Design for climate

Design for climate requires that homes be designed or modified to ensure that the occupants remain thermally comfortable with minimal auxiliary heating or cooling in the climate where they are built. Passive design — working with the climate, not against it — is an important component, as are energy efficient heating and cooling systems, and smart behaviour by the occupants.

Approximately 40% of household energy is used for heating and cooling to achieve thermal comfort. This rate could be cut to almost zero in new housing through sound climate responsive design and, indeed, should be our aspirational goal. Taking into account current consumer preferences and industry practices, halving the rate to 20% is a highly achievable in the short term.

The 40% of household energy used for heating and cooling to achieve thermal comfort could be cut to almost zero in new housing through sound climate responsive design.

Reducing or eliminating heating and cooling needs in existing homes is a significant challenge, particularly those designed and built before building energy efficiency standards were introduced, when appliances were effective but inefficient. Based on 1.5% annual renewal rates, at least 50% of our current housing stock will still be in service in 30 years' time.

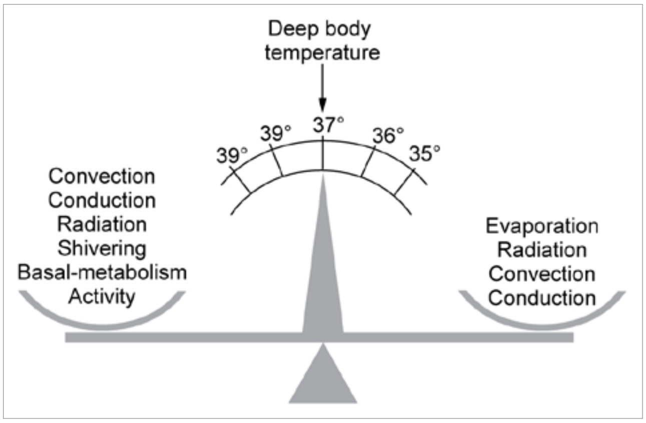
New homes built now will be in service in future times when we expect to see significant changes in the climate. Designing for today's climate is important; ensuring that those designs can be just as efficient after 30 years of climate change would certainly be desirable.

Affordability is often cited as the main barrier to greater efficiency but increasing energy costs are rapidly shifting the affordability focus from initial or upfront cost to ongoing or operational cost. With this shift, high levels of thermal performance are becoming increasingly valuable and the payback or amortisation period for thermal performance upgrades is diminishing rapidly.

This introductory overview of key design objectives and responses to creating thermally comfortable homes in each main climate zone in Australia needs to be further refined and customised to your individual site, locality and design brief. Use this overview, and the references to other articles, to access more detailed information as you proceed through the various stages of designing, purchasing or altering your home.

Human thermal comfort

Humans are comfortable only within a very narrow range of conditions. Our body temperature is about 37°C, despite the fact that the body generates heat even while at rest: we must lose heat at the same rate it is produced and gain heat at the same rate it is lost. The diagram below shows the various ways by which our bodies achieve this.



Source: Steve Szokolay

Human thermal comfort has two components: psychological and physiological. Both are governed by the processes in the diagram but reach the brain and trigger responses by very different pathways. Both needs must be met before we feel truly comfortable.

The main factors influencing both physical and psychological human comfort are:

- temperature
- humidity
- air movement (breeze or draught)
- exposure to radiant heat sources
- exposure to cool surfaces to radiate, or conduct to, for cooling.

Thermal simulation software can model with great accuracy the amount of heating or cooling energy required to achieve physiological comfort; it is unable to model highly variable human perceptions of comfort. Sound building envelope design based on modelling delivers an environment that addresses all the physical factors necessary for comfort (except humidity) but can't always meet our psychological comfort needs.

Important triggers for psychological discomfort are radiation, air movement and conduction. Although they are less effective physiologically, they trigger innate self-preservation responses that override our ability to perceive physical comfort. Until they are met, we don't feel thermally comfortable and our behaviour can render the best of design solutions ineffective. Acclimatisation is a critical component of psychological comfort.

Psychological thermal discomfort can make us set the thermostat on heating or cooling systems well beyond levels required for comfort. For every 1°C change in thermostat setting, it is estimated that our heating or cooling bill rises by around 10%. In other words, failure to address psychological comfort can increase heating and cooling energy use by up to 50% (Australian Greenhouse Office 2005).

Losing body heat

We lose heat in three ways: through evaporation, radiation and conduction.

Our most effective cooling method is the evaporation of perspiration. High humidity levels reduce evaporation rates. When relative humidity exceeds 60%, our ability to cool is greatly reduced.

> *Evaporation rates are influenced by air movement. Generally, a breeze of 0.5 m per second provides a one-off comfort benefit equivalent to a 3°C temperature reduction.*

We also lose heat by radiating to surfaces cooler than our body temperature, such as tiled concrete floors cooled by night breezes or earth coupling. The greater the temperature difference, the more we radiate. While not our main means of losing heat, radiation rates are very important to our psychological perception of comfort.

A third way to lose heat is conduction, i.e. through body contact with cooler surfaces such as when going for a swim or sleeping on an unheated waterbed. Conduction is most effective when we are inactive (e.g. sleeping) and is a particularly important component of psychological comfort.

Gaining body heat

When the heat produced by our bodies is insufficient to maintain body temperature, we shiver. This generates body heat and has a short-term physiological effect but also triggers our deepest psychological discomfort warning mechanisms. Our first response is generally to insulate ourselves by putting on more clothes and sheltering from wind and draughts. These actions are effective because we generate most of the heat we require from within, and reducing heat loss makes body heat more effective. Our minds quickly decide whether the adjustment is adequate for thermal comfort.

A secondary source of heat gain is radiation. As with cooling, radiation is very important to our perception of comfort. For example, we can feel cold in a room that is a comfortable 22°C if there is a cold window nearby; conversely, we can feel warm at 0°C if we are well insulated with warm clothing and standing in the sun.

The final source of heat gain is conduction. Simply holding someone's hand can create psychological thermal comfort though a small amount of conduction. We conduct to cool floors and from heated floors. Heated floors also provide radiant heat and raise air temperatures through conduction and convection.

Building thermal comfort

The Nationwide House Energy Rating Scheme (NatHERS) uses computer simulations to assess the potential thermal comfort of Australian homes on a scale of zero to 10 stars. The more stars, the less heating or cooling energy is likely to be required to keep the occupants comfortable. The computer simulations take into account standard occupancy patterns, climate, season and envelope design but not psychological comfort.

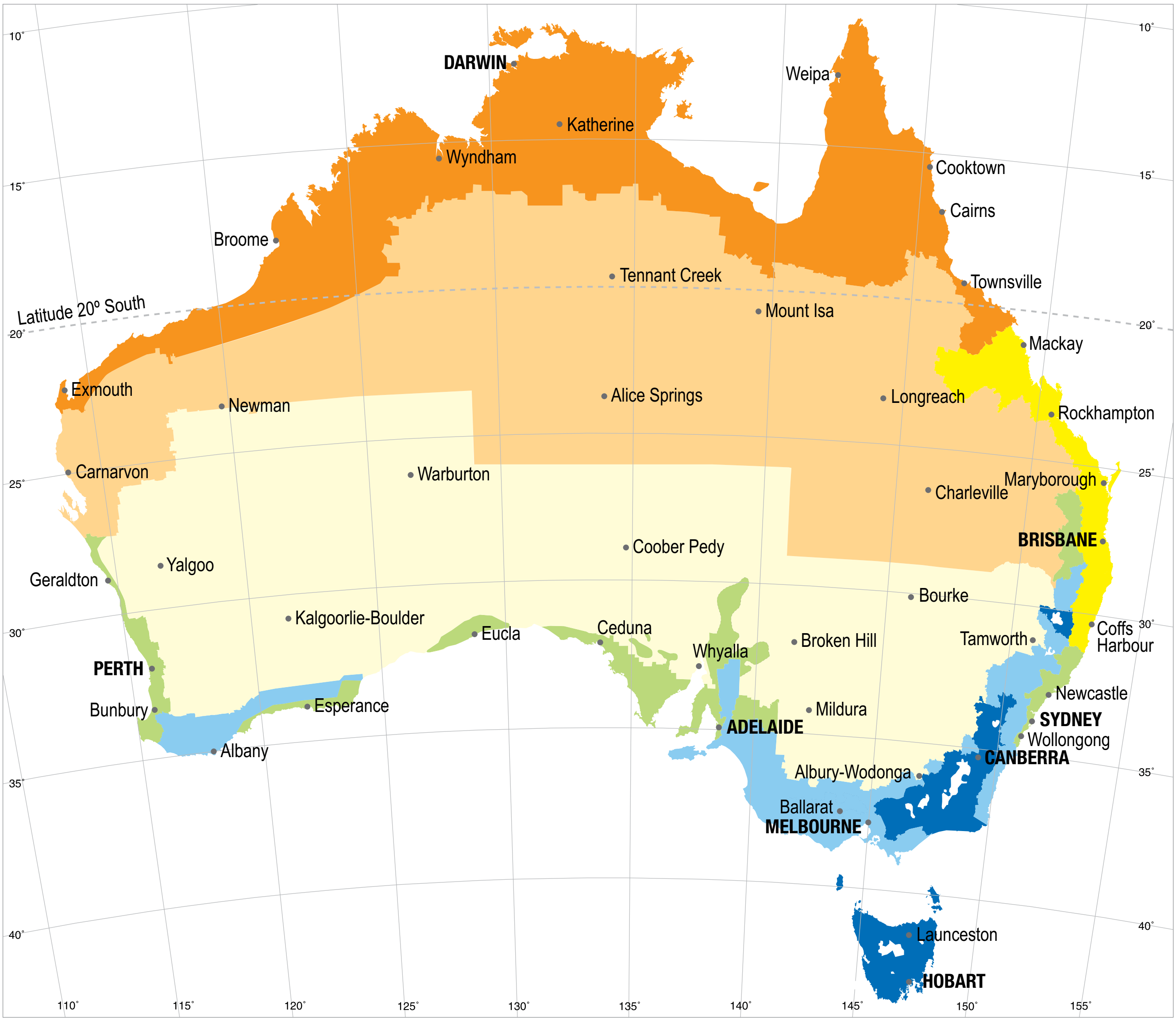
A thermal comfort rating reveals only the energy performance of a building's design and fabric: it does not measure other areas of energy consumption (e.g. appliance efficiency, transport costs, embodied energy). In warmer climates, these variables can account for more energy consumption during the life span of a home than the performance of the envelope. The rating is also based on the combined heating and cooling energy required over a year, but the proportions of heating and cooling required varies across climate zones. For that reason, both heating and cooling options are addressed in the overviews of climate responsive design strategies below.

Australian climate zones

The eight climate zones used in *Your Home* are defined by the Building Code of Australia (BCA). Each climate zone has distinctly different design and construction requirements. Within each main zone are many regional sub-zones determined by local geographic features including wind patterns and height above sea level. NatHERS identifies 69 of these sub-zones, which the BCA addresses and which can be called up by postcode.

Climate change is likely to alter the characteristics of each zone during the life span of homes currently being built or renovated.

Zone	Description
1	Hot humid summer, warm winter
2	Warm humid summer, mild winter
3	Hot dry summer, warm winter
4	Hot dry summer, cool winter
5	Warm temperate
6	Mild temperate
7	Cool temperate
8	Alpine



Source: Australian Building Codes Board

Australian climate zones.

Zone 1: Hot humid summer, warm winter

Main characteristics

High humidity with a degree of 'dry season'

Moderate to high temperatures year round

Low to moderate seasonal temperature variation

Minimal diurnal (day–night) temperature range

Key design objectives

Homes in these climates use substantially more energy to achieve thermal comfort than homes with the same NatHERS star rating in more benign climates. It is therefore imperative to use design strategies that reduce cooling energy use to achieve similar carbon reductions. For example, a 6 star house in Darwin uses more than double the energy of a 1 star house in Brisbane, and a 9 star house in Wyndham (WA Kimberley region) uses about the same as the Brisbane 1 star house.

One of three distinctly different design approaches should be chosen at the outset of the design process. Each produces a very different solution that is often difficult to change in the future.

- **Free running**: These buildings should not be conditioned (mechanically heated or cooled). Abundant air movement from fans, whirlybird ventilators, stack ventilation and cross-ventilation is essential.
- **Conditioned**: These buildings must be well insulated and able to be made airtight while conditioning is running. Both inward and outward condensation issues should be addressed.
- **Hybrid design**: These buildings include air conditioned, insulated core rooms in the centre of the house (e.g. a TV room) for peak discomfort periods, surrounded by free running spaces.

Unconditioned sleeping comfort is a critical design consideration in both conditioned and hybrid design approaches.

Key responses

Design considerations

- Orientate the building to take full advantage of cooling breezes, and position landscaping and outbuildings to funnel breezes over, under and through the building (see *Orientation* and *Passive cooling*).
- Prioritise design for night-time sleeping comfort. Consider sleep-out spaces.
- Provide shaded outdoor living areas.
- Locate pools and spas on the northern side of the building where they are shaded in the hot humid season and warmed during the dry season.
- Install ceiling fans in all rooms.

Windows and shading

- Shade all windows and walls, including south facing, with extended eaves where possible or vertical shading where not.
- Use low solar heat gain coefficient (SHGC) glazing (see *Glazing*).
- Use multiple layers of reflective roof and ceiling insulation to create a one-way valve effect.
- Insulate internal wall surfaces well from any external thermal mass (e.g. brick veneer).
- Exclude solar radiation from roof, windows and walls (see *Shading*).
- Consider shading the whole building with a fly roof (see *Passive cooling*).

Insulation

- Refer to *Insulation* for appropriate insulation levels in each climate zone.
- Avoid bulk insulation to ceilings and walls except in conditioned spaces.
- Ventilate roof spaces well with fans or whirlybirds and design for condensation removal (see *Passive cooling*).
- Insulate elevated floors with reflective, closed-cell bulk insulation to resist upward heat flow and condensation.
- Line open ventilated spaces with reflective foil insulation.

In conditioned buildings

- Avoid overuse of glazing.
- Use the highest energy rated conditioning appliances and install smart control systems and a variable output speed compressor to maximise efficiency (see *Heating and cooling*).
- Condition only critical rooms in preference to the entire house.
- Design air conditioned spaces to be sealed off, preventing loss of cooling when running.
- Design to accommodate both inward and outward condensation (wherever humid warm air first meets a cooler surface).

- Use low U-value glazing to avoid ambient or conducted heat gain or cooling loss (see *Glazing*).
- Provide ceiling fans in conditioned spaces — they provide effective cooling when conditioning lowers humidity.
- Use internal thermal mass walls surrounding conditioned central cores for radiant cooling of adjoining unconditioned sleeping spaces.

In free running buildings

- Encourage natural air flow with large, high level openings.
- Use only 100% openable windows such as louvre or casement.
- Locate sleeping spaces in lower levels.
- Use low or no thermal mass finishes in sleeping spaces to prevent radiant heat at bed-time.
- Maximise external wall areas (plans with one room depth are ideal) to encourage cross-ventilation.
- Elevate building to permit air flow beneath floors.

Construction systems

- Use lightweight (low mass) construction (see *Thermal mass*).
- Use light coloured reflective materials externally.
- Design and build for cyclonic conditions.

Zone 2: Warm humid summer, mild winter

Main characteristics

High humidity with a definite 'dry season'

Hot to very hot summers with mild winters

Distinct summer/winter seasons

Moderate to low diurnal (day–night) temperature range, which can vary significantly between regions (e.g. inland to coastal)

Key design objectives

Eliminate auxiliary heating and substantially reduce cooling with appropriate passive design.

Key responses

Design considerations

- Always site for exposure to cooling breezes and design for cross-ventilation.
- Use thinner plans and design openings to encourage movement of breezes through and within the building (see *Passive cooling*).
- Always design for night-time sleeping comfort.
- Provide screened and shaded outdoor living areas.

Windows and shading

- Avoid overuse of glazing.
- Use low SHGC glazing in all cases and low U-value glazing in regions with cooler winters or hotter summers (see *Glazing*).
- Shade all east and west-facing walls and glass year round (see *Shading*).
- Shade south-facing walls north of the tropic of Capricorn.
- Use appropriate levels of passive shaded north-facing glass as heating requirements increase in more southerly and inland regions.
- Use 100% openable windows area such as louvre or casement.

Insulation

- In areas where no winter heating is required, use multiple layers of reflective foil in ceiling/roof to create a one-way valve effect.
- Insulate internal wall surfaces from any external thermal mass (e.g. brick veneer).

- Refer to *Insulation* for recommended minimum insulation levels.
- Use highly breathable reflective vapour barriers in walls and add bulk insulation to rooms that are air conditioned.
- Use roof spaces to provide heat loss/gain buffer zones by ventilating them in summer and sealing them in winter with fans or 'smart' ventilators (see *Passive cooling*).
- Line open ventilated spaces with reflective foil insulation and design to remove condensation.
- Avoid installing bulk insulation in ceilings and walls unless winter heating is used.

Heating and cooling

- Avoid auxiliary heating as it is unnecessary with good design.
- Check typical heating/cooling requirements in the local area to determine appropriate passive heating levels (consult your local thermal performance expert).
- Provide ceiling fans in all living and sleeping spaces.
- Use high energy rated cooling appliances in selected rooms if this is required.

Construction systems

- Where summer ground temperatures exceed 19°C at 3m depth, use elevated lightweight floors.
- Consider using earth coupled slabs in all areas where deep ground temperatures are less than 19°C in summer.
- Use lightweight wall construction where day–night temperature ranges are low and add thermal mass as these ranges exceed 6°C.
- Choose light coloured roof and wall materials.

Zone 3: Hot dry summer, warm winter

Main characteristics

Distinct wet and dry seasons

Low rainfall and low to moderate humidity

No extreme cold but can be cool in winter

Hot to very hot summers common

Significant day–night temperature range

Key design objectives

This climate zone has high heating and cooling energy requirements but the task of reducing them through passive design is relatively straightforward and cost effective due to low humidity, high solar incidence and high day–night temperature ranges.

Use well-insulated thermal mass to even out temperature ranges with night purging in summer and passive solar heating in winter. On difficult sites, try to take advantage of clear night skies and high solar incidence.

Key responses

Design considerations

- Use high levels of well-insulated thermal mass.
- Select site for exposure to cooling breezes; design for cross-ventilation and night purging (see *Passive cooling*).
- Use north-facing, high thermal mass living areas with passive solar access (see *Passive solar heating*).
- Limit external wall area.
- Consider compact floor plans with central, closable stack ventilation shafts or solar chimneys.
- Consider mechanical ventilation of ceiling spaces to ensure high level flows of cooler (south-side) air in summer and a complete seal in winter.
- Provide screened, shaded outdoor living areas that allow winter sun penetration.
- Use garden ponds and water features to provide evaporative cooling.

Windows and shading

- Avoid overuse of glazing.
- Use low U-value glazing in all cases (see *Glazing*).
- Use double glazing in regions with cooler winters.

- Use low SHGC glazing in regions with hot summers and mild winters.
- Shade all east and west-facing glass in summer (see *Shading*).
- Shade south-facing glass north of the tropic of Capricorn.

Insulation

- Use bulk **and** reflective insulation in ceilings, and bulk **or** reflective insulation in walls.
- Provide external insulation to all thermal mass.
- Insulate under concrete slabs if using in-slab heating.
- Insulate elevated floors (lightweight or concrete).
- Refer to *Insulation* for recommended minimum insulation levels.
- Ensure all spaces are effectively air sealed.

Heating and cooling

- Use evaporative cooling and passive solar heating in living areas.
- Provide ceiling fans in all living and sleeping spaces.
- In more extreme regions consider active solar heating and reverse night cooling connected to in-slab hydronic systems.
- Check typical heating and cooling requirements in the local area to determine appropriate passive heating levels (consult your local thermal performance expert).

Construction systems

- Use high thermal mass construction.
- Where summer ground temperatures exceed 19°C at 3m depth, use insulated concrete slabs or insulated elevated lightweight floors with high thermal mass walls.
- Consider using earth coupled slabs in all areas where deep ground temperatures are less than 19°C in summer.
- Choose light coloured roof materials.

Zone 4: Hot dry summer, cool winter

Main characteristics

Distinct seasons with low humidity all year round

High diurnal (day–night) temperature range

Low rainfall

Very hot summers common with hot, dry winds

Cool winters with cold dry winds

Key design objectives

Well-designed passive solar heating and cooling are equally important. Application of sound passive design principles can achieve cost effective 8 star or better thermal performance in this climate zone. High thermal mass solutions are particularly effective.

Active solar heating and cooling systems are well suited to sunny winters and clear summer night skies, and will also provide flexible thermal comfort solutions for future climate change.

Key responses

Design considerations

- Use high levels of well-insulated thermal mass.
- Use north-facing, high thermal mass living areas with passive solar access (see *Passive solar heating*).
- Select a site exposed to cooling breezes, and design to exclude adverse winds while allowing for cross-ventilation and night purging (see *Passive cooling*).
- Design to capture cool air drainage on still nights (cool air flows in similar patterns to water as surface temperatures drop due to night sky radiation).
- Limit external wall area.
- Choose compact floor plans with central, closable stack ventilation shafts or solar chimneys.
- Consider central courtyards with evaporative cooling water features to allow night cooling with wind protection.
- Use mechanical ventilation in ceiling spaces to ensure high level flows of cooler (south-side) air in summer and a complete seal in winter.
- Provide screened, shaded outdoor living areas that allow winter sun penetration.
- Use garden ponds and water features outside windows to provide evaporative cooling.

Windows and shading

- Avoid overuse of glazing.
- Use different glazing types for each façade; low U-value glazing is essential in all cases.
- Double glaze living areas and consider using it in bedrooms.
- For north-facing windows select high SHGC glazing and passive shading.
- For east and west façades select low SHGC coatings (e.g. low-e).
- South-facing glass should have low U-value and high visible light transmittance.
- Thermally improved or insulated frames (timber or PVC) are important.
- Passive solar shading to northerly windows is critical.
- Shade all east and west glass in summer (see *Shading*).
- Consider adjustable shading to allow variable solar access in spring and autumn.

Insulation

- Refer to *Insulation* for appropriate insulation levels in each climate zone and recommended minimum insulation levels.
- Use bulk **and** reflective insulation in ceilings, and bulk **or** reflective insulation in walls.
- Provide external insulation to all thermal mass.
- Insulate under concrete slabs if using in-slab heating.
- Insulate elevated floors (concrete or lightweight).
- Ensure all spaces are effectively air sealed.

Heating and cooling

- Use evaporative cooling and passive solar heating in living areas.
- Provide ceiling fans in all living and sleeping spaces.
- Consider active solar heating and reverse night cooling connected to in-slab hydronic systems in more extreme regions.
- Check typical heating and cooling requirements in the local area to determine appropriate passive heating levels (consult your local thermal performance expert).

Construction systems

- Prefer high thermal mass construction.
- Use earth coupled slabs.
- Choose light coloured roof materials.

Zone 5: Warm temperate

Main characteristics

Moderate diurnal (day–night) temperature range near coast to high diurnal range inland

Four distinct seasons: summer and winter can exceed human comfort range; spring and autumn are ideal for human comfort

Mild winters with low humidity

Hot to very hot summers with low to moderate humidity

Widely variable solar access and cooling breeze directions and patterns

Key design objectives

This is an atypical zone in that it includes a more diverse range of climatic conditions than other zones. This diversity is particularly evident in the hours of sunlight, and direction and reliability of cool breezes.

For example, the Illawarra escarpment in NSW receives less sunshine than the coastal suburbs of Perth. Newcastle has very different cool breeze patterns and seasonal humidity variations to Adelaide; Perth is distinctly different to both these cities in terms of humidity and breezes. Waterfront properties in Sydney have very different thermal mass requirements to those in SA's wine-growing regions owing to Sydney's oceanic temperature stabilisation, diurnal ranges and cool breezes.

For this reason, pay careful attention to the 69 sub-zones in NatHERS to decide the best design responses for your site and compare them with those in adjoining zones (4 or 6) that may have more closely matching micro-climate variations.

Key responses

Because these climates require relatively simple design considerations to achieve 8–10 star NatHERS ratings (zero heating and cooling energy use), this climate zone offers the most cost effective opportunities to achieve carbon zero or positive outcomes. Additionally, as a significant proportion of the Australian population lives in this climate zone, there is also the opportunity to achieve significant carbon emission reductions.

Minimising heating and cooling energy use should be a primary design objective.

Passive design

Design for climate

Design considerations

- Careful, individual site analysis is needed to identify conditions that call for specific design adjustments.
- In all sub-zones, passive solar heating and cooling are important.
- Different approaches are required for passive cooling depending on the patterns and reliability of cool breezes.
- To reduce heat gain, avoid inappropriate or overuse of glazing.
- Passive solar heating is always desirable and simply achieved where access to adequate sunlight is available. Where solar access is not available, consider using lightweight building frames that respond quickly and efficiently to minimal, carbon efficient auxiliary heating.
- Lower thermal mass requirements allow for low embodied energy solutions.
- Use roof spaces as a thermal buffer zone by ventilating them in summer and sealing them in winter.

Windows and shading

- Avoid overuse of glazing.
- Carefully size and orientate windows, as this will often yield ideal results with less expensive glazing options.
- Reduce expenditure on glazing and divert the savings to efficient appliances and on-site renewable energy generation, generating effective carbon reductions.
- Use passive solar shading on northerly windows.
- Shade all east and west-facing glass in summer (see *Shading*).
- Consider adjustable shading to allow variable solar access in spring and autumn.

Insulation

- Use bulk **and** reflective insulation in ceilings, and bulk **or** reflective insulation in walls.
- Insulate under concrete slabs if using in-slab heating.
- Provide external insulation to all thermal mass.
- Insulate elevated floors (concrete and lightweight)
- Refer to *Insulation* for recommended optimal insulation levels.
- Ensure all spaces are effectively air sealed.

Heating and cooling

- No auxiliary heating or cooling is required.
- Include ceiling fans in all living and sleeping spaces.

Construction systems

- Earth coupled slabs are highly beneficial.
- Choose low embodied energy walls, roofing and finishes.
- Composite thermal mass construction is ideal although most well-designed construction systems can achieve 10 star performance at relatively low cost.
- Choose light coloured roof materials.

Zone 6: Mild temperate

Main characteristics

Low day–night temperature range near coast, high range inland

Four distinct seasons: summer and winter exceed human comfort range; spring and autumn are ideal for human comfort

Mild to cool winters with low humidity

Hot to very hot summers, moderate humidity

Key design objectives

These climates present cost effective opportunities to achieve carbon zero or positive outcomes because they require relatively simple design adjustments to achieve low or zero heating and cooling energy use (NatHERS ratings of 8–10 star).

Minimising heating and cooling energy use should be a primary design objective.

Key responses

Design considerations

- Individual site analysis and location within the region will determine whether heating or cooling is the predominant need (see *Choosing a site*).
- Reducing heat gain though appropriate use of windows and glazing (size, location and type) is a critical design consideration (see *Glazing*).
- Cooling comfort is simply achieved with adequate cross-ventilation and minimising solar and ambient heat gains with shading and insulation (see *Passive cooling*).
- Passive solar heating is essential and simply achieved where solar access is available (see *Passive solar heating*).
- Minimise external wall areas (especially east and west-facing).
- Use convective ventilation and heat circulation.
- Use appropriate glass to mass ratios, as outlined in *Thermal mass*.
- Lower thermal mass requirements allow for low embodied energy solutions.
- Sites with solar access require north-facing living areas with majority of glazing.
- Where solar access is unavailable, lightweight solutions that respond quickly and efficiently to minimal, carbon-efficient auxiliary heating are a viable alternative.
- Roof spaces create a thermal buffer zone to summer heat gain (ventilated) and winter heat loss (sealed). Use thermostat controlled fans or closable ventilators.

Windows and shading

- Avoid overuse of glazing.
- Carefully size and orientate windows, as this will often yield ideal results with less expensive glazing options.
- Use high SHGC and low U-value glazing.
- Consider double glazing in regions with higher heating needs.
- Always use snug fitting drapes with pelmets.
- Reduce expenditure on glazing and divert the savings to efficient appliances and on-site renewable energy generation, generating effective carbon reductions.
- Use passive solar shading on northerly windows.
- Minimise and shade all east and west-facing glass in summer (see *Shading*).
- Consider adjustable shading to allow variable solar access in spring and autumn.

Insulation

- Use bulk **and** reflective insulation in ceilings, and bulk **or** reflective insulation in walls.
- Insulate all thermal mass externally.
- Refer to *Insulation* for recommended optimal insulation levels.
- Insulate under concrete slabs if using in-slab heating.
- Insulate elevated floors (concrete and lightweight)
- Seal thoroughly against draughts and use entry airlocks.

Heating and cooling

- No auxiliary heating or cooling should be required.
- Ceiling fans should be included in all living and sleeping spaces.
- Earth coupled slabs maintain comfortable summer temperatures that can easily be raised by passive solar heating in winter.

Construction systems

- Earth coupled slabs are highly beneficial (see *Concrete slab floors*).
- High thermal mass walls can be used if within glass to mass ratios (see *Thermal mass*).
- Choose low embodied energy walls, roofing and finishes.

- Composite thermal mass construction is ideal although most well-designed construction systems can achieve 10 star performance in this zone.
- Choose light coloured roof materials.
- Calculate thermal lag in high thermal mass walls such as rammed earth or mud brick to determine appropriate insulation levels.

Zone 7: Cool temperate

Main characteristics

Low humidity, high diurnal (day–night) temperature range

Four distinct seasons: summer and winter exceed human comfort range; highly variable spring and autumn conditions (range increasing with climate change)

Cold to very cold winters with majority of rainfall (decreasing with climate change)

Hot dry summers (increasing with climate change)

Key design objectives

Homes in these climates use substantially more energy to achieve thermal comfort than homes with the same NatHERS star rating in more benign climates. An 8 star or better level of thermal performance is required to achieve life cycle carbon reductions equivalent to other zones.

Designers often include large north-facing windows to maximise solar gains in these climates, which can make double glazing very expensive. However, double glazing is recommended in this climate because on each winter's day there are 19–20 hours of heat loss through glass with a maximum of 4–5 hours of heat gain. The glass to mass ratios in *Thermal mass* indicate appropriate glazing levels in relation to exposed thermal mass. Exceeding these ratios can lower thermal performance and increase initial and operational costs.

Key responses

Design considerations

- Apply best practice passive solar design principles where access to sunlight permits. Use high glass to mass ratios.
- Consider climate change when choosing type, location and quantity of thermal mass.
- Maximise the use of north-facing walls and passively shaded glazing.
- Locate living areas on the north, bedrooms and service areas on the south.
- Minimise external wall areas, especially east and west.
- Use cross-ventilation and night-time cooling in summer.
- Avoid high ceilings and provide airlocks between lower and upper floors.

- Design for controllable (zoned) convective air movement throughout the house to distribute heat while minimising draughts and temperature stratification.
- Site new homes for solar access, exposure to cooling breezes and protection from cold winds.
- Where passive solar access is unavailable, minimise all glass areas and limit thermal mass except where exposed to heating sources.
- Design furniture layouts to minimise exposure to convection draughts.
- Ventilate roof spaces in summer and seal them in winter (use automated fans or closable roof ventilators).
- Install carbon efficient auxiliary heating.
- Use renewable energy sources.

(see also *Passive solar heating*; *Passive cooling*; *Thermal mass*; *Orientation*; *Renewable energy*)

Windows and shading

- Avoid overuse of glazing.
- Careful sizing and orientation of windows is essential.
- Use high SHGC, low U-value double glazing.
- Specify insulating or thermally improved frames.
- Design and detail for preventing window condensation.
- Passive solar shading to northerly windows is essential.
- Minimise and shade all east and west-facing glass in summer (see *Shading*).
- Consider using adjustable shading to some west-facing glass areas to boost afternoon solar heat gains in winter and allow variable solar access in spring and autumn.

Insulation

- Use bulk insulation in walls, ceilings and exposed floors.
- Use heavy drapes with sealed pelmets to insulate glass in winter.
- For walls use bulk insulation with highly breathable sarking or multiple layers of reflective foil insulation, with detailed design to ensure condensation discharge.
- Insulate all thermal mass externally (including rammed earth and mud brick).
- Use high levels of bulk insulation in ceilings and line underside of roofing material with down-facing reflective foil.
- Use closed cell reflective insulation in preference to compressed bulk insulation where supplier recommends an anti-condensation layer under roof material.
- Insulate all elevated floors (concrete and lightweight).
- Insulate slab edges.
- Insulate under concrete slabs if using in-slab heating.
- Provide airlocks to entries.
- Effectively air seal all spaces (see *Sealing your home*).
- Refer to *Insulation* for recommended optimal insulation levels.

Heating and cooling

- Even 10 star homes in the more extreme regions of these climates might require some auxiliary heating for psychological comfort.
- Lower rated homes will require heating.
- High level passive or active solar heating is highly desirable where available.
- Well-designed active solar energy systems with substantial heat storage capacity or an efficient heat pump (ground, water or air source) are the most carbon efficient (see *Heating and cooling*).
- Wood heating, although it is carbon neutral, has negative health and biodiversity impacts and should be avoided in built-up areas.
- Well-positioned, adequately heated thermal mass will provide sufficient thermal comfort in bedrooms (sleeping comfort is less of an issue in cool or cold climates).
- Cooling is unnecessary with good cross or closable ventilation and ceiling fans in living and sleeping spaces.

Construction systems

- Earth coupled slabs are beneficial except where 3m earth temperatures are below 16°C in winter (e.g. Tasmania). Insulate under the slab or use insulated, lightweight floors in these regions.
- Use low thermal mass walls on sites with no solar access.
- Use lightweight wall construction where diurnal temperature ranges are low (e.g. Hobart) and increase thermal mass and solar exposed glass as they increase above 6°C.
- Choose light coloured roof materials.

Zone 8: Alpine

Main characteristics

Low humidity, high diurnal temperature range

Four distinct seasons: winter exceeds human comfort range and will likely continue to do so under climate change

Cold to very cold winters providing majority of rainfall; some snow

Warm to hot, dry summers; highly variable spring and autumn conditions

Key design objectives

Homes in these climates have the highest thermal comfort energy use of any climate zone. For example, a 6 star house in Cabramurra uses more than double the energy of a 1 star house in Sydney's eastern suburbs and around the same energy as a 3 star house in Canberra.

Therefore, an 8 star or better thermal performance is imperative to match the life cycle carbon reductions of other zones. Because the need for cooling is low, design strategies can focus on heating energy use.

Key responses

Design considerations

- Apply best practice passive solar design principles where solar access is available.
- Use highest glass to mass ratios.
- Consider not building on sites without good access to sunlight.
- Maximise north-facing walls and passively shaded double glazing.
- Locate living areas on north; bedrooms and service areas on south.
- Consider multi-level designs that allow sunlight into all rooms while maintaining a compact form.
- Minimise external wall areas, especially east and west.
- Ensure the interior is airtight and consider a heat-recovery ventilation system.
- Opening windows usually provides adequate ventilation and night-time cooling in summer.
- Avoid high ceilings and provide airlocks between lower and upper floors.
- Design for controllable (zoned) convective air movement throughout the house to distribute heat while minimising draughts and temperature stratification.
- Site new homes for optimum access to sunlight and protection from cold winds.
- Design furniture layouts to minimise exposure to convection draughts and maximise exposure to radiant heat.
- Seal roof spaces.
- Install carbon efficient auxiliary heating.
- Use off-site renewable energy sources like GreenPower to compensate for snow related inefficiencies and maintenance.

(see also *Passive solar heating; Thermal mass; Orientation; Heating and cooling; Renewable energy*)

Windows and shading

- Use high SHGC, lowest U-value double glazing.
- Avoid overuse of glazing.
- Careful sizing and orientation of windows is essential.
- Specify thermally improved or insulated frames (timber or PVC).
- Design and detail for high levels of window condensation
- Minimise and shade all east and west-facing glass in summer (see *Shading*).
- Consider using adjustable shading on west-facing glass areas to boost afternoon solar heat gains and allow variable solar access in spring and autumn.
- Avoid east-facing glazing where fog limits winter solar gains but long periods of heat loss prevail.

Insulation

- Refer to *Insulation* for recommended optimal insulation levels.
- Bulk insulate all walls, ceilings and exposed floors.
- Consider using 150mm or 200mm deep studs to achieve higher rating wall insulation.
- Use additional layers of insulation fixed to frames to reduce thermal bridging.
- Detail and specify insulation provisions carefully and supervise installation.
- Use heavy drapes with sealed pelmets to insulate glass in winter.
- Consider double drapes or tight fitting airtight blinds behind drapes.
- Externally insulate all thermal mass to high levels, especially rammed earth and mud brick.
- Use highest levels of bulk insulation in ceilings.

- Line underside of roofing material with downward-facing, closed cell, foil-coated bulk insulation to avoid loss of R-value through compression.
- Insulate all elevated floors (concrete and lightweight) to highest level.
- Insulate slab edges and under concrete slabs.
- Provide airlocks to entries.
- Ensure all spaces are effectively air sealed (see *Sealing your home*).

Heating and cooling

- All homes in this zone require auxiliary heating for both physiological and psychological comfort.
- As heating is a major cost in these climates, the additional cost of 10 star design is quickly recouped.
- High level passive or active solar heating is essential for reducing auxiliary heating and creating psychological comfort.
- Well-designed active solar energy systems with substantial heat storage capacity or an efficient heat pump (ground or water source) are the most carbon efficient (see *Heating and cooling*).
- Wood heating, although it is carbon neutral, has negative health and biodiversity impacts and should be avoided in built-up areas.
- Consider highly insulated first floor bedrooms that are heated by convection and conduction from ground floor heating.

Construction systems

- Insulate under slabs or use highly insulated, lightweight floors in these regions.
- Use highly insulated, low thermal mass walls in rooms with no exposure to direct sunlight.
- Choose dark coloured roof and wall materials.

References and additional reading

Contact your state, territory or local government for further information on passive design considerations for your climate. See www.gov.au

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