling (Narrow lot, Renovation Extension, Urban), Class 1
Location		Yeronga, Brisbane QLD
NCC Climate Zone		Zone 2 - Warm Humid Summer, Mild Winter
Build description		1-storey suspended flooring, lightweight, timber cladding, aluminum sheeting (gable and skillion)
Floor area		230m²
Project team		Tim Bennetton and Ryan Bunn (Architects), Ad Structure, Greg Thronton/Charles Warren Constructions
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), lightweight materials, cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	lightweight materials, evapotranspiration (green landscaping), operable shading (thermal comfort), natural shading (deciduous trees), colour rendering and exposure (daylighting), glare control (operable shading), reflective illumination (wall and ceiling finishes)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟢	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

○ Data not available

Commentary:
Rear extension to the existing Queenslander, using same lightweight construction and suspended flooring to follow slope. South facing windows for indirect passive lighting without solar gains.

Second left top and bottom: Operable shading facing east for ventilation and solar protection. Deciduous trees for natural shading and green landscaping for evapotranspiration.

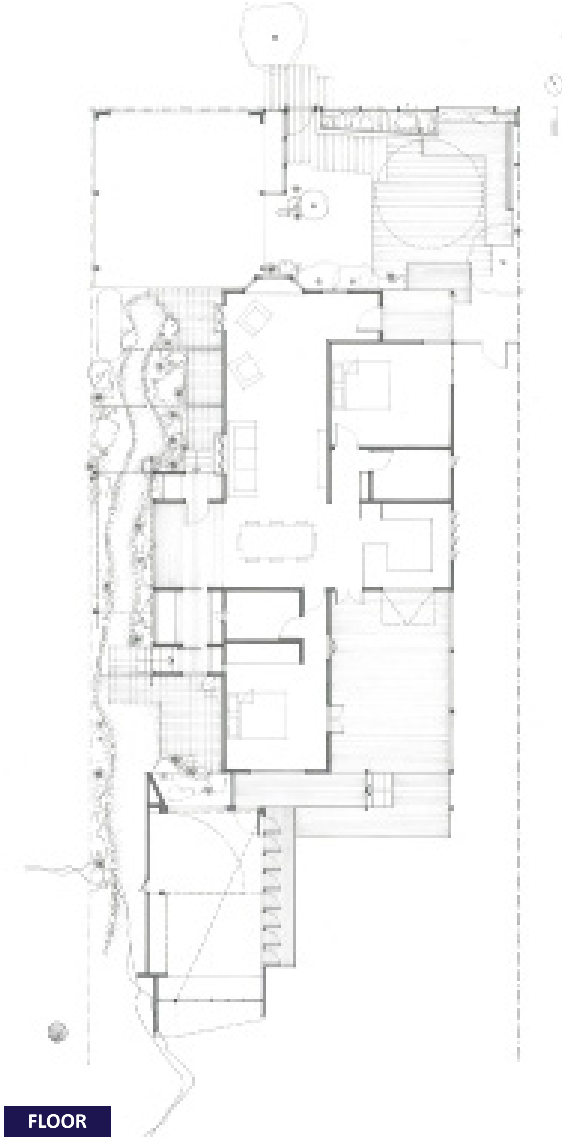
Third left: Urban interfacing using built and natural surfaces to engage the urban environment.

Right: Interior of rear extension using low thermal materials and light colour finishes for reflective illumination and colour rendering(reflectances).

Information and images sourced from: https://www.archdaily.com/913105/yeronga-house-tim-bennetton-architects?ad_source=search&ad_medium=search_result_projects
https://www.timbennetton.com.au/projectdetail/14

SCHEMATIC: REAR

SCHEMATIC: FRONT



FLOOR

Class 1 | 2007 | Yeronga House

Class 1 | 2015 | M Residence

Project summary

Building type		Detached dwelling (Courtyard, Rural), Class 1
Location		Kingsthorpe, Toowoomba QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey slab on ground, brick veneer, fiber cement cladding and metal sheeting (gable roof)
Floor area		Data not available
Project team		Elia Architects
Design features	*Tier 1*	Solar gains (form orientation), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form
	Tier 2	Solar infiltration (openings), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), cool materials , lightweight materials, heat ventilation (SVR), cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Direct gains (apertures), indirect gains, night-flushing, heat sinks (slab on ground), lightweight materials, cross-ventilation (aperturess), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), reflective illumination (light interior colours)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ○ Data not available

Commentary:

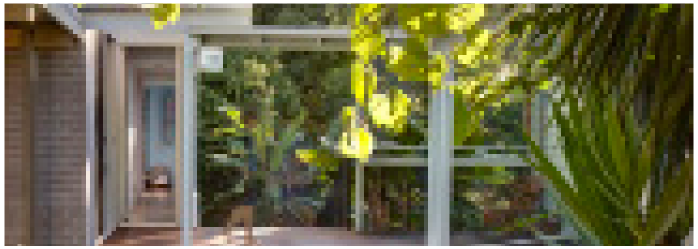
Courtyard for cross ventilation with green landscaping for evapotranspiration. High ceiling windows for heat ventilation and night flushing. Masonry walls for thermal gain in winter. Lightweight reflective materials in non-living areas.

Middle top/bottom: High thermal mass (masonry walls and earth coupling) for cooling in summer and heating in winter using deep lighting from clerestory and woodfire with masonry heat sink.

Right: high thermal mass materials and finishes.

Information and images sourced from: https://elia.com.au/interior-design-m-residence/

Class 1 | 2018 | Verandah House



Project summary

Building type		Detached dwelling (Pavillion, Renovation Extension, Urban), Class 1
Location		Sydney, NSW
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey suspended timber and slab on ground, brick cavity, timber cladding
Floor area		117m²
Project team		Still Space Architecture
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), thermal gains (topography blending)
	Tier 2	Solar infiltration (openings), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), lightweight materials, heat ventilation (SVR), cross-ventilation (openings), spatial zoning, daylight access (apertures), daylight distribution (width and height), outdoor living
	Tier 3	Active heating/cooling, evaporative cooling , heat sinks (slab on ground), lightweight materials, cross-ventilation (aperturess), operable shading (thermal comfort), natural shading (deciduous trees), evapotranspiration (waterbody), colour rendering and exposure (daylighting), glare control (operable shading), reflective illumination (wall and ceiling finishes), electric lighting (solar power)
	Tier 4	Air-conditioning, ceiling fans, electrical lighting

Information and images sourced from: **https://www.archdaily.com/914129/verandah-house-still-space-architecture?ad_source=search&ad_medium=search_result_projects**

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ●	Cooling equipment ●	Electric light ●

Symbols

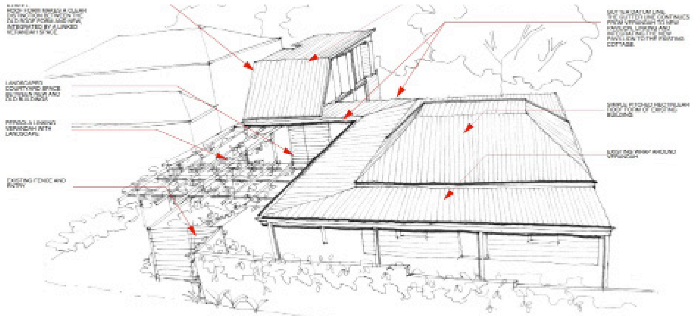
- ● Relevant design/climate responsive strategies.
- ● Relevant with other strategies or more information needed.
- ● Not ideal
- ○ Data not available

Commentary:

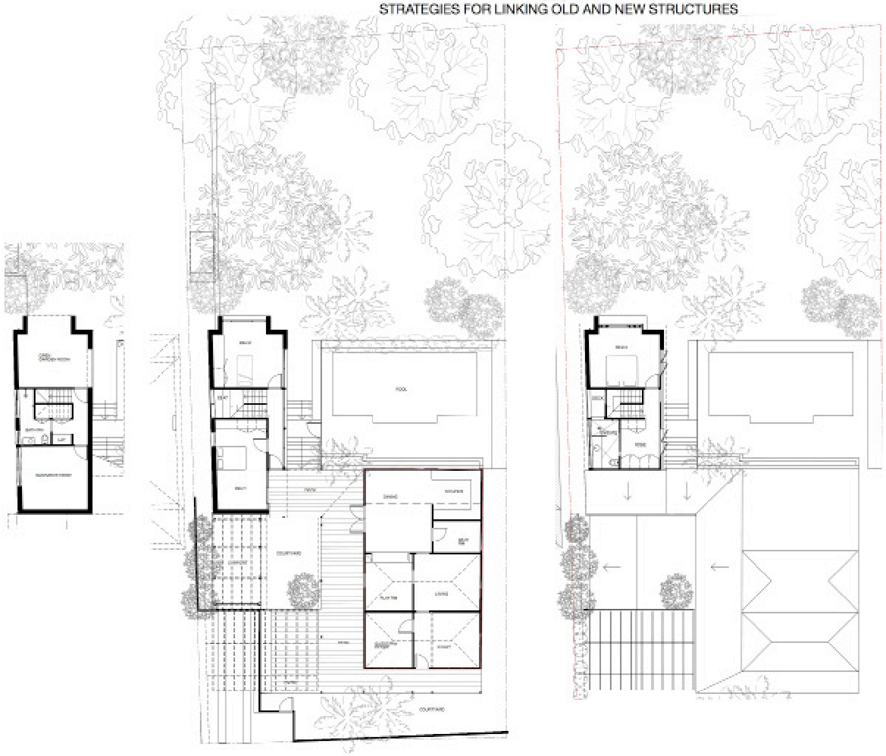
Left: Extension with brick pavillion combining low and high thermal mass, operable shading for glare and natural ventilation. Evapotranspiration with waterbody and deciduous trees for shading.

Second left: Ceiling fan for ventilation with operable window louvres for passive ventilation and perforated light directing panels for glare control and daylighting.

Top and bottom right: lightweight materials for low thermal mass and light finishes for reflectance and reflective illumination.



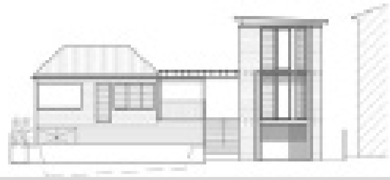
STRATEGIES FOR LINKING OLD AND NEW STRUCTURES



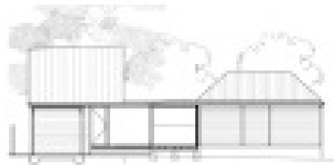
GROUND LEVEL PLAN AND SITE PLAN

BASEMENT LEVEL PLAN

UPPER LEVEL PLAN

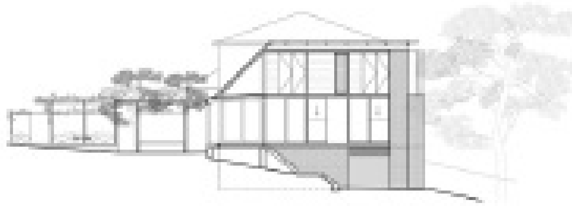


NORTH ELEVATION

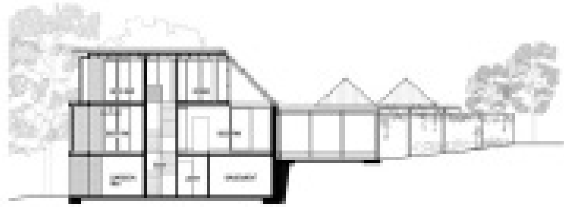


SOUTH ELEVATION

WEST ELEVATION



EAST ELEVATION/SECTION

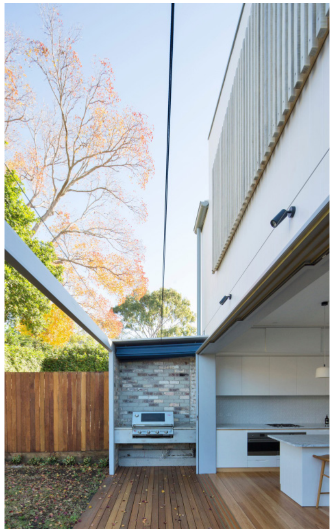


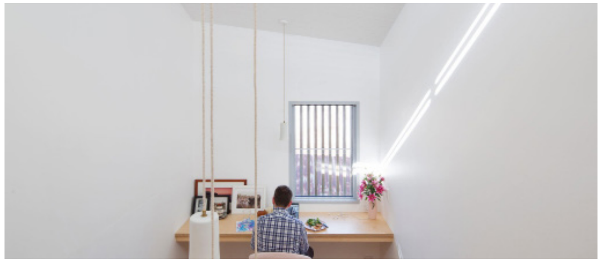
LONG SECTION

Class 1 | 2018 | Verandah House

Class 1 | 2018 | Sawtooth House







Project summary

Building type		Detached Dwelling (Narrow and compact, Renovation Extension, Urban, Heritage), Class 1
Location		Drummoyne, Sydney NSW
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-storey suspended timber flooring, masonry (existing) and lightweight construction with colourbond cladding (Sawtooth and hip/valley roof)
Floor area		Data not available
Project team		Adriano Pupilli Architects, AVB Constructions
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), daylight exposure (form orientation and layout), narrow form, narrow form
	Tier 2	Solar infiltration (openings), heat conservation (WWR), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), lightweight materials, daylight access (apertures), daylight distribution (width and height), traditional layout, outdoor living
	Tier 3	Heat conservation (insulation), draught sealing, active heating, cooling and lighting (solar power), lightweight materials, colour rendering and exposure (daylighting), double glazing, skylights
	Tier 4	Air-conditioning, ceiling fans

Information and images sourced from:

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ●	Cooling equipment ●	Electric light ●

Symbols

- ● Relevant design/climate responsive strategies.
- ● Relevant with other strategies or more information needed.
- ● Not ideal
- ○ Data not available

Image descriptions

Left: Renovation extension to building rear oriented south using lightweight solutions to maintain indoor climate with insulation and draft sealing. Skylights for passive lighting facing north-east.

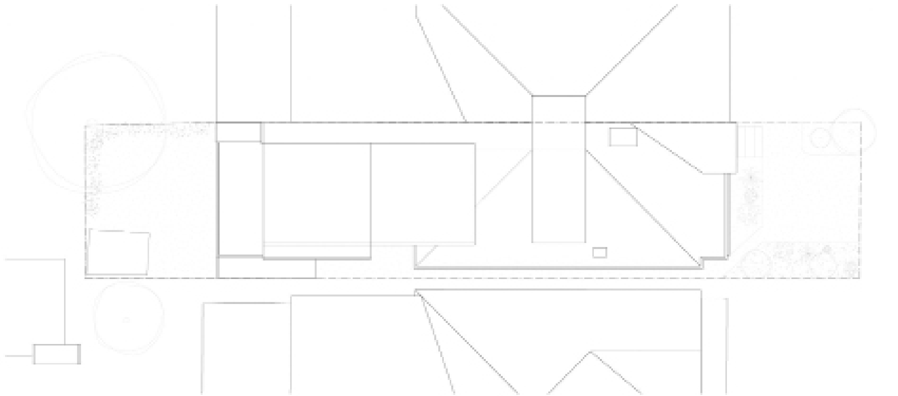
Second left: Existing building (heritage).

Third left: Extension with large operable openings to connect outdoor living.

Top right: Top view of extension, with sawtooth roofing and metal sheeting.

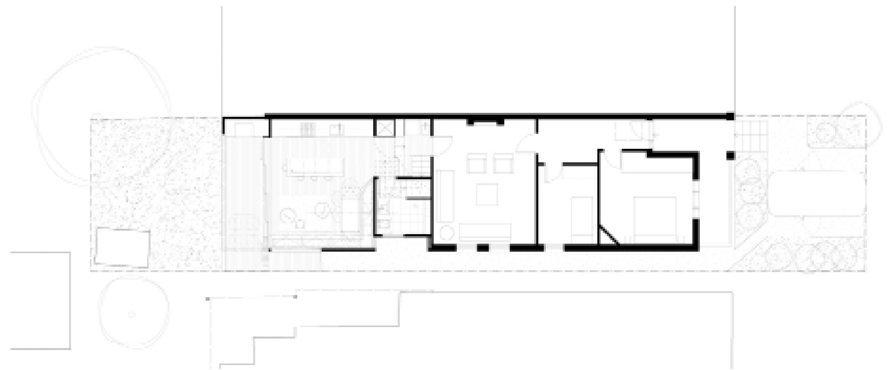
Top bottom: Interior view of extension, light finishes for reflective illumination.

Class 1 | 2008 | Sawtooth House



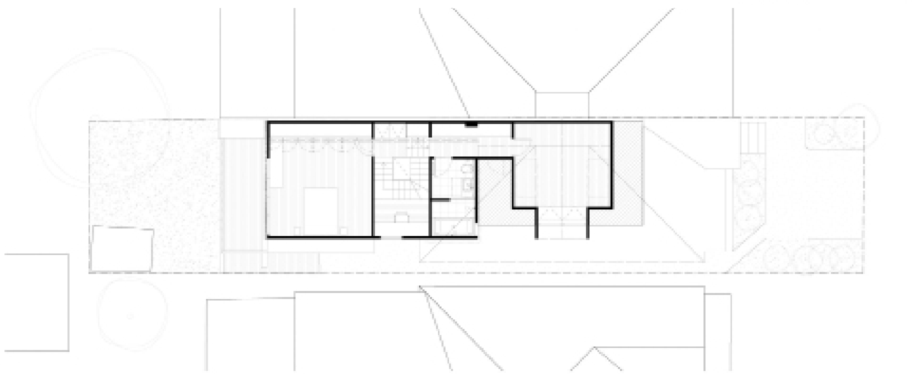
ROOF PLAN

1:100



GROUND FLOOR PLAN

1:100



FIRST FLOOR PLAN

1:100

SECTION

1:100

Class 1 | 2020 | Escarpment House





Project summary

Building type		Detached Dwelling (Traditional, Rural, Renovation Extension), Class 1
Location		Illawarra, NSW
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-storey suspended timber flooring, lightweight, timber cladding with metal roof shetting (gable and hip)
Floor area		320m²
Project team		Virgina Kerridge Architects, J2 Build (Contractor)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), lightweight materials, cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), traditional layout , outdoor living
	Tier 3	Heat conservation (insulation), draught sealing, active heating/cooling/lighting (solar power), lightweight materials, cross-ventilation (aperturess), natural shading (deciduous trees), evapotranspiration (water-body), colour rendering and exposure (daylighting), double glazing, wood fire
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟢	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🟢	Passive cooling 🟢	Daylighting 🟢
Tier 4	Heating equipment 🟠	Cooling equipment 🟠	Electric light 🟠

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

⚪ Data not available

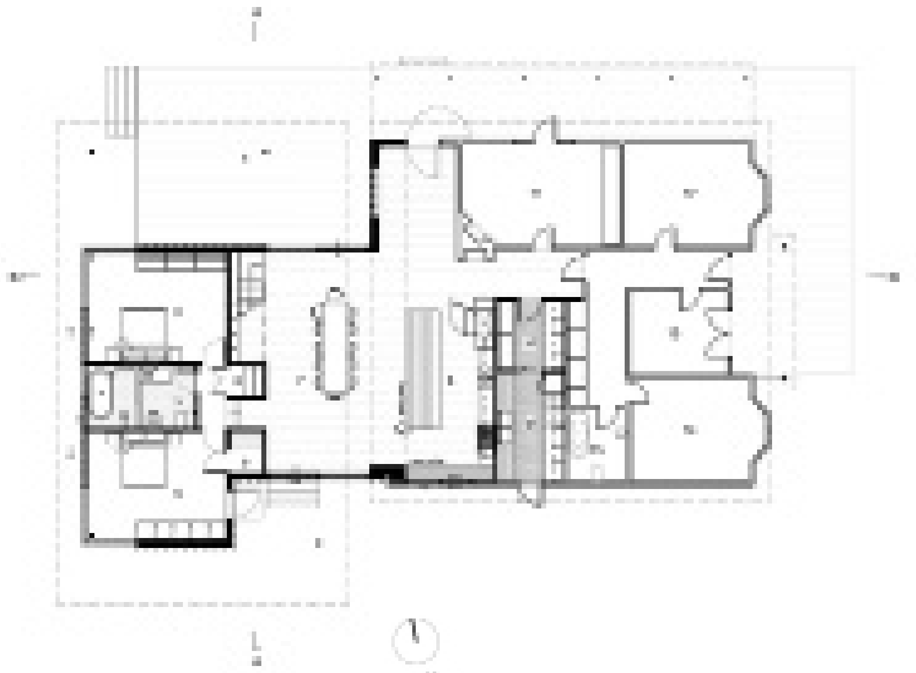
Image descriptions

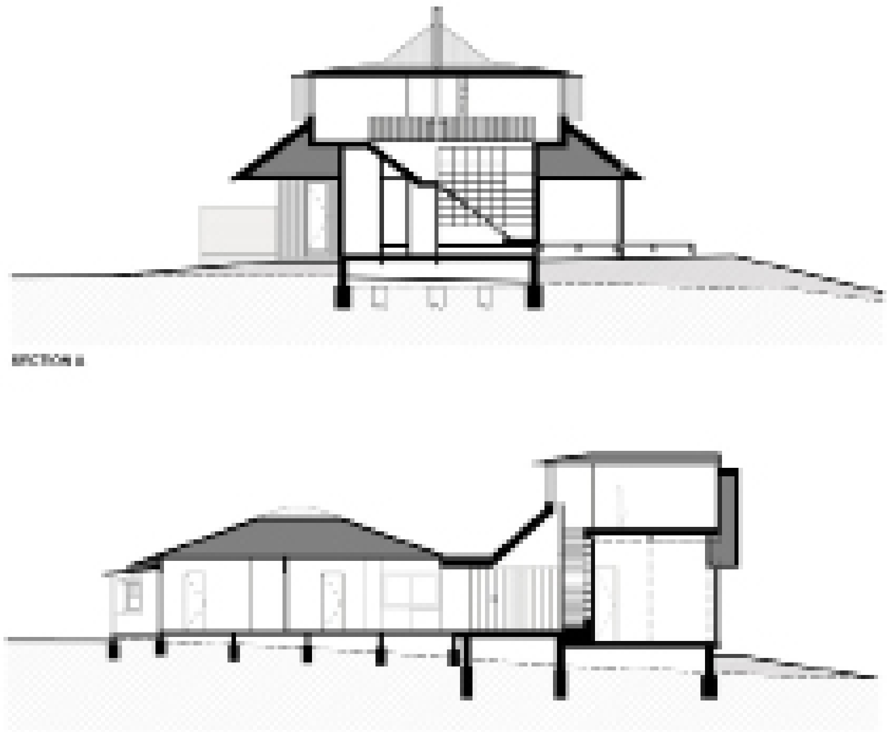
Left: Evapotranspiration from combination of large water body (evaporative), green landscaping and deciduous trees.

Second left top and bottom: lightweight construction materials with low thermal energy and light interior finishes for reflective illumination.

Third left and right: angled ceiling to direct passive lighting from upper floor to ground floor.

Information and images sourced from: https://www.vk.com.au/work/escarpment-house
https://www.archdaily.com/961981/escarpment-house-virginia-kerridge-architect?ad_source=search&ad_medium=search_result_projects
https://thelocalproject.com.au/articles/escarpment-house-by-virginia-kerridge-architect-project-feature-the-local-project/





Class 1 | 2020 | Escarpment House

Class 1 | 2020 | Ripple House




Project summary

Building type		Detached dwelling (Narrow lot, Heritage, Renovation Extension, Urban), Class 1
Location		Melbourne Victoria
NCC Climate Zone		Zone 6 - Mild Temperate
Build description		1-storey slab on ground, brick veneer, timber cladding and metal roof sheeting (hip and butterfly)
Floor area		160m^2
Project team		FMD Architects, BFC Built
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), solar shading (existing deciduous trees), daylight exposure (form orientation and layout), narrow form
	Tier 2	Solar infiltration (openings), heat conservation (WWR), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), lightweight materials, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Direct gains (apertures), heat conservation (insulation), draught sealing, active heating, cooling and lighting (solar power), operable shading (thermal comfort), colour rendering and exposure (daylighting), diffused glazing (skylights), reflective illumination (wall and ceiling finishes)
	Tier 4	Energy efficient lamps, data not available

Information and images sourced from: **https://www.fmdarchitects.com.au/ripple-house**

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🔴	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🔴	Passive cooling 🔴	Daylighting 🟢
Tier 4	Heating equipment 🟠	Cooling equipment 🟠	Electric light 🟠

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ⚪ Data not available

Image descriptions

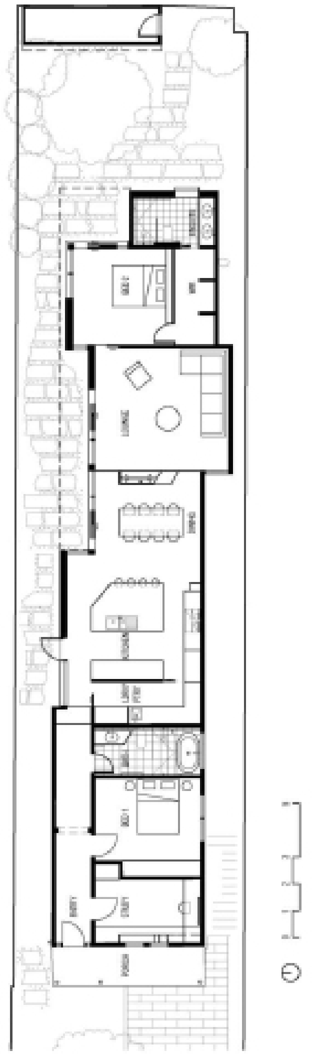
Left: Renovation extension to heritage building on narrow lot in urban context.

Second left: Lightweight construction with butterfly roofing and underside fitted with timber panelling. Extensive roof overhang provides shading from solar heating gain during summer.

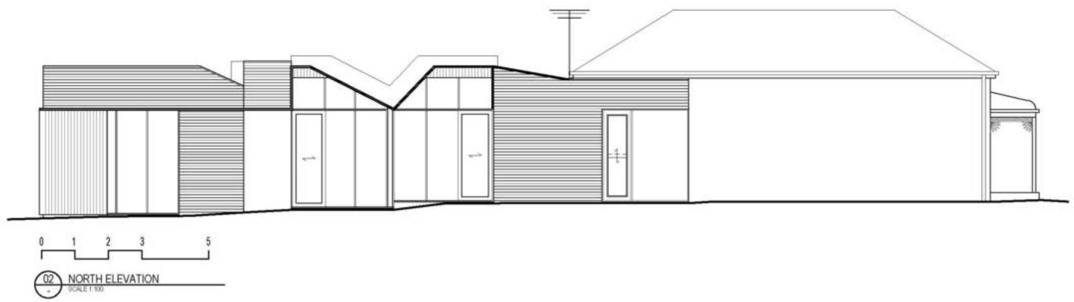
Third left: low and high mass flooring (timber and concrete) to modulate indoor temperature with diffused skylighting for passive lighting and reflective illumination (reflectance) on interior walls.

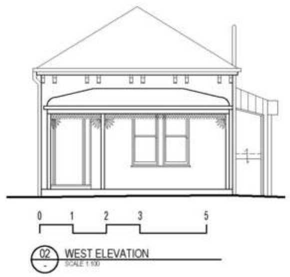
Right: Timber detailing and direct solar gain on concrete floor from skylighting.

Class 1 | 2020 | Ripple House



FLOOR





Class 1 | 2018 | Courtyard Home

Project summary

Building type		Detached dwelling (Modular, Courtyard, Compact, Rural), Class 1
Location		Hawks Nest, NSW
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		Suspended prefabrication modular construction, hardwood cladding
Floor area		96m²
Project team		CHROFI (Designer), FABPREFAB (Contractor)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), lightweight materials, heat ventilation (SVR), cross-ventilation (openings), spatial zoning, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Heat conservation (insulation), active heating (solar power), lightweight materials, cross-ventilation (ap-erturess), operable shading (thermal comfort), colour rendering and exposure (daylighting), low-e glazing, reflective illumination (wall and ceiling finishes)
	Tier 4	Electrical lighting, ceiling fans (off-grid)

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟠	Protection 🟠	Solar patterns 🟠
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟠
Tier 3	Passive solar 🟢	Passive cooling 🟢	Daylighting 🟢
Tier 4	Heating equipment 🟢	Cooling equipment 🟢	Electric light 🟢

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

○ Data not available

Image descriptions

Left: Modular construction using lightweight materials with low thermal mass in rural context.

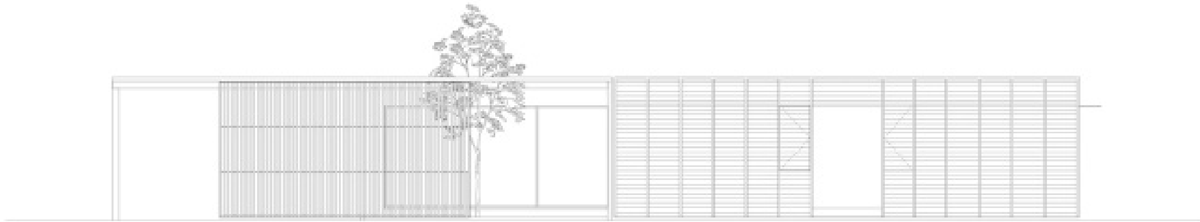
Second top/bottom left: Court-yard form with large operable windows and openings for cross ventilation.

Third left: Light interior finishes for indirecti llumination and ceiling fan for cross ventilation and purging.

Right: Fixed shading from solar gains in summer.

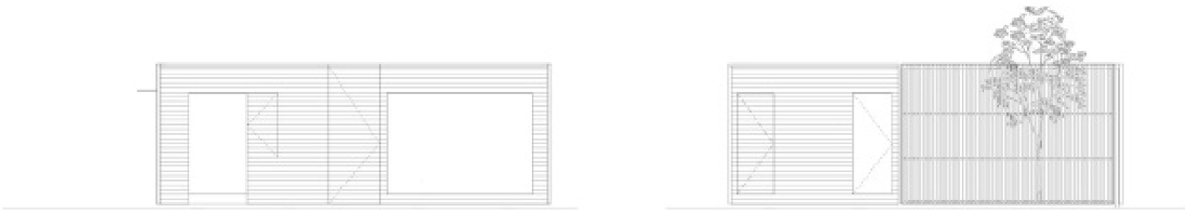
Information and images sourced from: **https://www.dwell.com/article/courtyard-house-chrofi-fabprefab-e6c80251**

Class 1 | 2018 | Courtyard Home

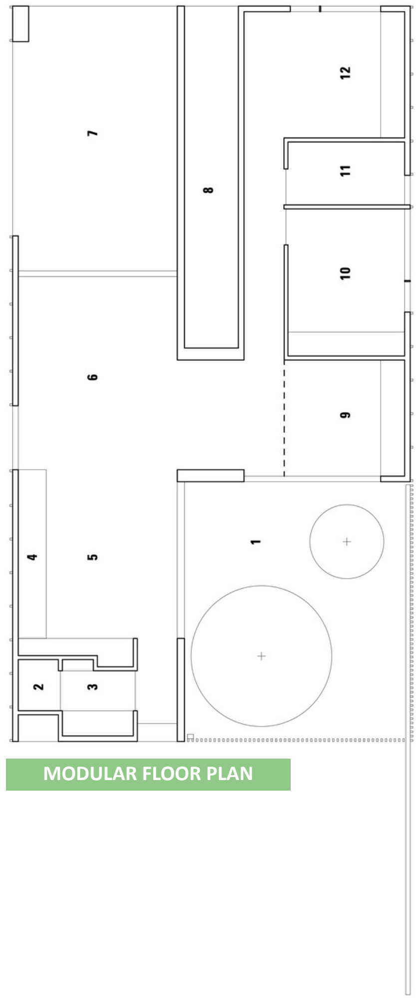


LONG AXIS ELEVATION 1

LONG AXIS ELEVATION 2



FRONT AND REAR ELEVATION



MODULAR FLOOR PLAN

Class 1 | 2020 | Our House Wandal

Project summary

Building type		Detached Dwelling (Narrow, Urban), Class 1
Location		Rockhampton, QLD
NCC Climate Zone		Zone 2 - Warm Humid Summer, Mild Winter
Build description		2-storey suspended timber flooring, lightweight, zinc and fibre cement cladding with metal roof sheeting (skillion roof)
Floor area		150m²
Project team		Design+Architecture and N Veenstra (Architects), Owner (Consultant)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), lightweight materials, heat ventilation (SVR), cross-ventilation (openings), spatial zoning, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Heat conservation (insulation), draught sealing, active heating, cooling, lighting (solar power), lightweight materials, cross-ventilation (apertures), natural shading (deciduous trees), evapotranspiration (green land-scaping), colour rendering and exposure (daylighting), low-e glazing, reflective illumination (wall and ceiling finishes), fixed shading (thermal comfort)
	Tier 4	Air-conditioning, ceiling fans

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ○	Cooling equipment ●	Electric light ○

Symbols

- ● (green) Relevant design/climate responsive strategies.
- ● (orange) Relevant with other strategies or more information needed.
- ● (red) Not ideal
- ○ Data not available

Image descriptions

eft: Lightweight construction with reflective materials and large overhangs for fixed shading.

Top/bottom middle: Light interior finishes for reflective illumination in open plan living. Double glazing for draught sealing. Urban activation with landscaping.

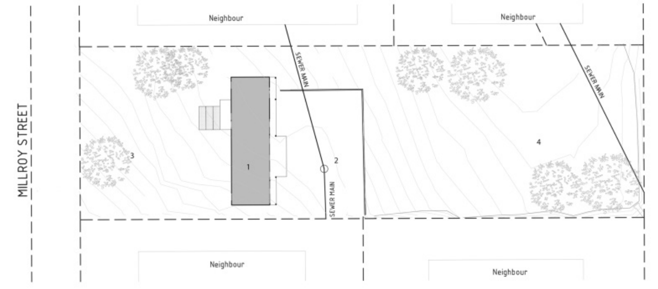
Third left: Operable windows for ventilation and large operable openings for connection to outdoor living.

Right: Reflective materials and insulation for low heat gain.

Information and images sourced from: **https://www.designaa.com.au/projects/%23OURHOUSEWANDAL**

Class 1 | 2020 | Our House Wandal

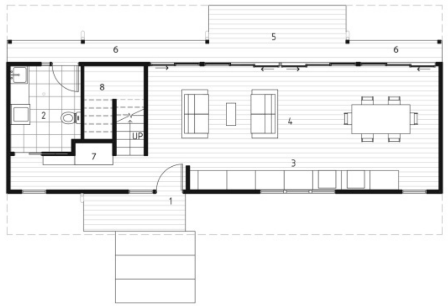
2 GRASSED TERRACE
3 STREET GARDEN
4 LOWER GARDEN



SITE PLAN

0 1m 2m 5m

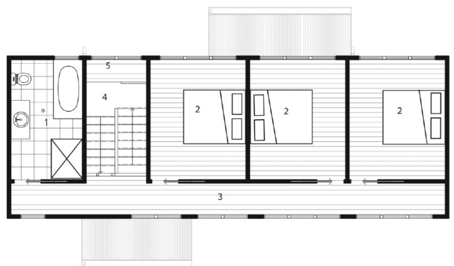
1 Front Deck Entry
2 Laundry
3 Gallery Kitchen
4 Living/ Dining
5 Open Verandah
6 Edge Verandah
7 Study Nook
8 Stairs



GROUND

0 1m 2m

2 Bedroom
3 Buffer Hallway
4 Stairs
5 Reading Nook



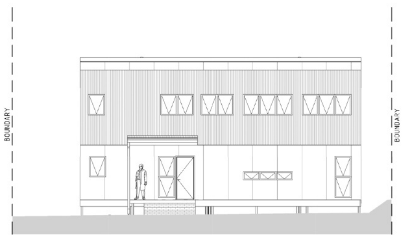
FIRST

0 1m 2m

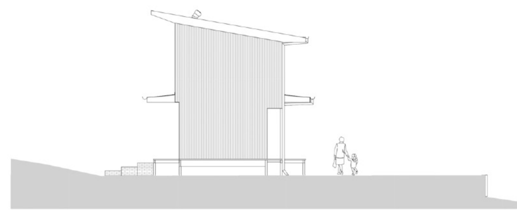
2 Lower Garden
3 Proposed Dwelling
4 Street Garden
5 Grassed Terrace

SECTION

0 2m 5m 10m



SOUTH ELEVATION



EAST ELEVATION

0 1m 2m

Class 1 | 2020 | Canning Street House

Project summary

Building type		Detached dwelling (Zero lot, Renovation Extension, Heritage), Class 1
Location		Canning Street, Melbourne Victoria
NCC Climate Zone		Zone 6 - Mild Temperate
Build description		2-storey slab on ground, reclaimed brick, timber cladding and metal sheeting (skillion roof)
Floor area		280m^2
Project team		Riofrio Carroll Architects, Highwill Constructions, Macbrick Bricklaying, Heidlebergsteel Steel Structures
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form, zero-lot
	Tier 2	Solar infiltration (openings), heat conservation (WWR), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout, outdoor living
	Tier 3	Direct gains (apertures), indirect gains, heat conservation (insulation), draught sealing, heat sinks (slab on ground), operable shading (thermal comfort), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes), active heating, cooling and lighting (solar power), high thermal mass
	Tier 4	Ceiling fans, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟢	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment 🟠	Electric light ○

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ○ Data not available

Image descriptions

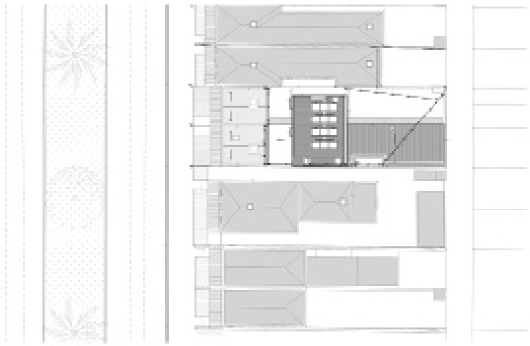
Left: High thermal mass envelope with upper floor timber cladding. External operable shading for solar and glare control.

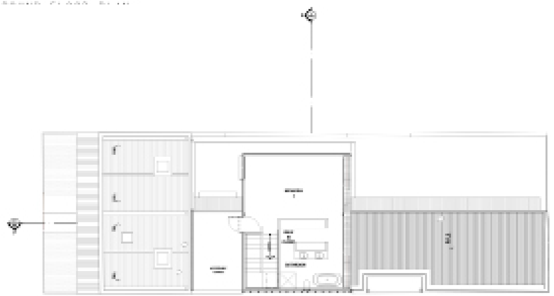
Second left: Large roof overhang for solar protection in summer and direct gains in winter.

Third top/bottom left: High thermal mass flooring with light exterior finishes for reflective illumination in open plan living.

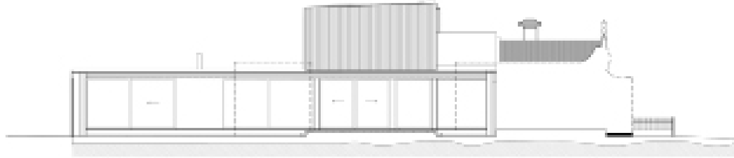
Top and bottom right: Timber flooring in upper floors (with expected insulation) to minimise heat transfer. High thermal mass flooring combined with earth coupling for thermal modulation.

Information and images sourced from: **https://www.archdaily.com/952857/canning-street-house-riofrio-carroll-architects?ad_source=-search&ad_medium=search_result_projects**
https://www.dwell.com/article/canning-street-house-riofrio-carroll-architects-melbourne-405d85e5

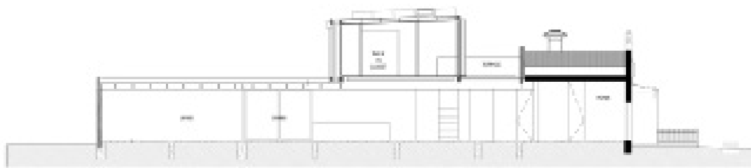




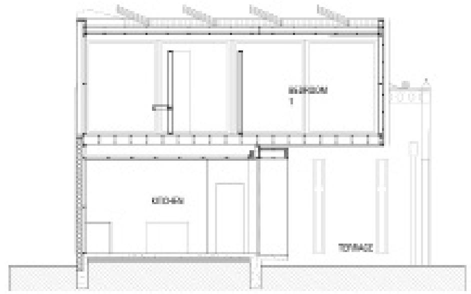
FIRST FLOOR

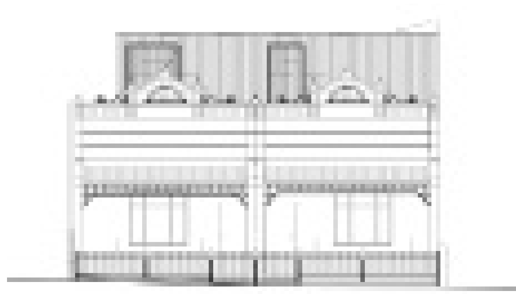


NORTH ELEVATION



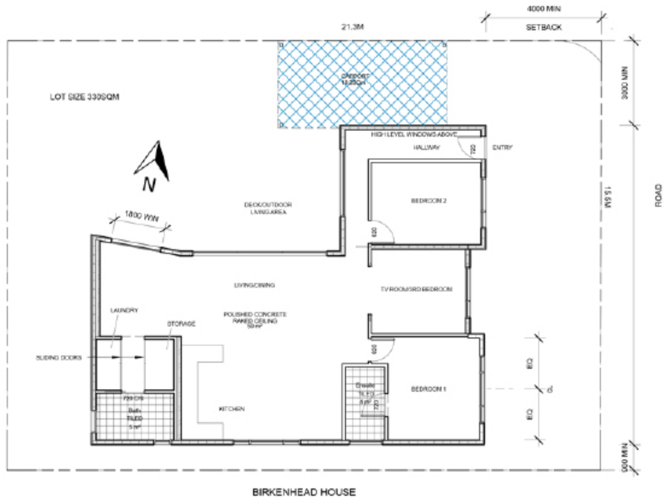
SECTION F-F





Class 1 | 2020 | Canning Street House

Class 1 | 2010 | Emily Street Residence



Project summary		
Building type		Detached dwelling (Urban), Class 1
Location		Clayton, SA
NCC Climate Zone		Zone 5 - Wam Temperate
Build description		1-storey slab on ground, reverse veneer and zincalume cladding with metal roofing (skillion roof)
Floor area		125m²
Project team		SUHStudio (Architects), Owner (builder)
Design features	*Tier 1*	Solar gains (form orientation), natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), cool materials , cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout, outdoor living
	Tier 3	Indirect gains, direct gains (apertures), draught sealing, heat conservation (insulation), cross-ventilation (aperturess), colour rendering and exposure (daylighting), double glazing, reflective illumination (wall and ceiling finishes), solar energy storage, solar heating (water)
	Tier 4	Smart home technologies (energy management), ceiling fans, energy efficient lamps

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟠
Tier 2	Conservation 🟢	Heat avoidance 🟢	Daylight 🟠
Tier 3	Passive solar 🟢	Passive cooling 🟢	Daylighting 🟠
Tier 4	Heating equipment 🟢	Cooling equipment 🟢	Electric light 🟢

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ○ Data not available

Image descriptions

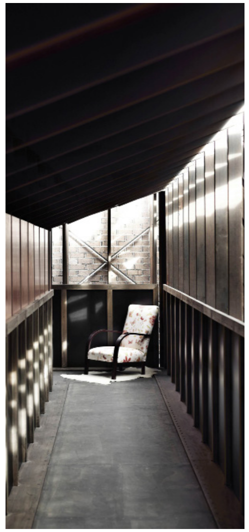
Left: Reverse brick veneer with high reflective metal cladding and low thermal mass timber decking for outdoor living. Skillion roofing for fixed shading from solar heat gains in summer.

Middle: High thermal mass interior using exposed brick veneer and earth coupling concrete flooring to modulate indoor temperature. Ceiling fans for thermal ventilation and solar powered heater for water.

Right: Floor plan showing spatial configuration of rooms oriented to maximise habitable spaces towards solar north. With limited openings on west to reduce solar gains in the afternoon. East facing windows require operable shading (data not available).

Information and images sourced from: **https://etoolglobal.com/portfolio-item/suho-studio-emily-st-residence/**

Class 1 | 2012 | Bisley Place



Project summary

Building type		Detached dwelling (Urban, Courtyard), Class 1
Location		Wakerly, Brisbane QLD
NCC Climate Zone		Zone 2 - Warm Humid, Mild Winter
Build description		1-storey slab on ground, brick veneer, metal roofing (skillion roof)
Floor area		258m²
Project team		James Russell Architect, Build Restore (Builder), Ad.Structure (Consultants)
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form, thermal gains (topography blending), urban interfacing (landscaping)
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), cross-ventilation (openings), daylight access (openings), daylight distribution (width and height), courtyard layout, outdoor living
	Tier 3	Direct gains (openings), heat sinks (slab on ground), cross-ventilation (openings, apertures), operable shading (thermal comfort), evapotranspiration (green landscaping and waterbody), colour rendering and exposure (daylighting), reflective illumination (wall and ceiling finishes), glare control (operable shading), lightweight materials, cool materials (high thermal mass with reflective coating), diffused lighting (shading with high VLT)
	Tier 4	Data not available

Information and images sourced from: **https://www.archdaily.com/437052/bilsey-place-house-james-russell-and-andrew-shindler**

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟢
Tier 3	Passive solar 🟢	Passive cooling 🟢	Daylighting 🟢
Tier 4	Heating equipment ⚪	Cooling equipment ⚪	Electric light ⚪

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

⚪ Data not available

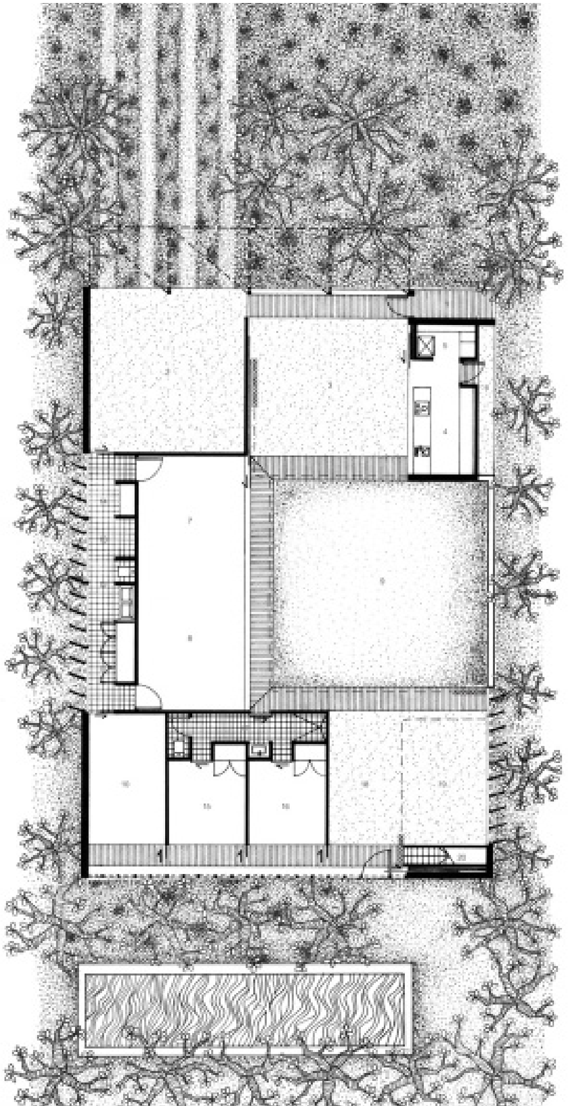
Image descriptions

Left: High thermal mass with reflective coating. Carport modulating solar transfer into courtyard. Dark colours on building facade not ideal for warm temperate climates unless coatings are used to add reflective properties.

Second top and bottom left: courtyard living with extensive openings for cross ventilation and daylighting. High thermal mass flooring with reflective coating and light interior colour finishes for reflective illumination.

Third left and right: Low thermal flooring and exposed skillion roofing for skylighting.

Class 1 | 2012 | Bisley Place



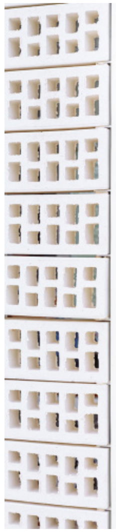
FLOOR PLAN

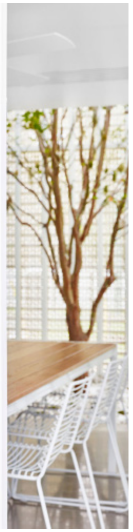
LEGEND

1. Entry
2. Car
3. Meals
4. Kitchen
5. Laundry & pantry
6. Drying
7. Dining
8. Lounge
9. Courtyard
10. Master bed
11. Robe
12. Ensuite
13. Shower
14. Study
15. Sleeping
17. Bathroom
18. Playroom
19. Sleep out
20. Stair to loft
21. Pool

URBAN STREETSCAPING

Class 1 | 2016 | Naranga Avenue





Project summary

Building type		Detached Dwelling (Urban, Bayside, Courtyard), Class 1
Location		Surfers Paradise, Gold Coast QLD
NCC Climate Zone		Zone 2 - Warm Humid Summer, Mild Winter
Build description		2-storey slab on ground, lightweight timber and steel frame, extruded claybrick facade and metal sheet roofing (gable roof)
Floor area		195m^2
Project team		James Russell Architect, James Davidson (owner builder), Josh Neale and Westera Partners (consultants)
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), cool materials , cross-ventilation (openings), spatial zoning, daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Evaporative cooling , heat sinks (slab on ground), cross-ventilation (aperturess), operable shading (thermal comfort), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), diffused glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes), low thermal mass
	Tier 4	Ceiling fans, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

● Relevant design/climate responsive strategies.

● Relevant with other strategies or more information needed.

● Not ideal

○ Data not available

Image descriptions

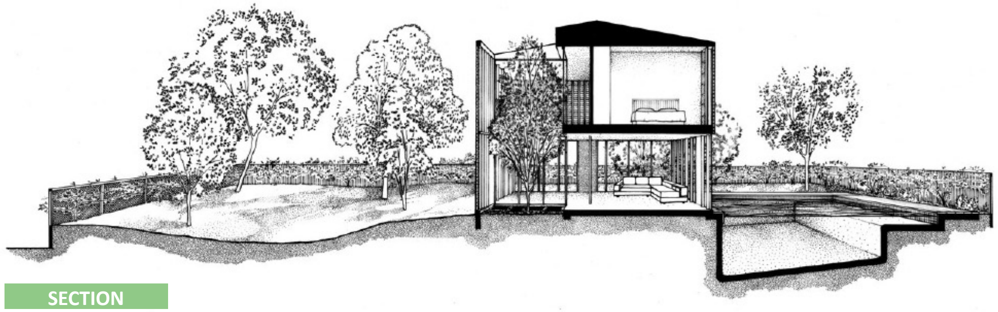
Left: Claybrick facade with extrusions to create low embodied energy and maximum cross ventilation. Strategic use of large deciduous trees to provide extensive shading and maximise prevailing winds.

Second top and bottom left: internal open courtyard and pool (located at rear) providing evapotranspiration for cooling. Light interior finishes for reflective illumination. Well shaded high thermal mass flooring for cooling with reflective coating.

Right: low thermal mass on upper floors with diffused and clear glazing and operable shading.

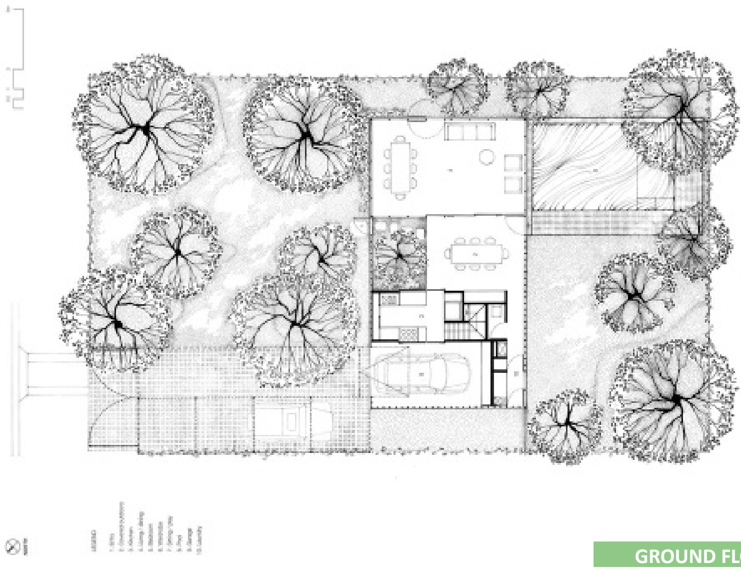
Information and images sourced from: https://www.archdaily.com/877186/naranga-avenue-house-james-russell-architect?ad_source=search&ad_medium=search_result_projects

Class 1 | 2016 | Naranga Avenue



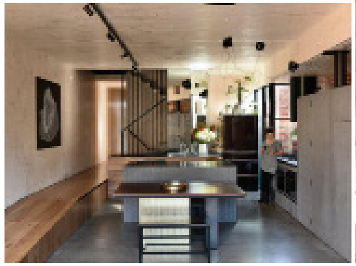
SECTION

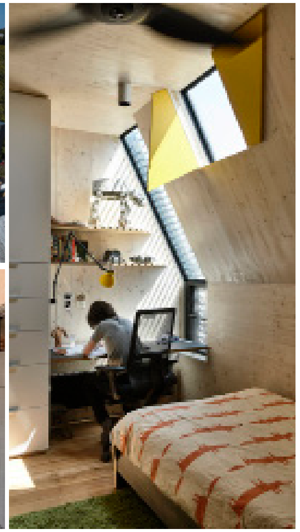
FIRST FLOOR

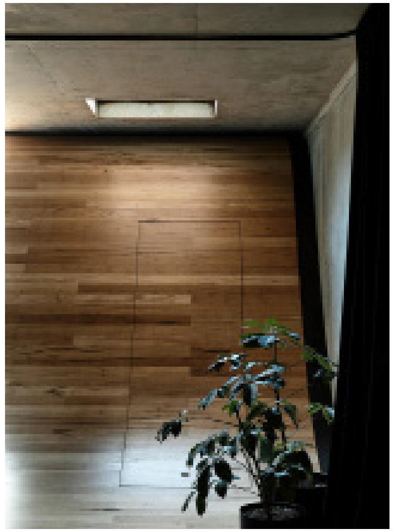


GROUND FLOOR

Class 1 | 2020 | Union House







Project summary

Building type		Detached dwelling (Zero Lot, Urban, Hertiage, New), Class 1
Location		Brunswick, Melbourne VIC
NCC Climate Zone		Zone 6 - Mild Temperate
Build description		2-storey concrete basement, CLT steel, concrete and brick (heritage) frame with metal cladding and green roof (dutch gable)
Floor area		285m²
Project team		Austin Maynard Architects, CBD Contracting (builder), Bush Projects (landscape), FytoGreen (green roof)
Design features	*Tier 1*	Solar gains (form orientation), thermal gains (urban interface), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form, urban interfacing (party walls, facade reinstated)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), solar absorption (exterior finishes), heat transfer (exterior materials), reflectances (exterior/interior finishes), lightweight materials, cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Direct gains (apertures), indirect gains (thermal mass), heat conservation (insulation), draught sealing, heat sinks (slab on ground), low thermal mass (upper floors), cross-ventilation (aperturess), colour rendering and exposure (daylighting), double glazing, glare control (operable shading), reflective illumination (wall and ceiling finishes), cool roofs (green roof)
	Tier 4	Ceiling fans, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟠	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟢	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment 🟠	Electric light ○

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ○ Data not available

Image descriptions

Left: victorian heritage facade reinstated.

Second left: High thermal mass materials situated close to earth to modulate thermal temperature. Extensive brick landscaping can cause overheating in warm temperate climates (green landscaping with deciduous trees would provide shading and cooling for high thermal mass.

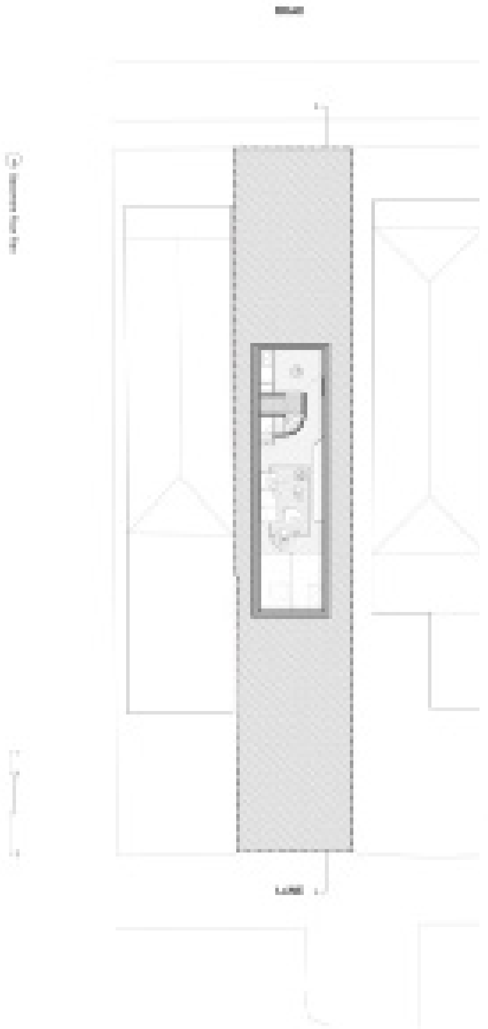
Third top left: green roof system ideal for evapotranspiration and cooling in warm climates.

Third bottom left: well shaded thermal mass can optimise passive cooling.

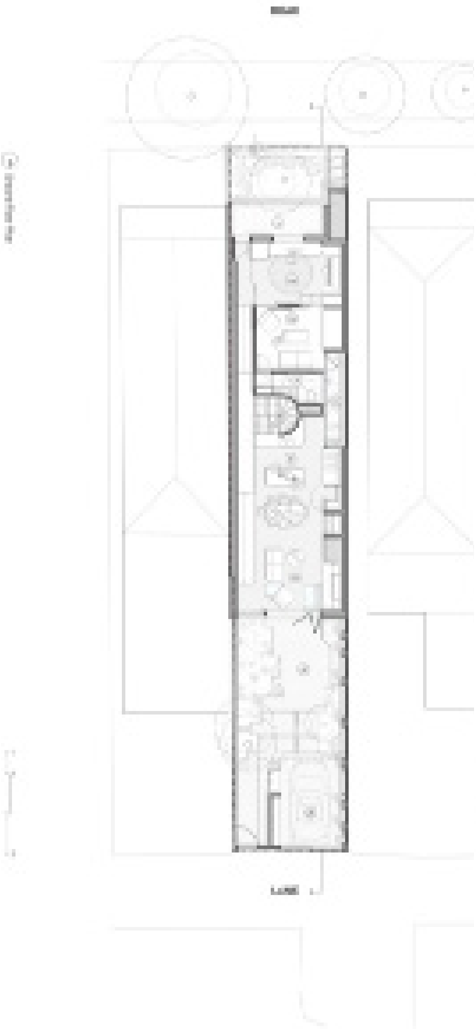
Fourth left and right: angled clerestories and skylights for deep passive lighting.

Information and images sourced from: **https://www.archdaily.com/949886/union-house-austin-maynard-architects**

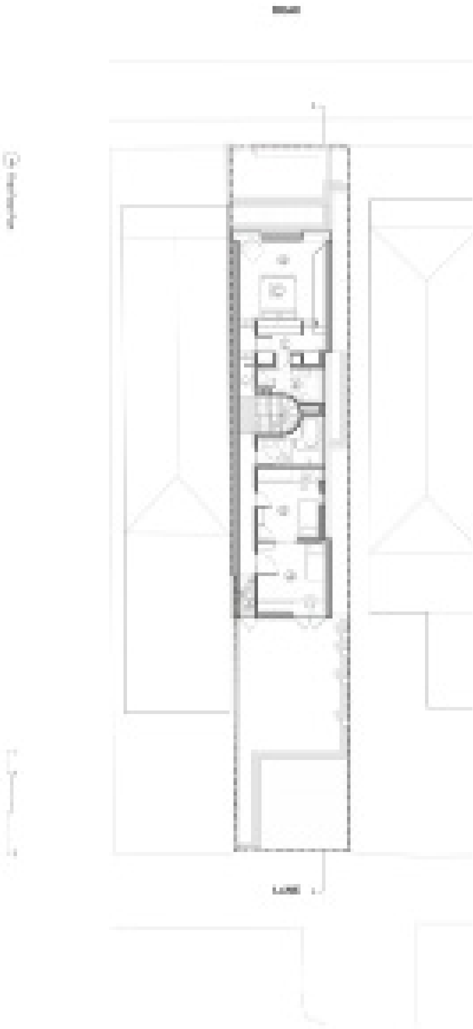
Class 1 | 2020 | Union House



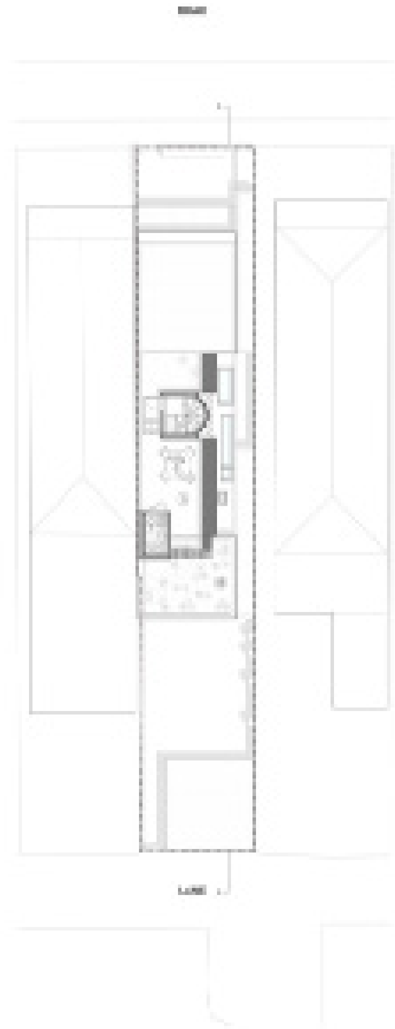
BASEMENT



GROUND

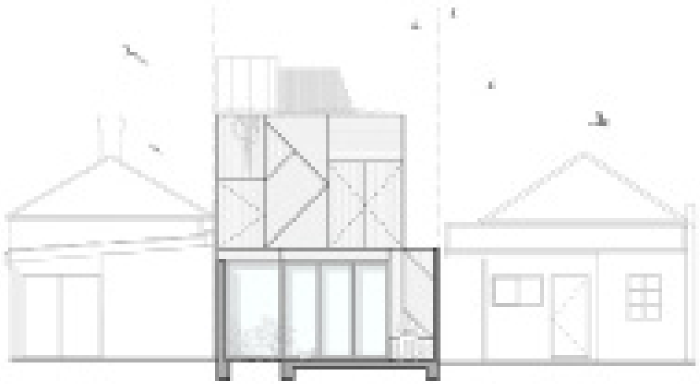


FIRST



ROOF

South Elevation (Front)



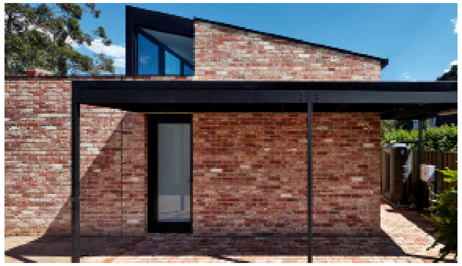
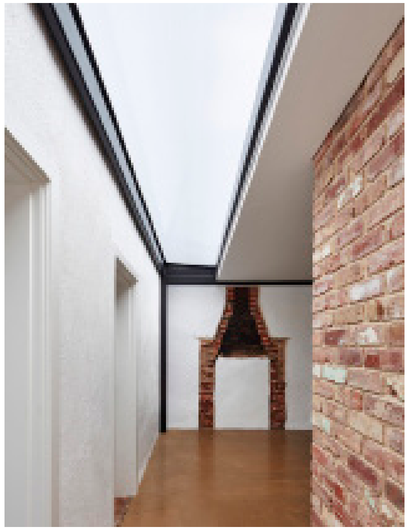
North Elevation (Rear)

Section A

1. Porch
2. Study
3. Sitting
4. Bathroom
5. Lightwell
6. Kitchen
7. Dining
8. Living
9. Rear Yard
10. Carport
11. Laundry
12. Rumpus
13. Bedroom
14. W.I.R.
15. Ensuite
16. Hall
17. Roof Deck
18. Roof Garden
19. Roof Storage

Class 1 | 2018 | Leahbrook Home




Project summary

Building type		Detached dwelling (Urban, Heritage, Renovation Extension), Class 1
Location		Leabrook, Adelaide SA
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-storey slab on ground (with sub-basement), brick and steel frame, metal roof sheeting (skillion, hip roof)
Floor area		265m²
Project team		Ply Architecture, Centric Construct
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees and neighbouring buildings), natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), heat ventilation (SVR), cross-ventilation (openings), spatial zoning, daylight access (apertures), daylight distribution (width and height)
	Tier 3	High thermal mass (cooling), colour rendering and exposure (daylighting), solar filtering (low-e glazing), reflective illumination (wall and ceiling finishes), fixed shading, deep daylighting (clerestories, diffused skylighting)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟢
Tier 3	Passive solar 🟢	Passive cooling 🟢	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

○ Data not available

Image descriptions

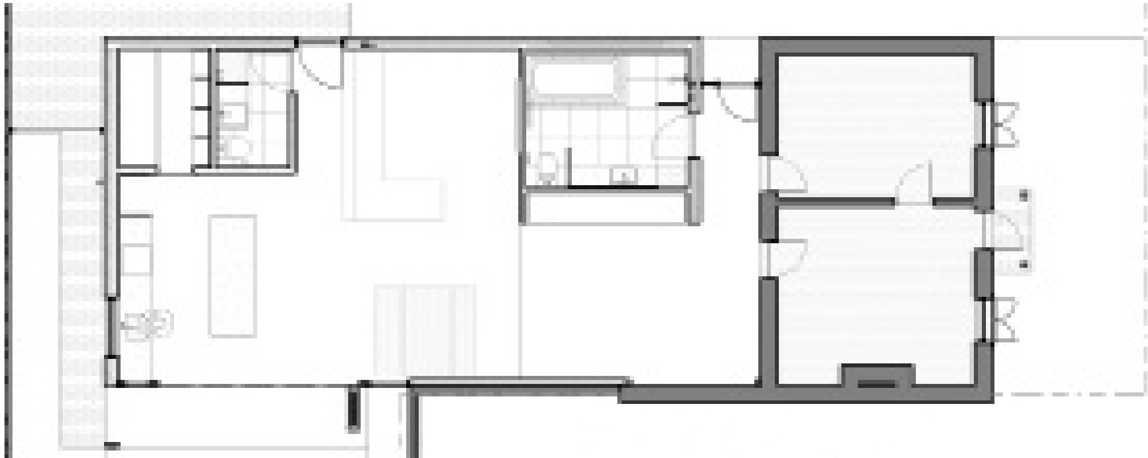
Left: Rear extension in south. Large openings and apertures for daylighting without solar heat gain.

Second top left and bottom: slab on ground with reflective coating for cooling. Reflective materials for fixed shading over high thermal mass facing west. However, green landscaping in unshaded areas preferable to minimise overheating.

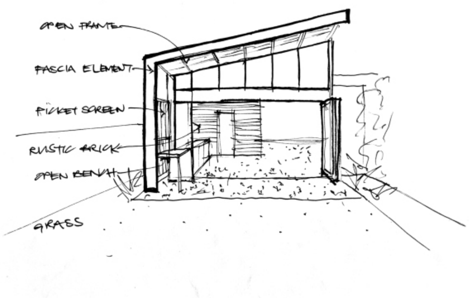
Third left and right: Thermal mass in shaded areas with diffused glazing to minimise heat gain. Clerestories, skylights and light colour finishes providing well distributed passive lighting and illumination.

Information and images sourced from: https://www.archdaily.com/900949/lbk-ply-architecture?ad_source=search&ad_medium=search_result_projects

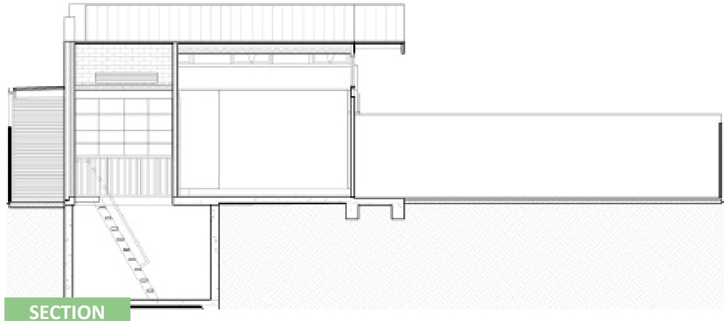
Class 1 | 2018 | Leahbrook Home



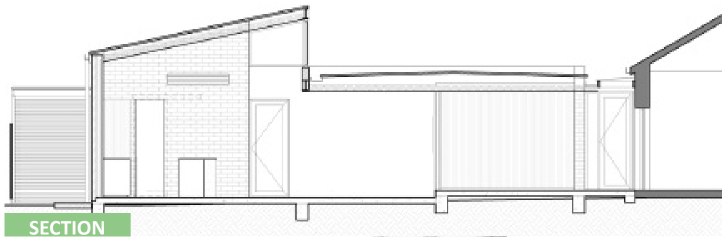
GROUND FLOOR EXTENSION



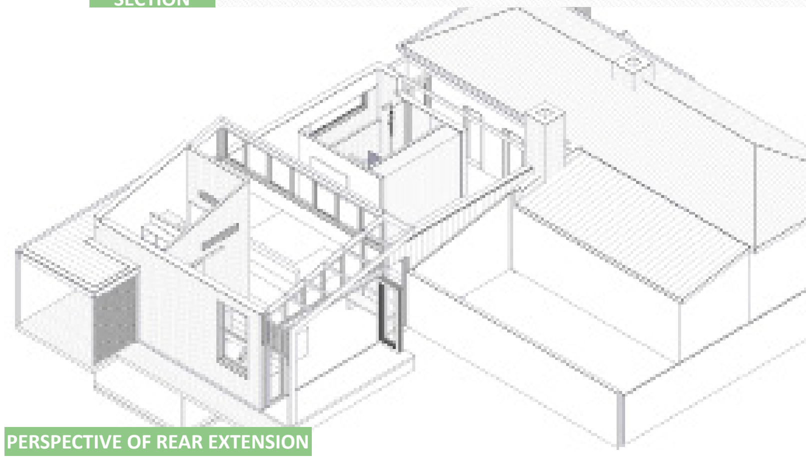
REAR ELEVATION SKETCH



SECTION



SECTION



PERSPECTIVE OF REAR EXTENSION

Class 1 | 2018 | Ballarat House

Project summary

Building type		Detached dwelling (Highlands, Urban, Subdivision), Class 1
Location		Ballarat, Melbourne VIC
NCC Climate Zone		Zone 6 - Cool Temperate
Build description		1-Storey slab on ground masonry and metal roof sheeting (skillion roof)
Floor area		200m^2
Project team		Eldridge Anderson Architects, P.J Yttrup & Associates (consultants)
Design features	*Tier 1*	Natural ventilation (building layout), daylight exposure (form orientation and layout), solar gains (form orientation), thermal gains (topography blending), cooling (urban interface)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), solar absorption (exterior finishes), cross-ventilation (openings), daylight access (apertures), daylight distribution (width and height), open-plan layout, outdoor living
	Tier 3	Direct gains (apertures), heat conservation (insulation), draught sealing, cross-ventilation (apertures), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), glare control (roof overhang), reflective illumination (wall and ceiling finishes), high thermal mass (direct gains)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟢
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟠
Tier 4	Heating equipment ⚪	Cooling equipment ⚪	Electric light ⚪

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

⚪ Data not available

Image descriptions

Left: Masonry veneer construction for high thermal mass, suitable for warm temperate with extensive shading to prevent overheating.

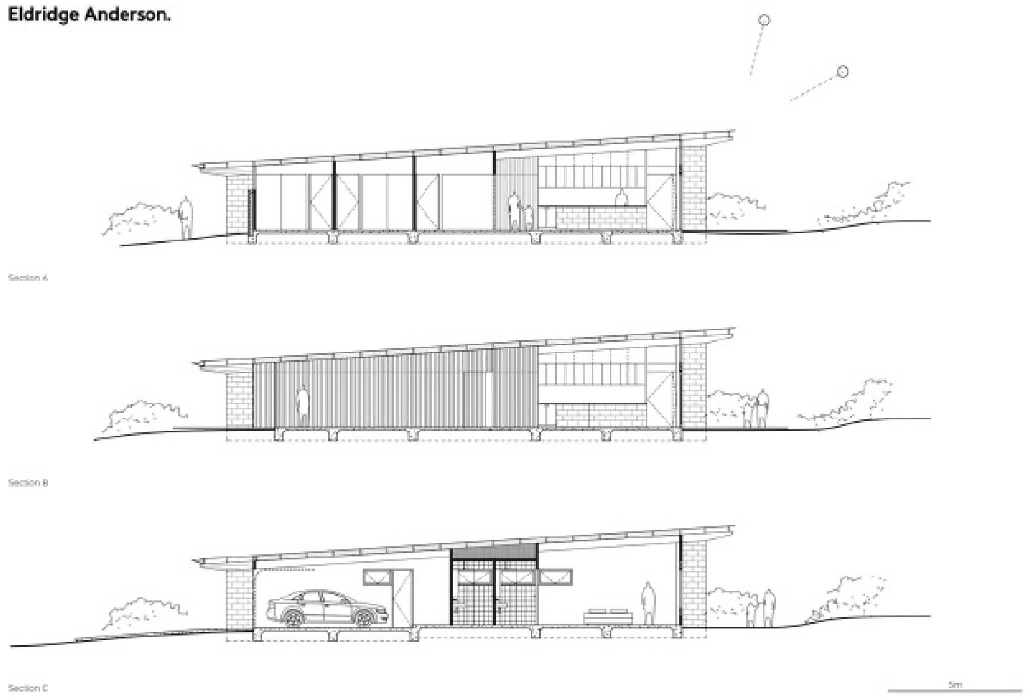
Second left: high ceiling with clerestories for heat ventilation. Light interior walls and ceiling for reflective illumination.

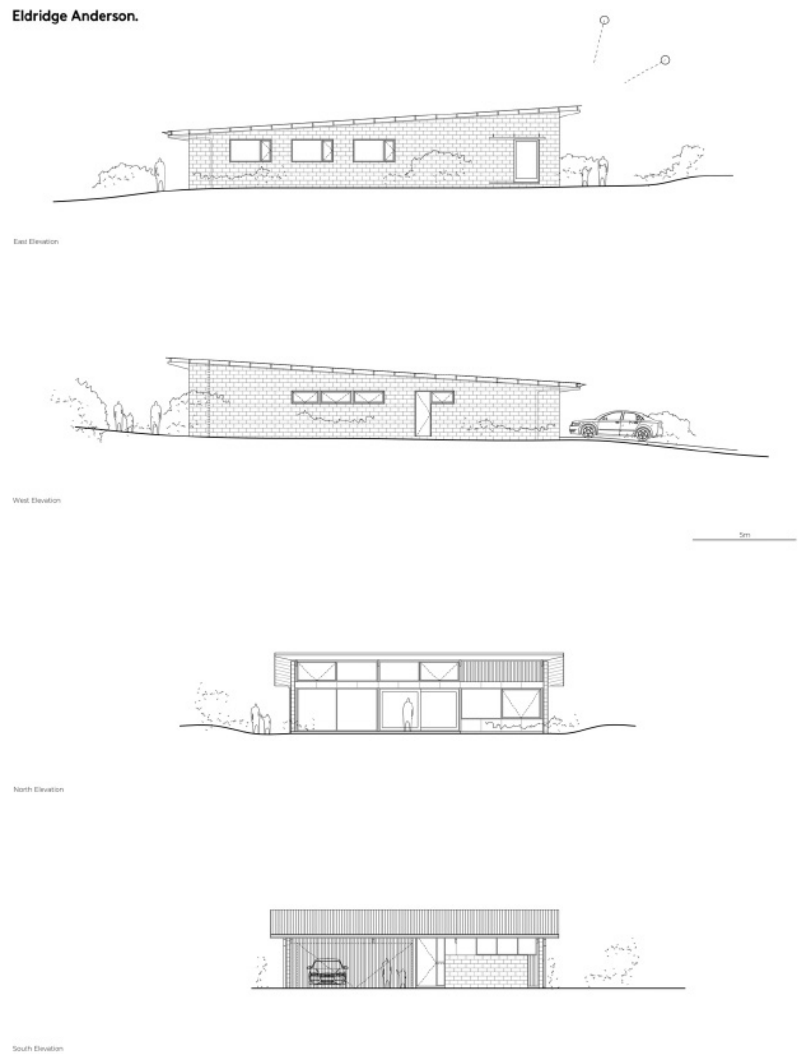
Third top/bottom left: Extensive fixed shading from roof overhang can cool thermal mass envelope and green landscaping for evapotranspiration.

Right: Operable venetian blinds for glare control and solar protection.

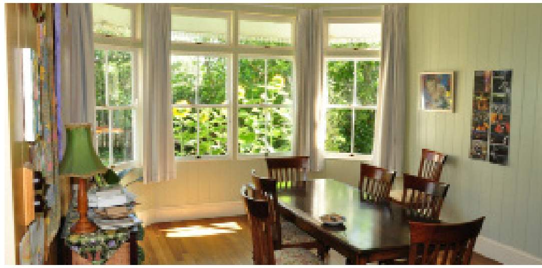
Information and images sourced from: **https://www.archdaily.com/936799/ballarat-house-eldridge-anderson-architects**

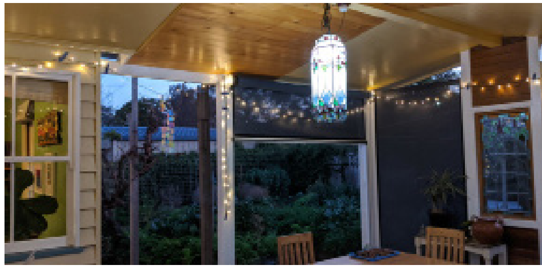
Class 1 | 2018 | Ballarat Home





Class 1 | NA | Old Toowoomba





Project summary

Building type		Detached dwelling (Urban, Renovation), Class 1
Location		Newtown, Toowoomba QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		1-Storey suspended timber floor, lightweight, timber cladding and aluminium roof sheeting (hip and valley)
Floor area		Data not available
Project team		Eco Blueprints (designer), Owner Builder, McNamara Builders, Kerry Morley (construction)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltration (openings), heat conservation (WWR), reflectances (exterior/interior finishes), lightweight materials, cross-ventilation (openings), spatial zoning, daylight access (apertures), traditional layout , outdoor living, reflective illumination (exterior/interior finishes)
	Tier 3	Direct gains (apertures), active heating (solar power), cross-ventilation (apertures), operable shading (thermal comfort), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), gap sealing
	Tier 4	Ceiling fans, Split air-conditioning, wood stove, efficient LED lighting

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ●	Cooling equipment ●	Electric light ●

Symbols

- ● (green) Relevant design/climate responsive strategies.
- ● (orange) Relevant with other strategies or more information needed.
- ● (red) Not ideal
- ○ Data not available

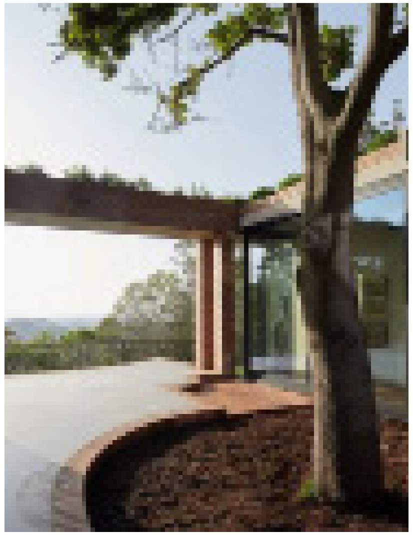
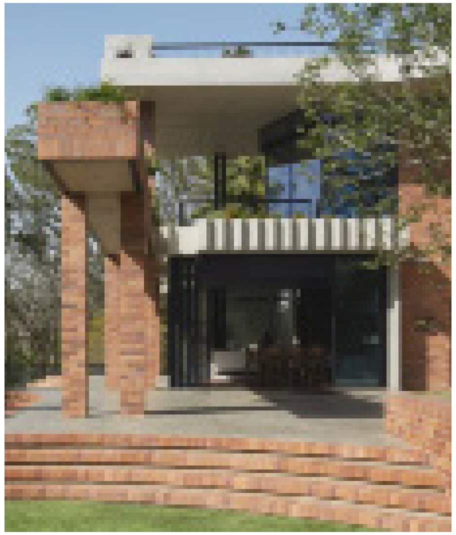
Image descriptions

Left, top and bottom middle: Renovatio mto 1900 home. Solar panels exports electricity to the grid. Fixed shading above windows added to block unwanted heat and direct sunlight in summer.

Top and bottom right: Living area extended towards solar north with operable shading for outdoor living areas.

Information and images sourced from: **https://sustainablehouseday.com/listing/120-year-old-toowoomba-house-upgrade/**

Class 1 | 2019 | Tjuringa House


Project summary

Building type		Detached dwelling (Rural, Renovation, Indigenous land), Class 1
Location		Toowoomba, QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-Storey slab on ground, brick veneer with concrete and euroclas zinc roofing
Floor area		723m²
Project team		Jesse Bennett Architect, Mark Ross Timber Homes (builder), Optimum Structures (engineer), Cloudlake Design (landscaping), Ashburner Francis (lighting designer)
Design features	*Tier 1*	Natural ventilation (building layout), daylight exposure (form orientation and layout)
	Tier 2	Solar infiltration (openings), solar absorption (exterior finishes), cool materials , daylight access (apertures), daylight distribution (width and height), high thermal mass (brick and clay pavements), colour rendering and reflective illumination (interior finishes)
	Tier 3	heat sinks (slab on ground), low-e glazing, cross-ventilation (aperturess), glare control (operable shading), evapotranspiration (vegetation, landscaping and swimming pool)
	Tier 4	Data not available

Analytical Design Framework

	Heating	**Cooling**	**Lighting**
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟠
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟠
Tier 4	Heating equipment ⚪	Cooling equipment ⚪	Electric light ⚪

Symbols

- 🟢 Relevant design/climate responsive strategies.
- 🟠 Relevant with other strategies or more information needed.
- 🔴 Not ideal
- ⚪ Data not available

Image descriptions

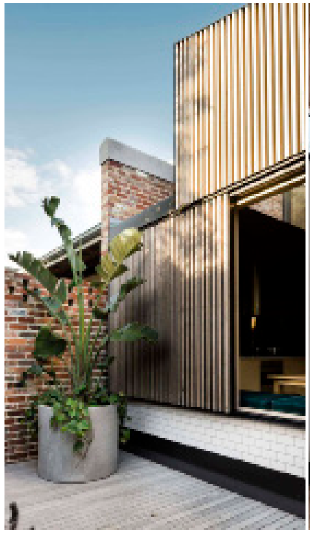
Far left:
Renovation of high thermal mass masonry and concrete construction with low-e glazing. Extensive shading required to reduce radiant heating from building envelope.

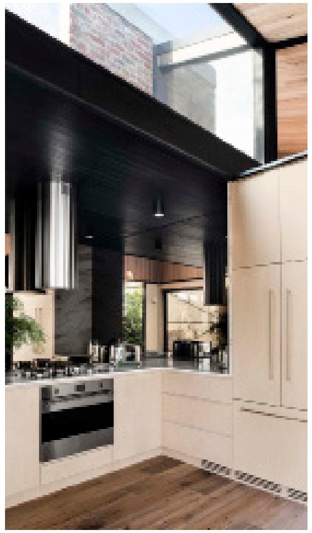
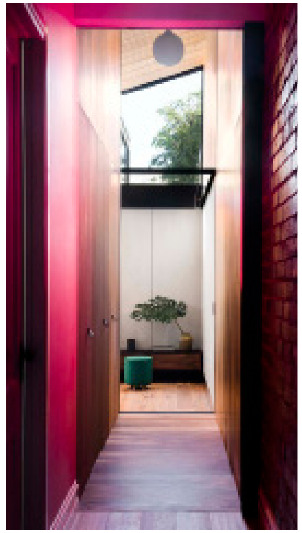
Second left: green planting on roofs reduces solar gains on thermal mass and provides evapotranspiration.

Third left and far right: extensive use of high thermal mass materials can create hot environments if shading strategies are not used to block solar gains.

Information and images sourced from: **https://architectureau.com/articles/tjuringa-house/**

Class 1 | 2017 | Light Corridor House

Project summary

Building type		Detached dwelling (Zero lot, Urban, Heritage facade, Cottage, Extension), Class 1
Location		Cremorne, Melbourne VIC
NCC Climate Zone		Zone 6 - Mild Temperate
Build description		1-storey suspended timber flooring, brick veneer and vertical timber slats (saw-tooth roof)
Floor area		$110m^2$
Project team		FIGR Architecture & Design ,Mud Office (landscaping), Grundella Constructions (builder), Meyer Consulting Engineers (engineer), Michel Group Building Surveyors (surveyors), Ruth Welsby (styling)
Design features	*Tier 1*	Solar gains (form orientation), daylight exposure (form orientation and layout), zero-lot, narrow form
	Tier 2	Solar infiltration (openings), reflectances (exterior/interior finishes), cool materials , lightweight materials, spatial zoning, daylight access (apertures), daylight distribution (width and height), outdoor living
	Tier 3	Heat conservation (insulation), double glazing, low-e glazing, draught sealing, lightweight materials, operable shading (thermal comfort), direct gains (apertures)
	Tier 4	Energy efficient lamps, data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🟢	Protection 🟢	Solar patterns 🟢
Tier 2	Conservation 🟢	Heat avoidance 🟠	Daylight 🟢
Tier 3	Passive solar 🟢	Passive cooling 🟠	Daylighting 🟢
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light 🟢

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

○ Data not available

Image descriptions

First and second left: Vertical timber slats used for daylighting and low thermal mass. Sawtooth roofs can utilise clerestories to permeate daylighting deep into indoor spaces and offsetting electrical lighting. Outdoor space with shading and vegetation cools down outdoor and indoor spaces (especially where adjacent buildings have high thermal mass).

Third, fourth left and far right: Clerestories for deep daylighting with light colours and low thermal mass (the orientation of clerestories important for warm temperate climates, to prevent overheating - shading would be required).

Information and images sourced from: **https://www.archdaily.com/888013/light-corridor-house-figr-architecture-and-design**

Class 1 | 2018 | Lacuna House





Project summary

Building type		Detached dwelling (Urban, Renovation, Extension), Class 1
Location		Willoughy, NSW (Cammeraygal Land)
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-Storey slab on ground, brick veneer, clay tiles and metal roof shetting (gable and skillion roof)
Floor area		260m^2
Project team		Bijl Architects, Space Landscape Design (landscaping), Cantilever Consulting Engineers (engineers), Partridge Hydraulic (consultants), Driftwood Joinery (collaborators)
Design features	*Tier 1*	Daylight exposure (form orientation and layout), relocating living areas to south (due to poor planning)
	Tier 2	Solar infiltration (openings), solar absorption (exterior finishes), heat transfer (exterior materials), spatial zoning, daylight access (apertures), daylight distribution (width and height), traditional layout , outdoor living
	Tier 3	Evapotranspiration (green landscaping), colour rendering and exposure (daylighting), cross-ventilation (apertures), operable shading (thermal comfort), glare control (operable shading), reflective illumination (wall and ceiling finishes)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending 🔴	Protection 🔴	Solar patterns 🔴
Tier 2	Conservation 🟠	Heat avoidance 🟠	Daylight 🟠
Tier 3	Passive solar 🟠	Passive cooling 🟠	Daylighting 🟠
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

🟢 Relevant design/climate responsive strategies.

🟠 Relevant with other strategies or more information needed.

🔴 Not ideal

○ Data not available

Image descriptions

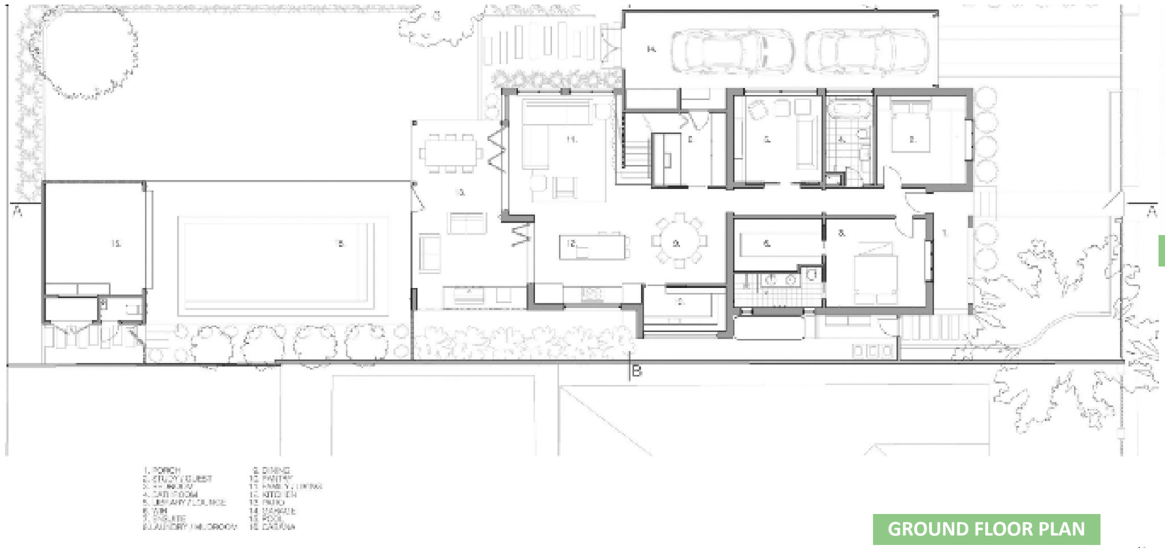
First and second left:
Front view of the existing home with extension added to south rear of the home to relocate living areas to create a liveable environment caused by poor orientation and planning.

Top and bottom third left:
Large operable windows with shading to reduce direct heat gains and allow cross-ventilation.

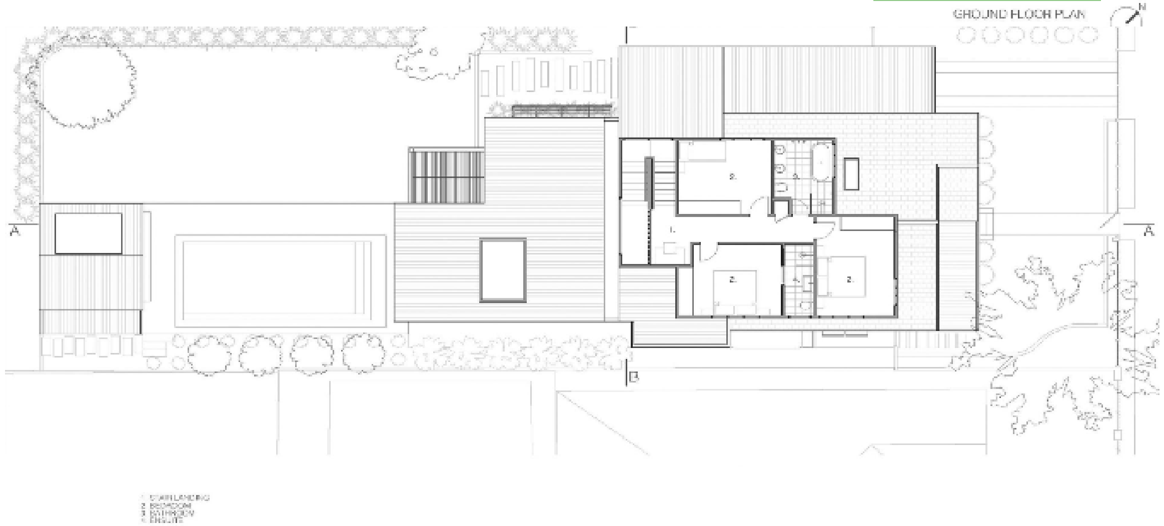
Far right: outdoor living using lightweight construction.

Information and images sourced from: https://www.archdaily.com/925352/lacuna-house-bijl-architecture?ad_source=search&ad_medium=search_result_projects

Class 1 | 2018 | Lacuna House



GROUND FLOOR PLAN



FIRST FLOOR PLAN

LONG SECTION

SHORT SECTION

REAR ELEVATION

Class 1 | 2017 | Aquas Perma Solar Firma House

Project summary

Building type		Detached dwelling (Urban, Urban Farming, Zero lot, Terrace), Class 1
Location		Alexandria, Sydney NSW
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-Storey slab on ground, lightweight construction with masonry party walls
Floor area		110m^2
Project team		CPlusC Architectural Workshop
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), courtyard form, zero-lot
	Tier 2	Solar absorption (exterior finishes), reflectances (exterior/interior finishes), lightweight materials, cool materials , cross-ventilation (openings), lightweight materials, spatial zoning, daylight access (apertures), daylight distribution (width and height), daylight access (apertures), daylight distribution (width and height), open-plan layout
	Tier 3	Active heating (solar power), active cooling (solar power), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), glare control (operable shading), reflective illumination (wall and ceiling finishes), electric lighting (solar power), central skylights
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending	Protection	Solar patterns
	Green	Green	Green
Tier 2	Conservation	Heat avoidance	Daylight
	Green	Green	Green
Tier 3	Passive solar	Passive cooling	Daylighting
	Green	Green	Green
Tier 4	Heating equipment	Cooling equipment	Electric light
	Orange	Orange	Orange

Symbols

- (Green) Relevant design/climate responsive strategies.
- (Orange) Relevant with other strategies or more information needed.
- (Red) Not ideal
- (White) Data not available

Image descriptions

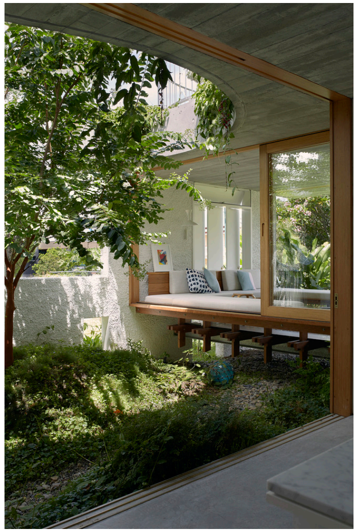
First, second and third top and bottom left: low and high thermal mass materials with operable shading and large openings to permeate daylighting on zero lots, with internal courtyard to increase evapotranspiration (cooling effect on masonary party wall).

Fourth top and bottom left and far right: combining low and high thermal mass with reflective colours to reduce solar gains and operable shading for control of air-flow and daylighting. Outdoor vegetation and shading increases cooling effects in summer.

Information and images sourced from: **https://www.archdaily.com/923086/aquas-perma-solar-firma-cplusc-architectural-workshop?ad_source=search&ad_medium=search_result_projects**
https://homeworlddesign.com/alexandria-house-aqua-perma-solar-firma-cplusc/

Class 1 | 2016 | Gibbon Street





Project summary

Building type		Detached dwelling (Urban, Narrow lot, Renovation extension), Class 1
Location		New Farm, Brisbane QLD
NCC Climate Zone		Zone 5 - Warm Temperate
Build description		2-Storey timber frame construction with concrete extension (rear)
Floor area		265 m^2
Project team		Cavill Architects, Dan Young (landscape), Westera Partners (landscape consultant)
Design features	*Tier 1*	Solar gains (form orientation), solar shading (existing deciduous trees), natural ventilation (building layout), daylight exposure (form orientation and layout), narrow form
	Tier 2	Solar infiltration (openings), cool materials , cross-ventilation (openings), spatial zoning, daylight access (apertures), outdoor living
	Tier 3	Cross-ventilation (aperturess), colour rendering and exposure (daylighting), natural shading (deciduous trees), evapotranspiration (green landscaping), colour rendering and exposure (daylighting), reflective illumination (wall and ceiling finishes)
	Tier 4	Data not available

Analytical Design Framework

	Heating	Cooling	Lighting
Tier 1	Blending ●	Protection ●	Solar patterns ●
Tier 2	Conservation ●	Heat avoidance ●	Daylight ●
Tier 3	Passive solar ●	Passive cooling ●	Daylighting ●
Tier 4	Heating equipment ○	Cooling equipment ○	Electric light ○

Symbols

● Relevant design/climate responsive strategies.

● Relevant with other strategies or more information needed.

● Not ideal

○ Data not available

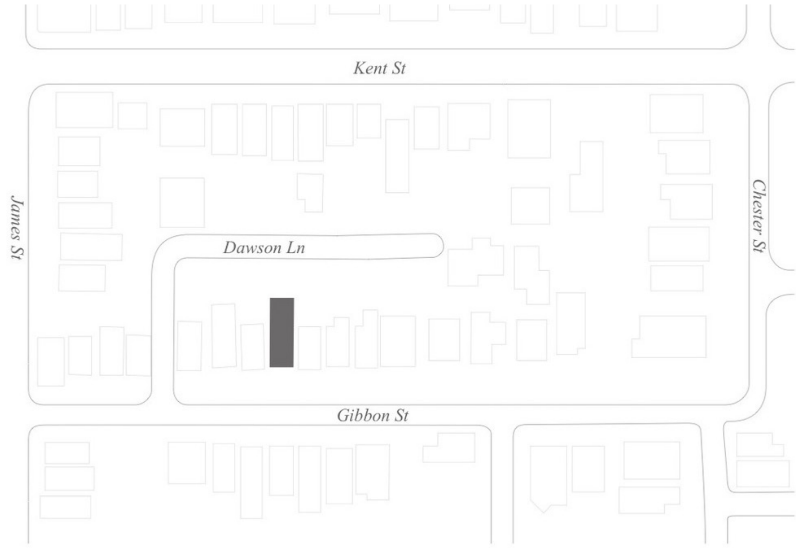
Image descriptions

First left: Renovation to an existing Queenslander house, retaining existing features and building structure.

Other images: using high thermal mass in areas that can be well-shaded can significantly cool down the building in summer, with vegetation and trees for evapotranspiration where dirunal ranges are low. Light colours for reflective illumination and large openings for air-flow and cross ventilation. Great example of combining indoor and outdoors spaces for warm temperate climates and high thermal mass.

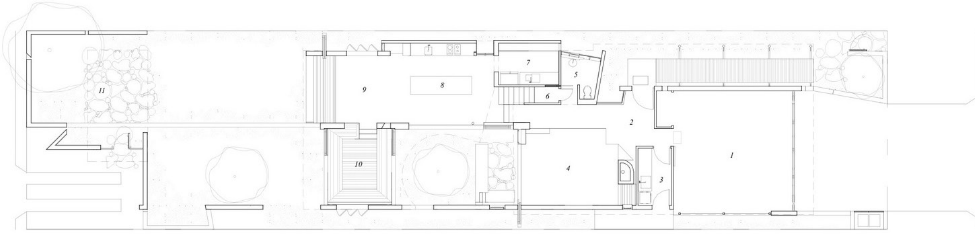
Information and images sourced from: **https://www.archdaily.com/903083/gibbon-street-cavill-architects/5bb36842f197c-c49e2000274-gibbon-street-cavill-architects-photo?next_project=no**

Class 1 | 2016 | Gibbon Street



Site Plan 1:4000

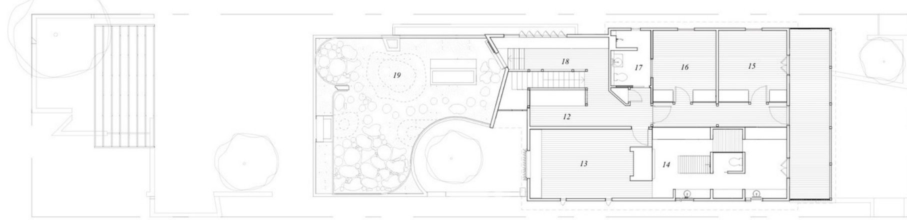
0 200 m



Ground Floor Plan 1:200

0 10 m

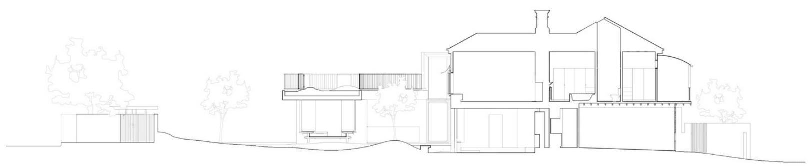
1. Garage
2. Entry
3. Laundry
4. Living
5. Powder Room
6. Store
7. Pantry
8. Kitchen
9. Dining
10. Sitting Room
11. Arbour



First Floor Plan 1:200

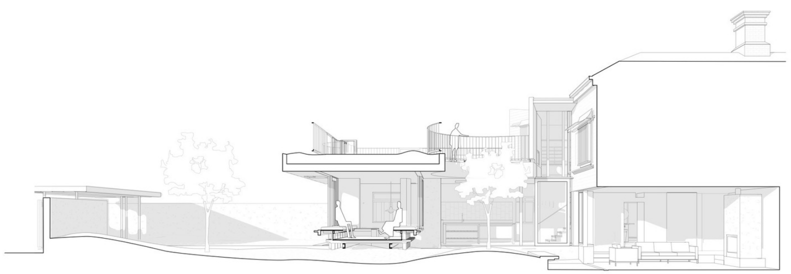
0 10 m

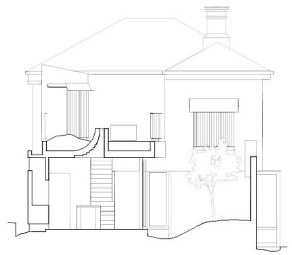
12. TV Room
13. Master Bed
14. Ensuite
15. Bed 1
16. Bed 2
17. Bathroom
18. Study
19. Rooftop Garden



Cross Section 1:200

0 10 m





Cross Section 1:200

0 10 m