Case studies
Darwin River, Northern Territory

This home demonstrates an impressive range of passive cooling design principles in a challenging tropical climate, creating a comfortable, responsive and low maintenance home with minimal environmental impacts.

The construction technique uses low thermal mass and highly reflective materials. Built to last and to be resource independent, it has also been designed to adapt to the changing needs of its occupants.

Site, location and climate
Darwin River is a largely wooded rural suburb some 65km south-east of Darwin. The 80 hectare block is almost entirely uncleared open eucalypt woodland and is a registered Land for Wildlife property. As the Darwin River runs through the eastern end of the block, up to two-thirds of the block is river floodplain and becomes seasonally inundated. The house is sited in the western half of the block, away from the river, on the highest point to make the most of seasonal winds: south-easterlies in the dry and north-westerlies in the wet. The site chosen is also above the highest expected flood level. An unsealed access road connects the site with Darwin River Road, where only electrical services are available: there are no sewerage or gas services to the site. The nearest neighbour is 0.5km away.

The Top End’s tropical climate has high humid summers and warm winters, with mean maximum temperatures of 32°C and a mean minimum of 23.2°C. In the wet season, from November to April, mean January rainfall is 423.8mm; in the dry season, from May to October, rainfall drops to 1.2mm in July. During the wet season the region is prone to cyclone activity, heavy monsoonal downpours and flooding. The fire season occurs during the dry, from late autumn through to late spring.

Design brief
The couple wanted a modestly sized, two-bedroom home with generous living spaces and a ‘look-out’ space to watch for wildlife and fires, and make the most of the views. A ground-floor utility room was part of the original design but was not built because of budget constraints.
The block is in a high risk area for fire and termite attack, so the home needs to be able to withstand these attacks. The clients want to demonstrate through this home that a passively cooled, solar powered house can be built to withstand the extremes of climate common to this region for the same amount as a conventional air conditioned home typical to new suburban developments in Darwin.

The owners have added a 12x6m shed to the side of the house.

This home is built entirely with steel which has a low thermal mass. The home and outdoor living area are shaded year-round by the roof and eaves. (see Shading)

The home has been orientated west-south-west/east-north-east to capture breezes common to this site. (see Orientation)

The design makes the most of passive cooling principles. The cross-shaped plan ensures the home is only one room wide throughout to encourage cross ventilation. Solid internal walls have been placed on a north-west/south-east axis so they increase natural ventilation by not obstructing air paths through the house. The house has been elevated to allow air to circulate beneath it and to enable bedroom and living areas to be raised above the surrounding vegetation understorey to best catch breezes. The loft over the kitchen draws cooler air through the living spaces by convective air movement (hot air rising to exit at the highest point) from shaded areas below. (see Passive cooling)

Large windows to the north, east and south admit maximum ventilation and are fitted with insect screens so that they can remain open through the night. Smaller windows to the west — which receive the late heat of the day — are fitted with aluminium louvres that can be angled to keep the sun out but still admit breezes. The bathroom on the western side of the home buffers the bedroom from the sun’s heat. (see Passive cooling)

Apart from a split system air conditioner for occasional use in the guest bedroom, this house has no air conditioning. Each room has one ceiling fan centrally installed; the living room has three fans. Ceiling fans are the most efficient way to keep cool in summer. They work by circulating air, which increases evaporation of sweat from your skin — they cool the person, not the room. (see Heating and cooling)

Windows are fitted with roller shutters to protect the house from fire or storm damage.

Passive design
In highly humid summer and warm winter climate zones where there are no heating requirements, buildings with high thermal mass are undesirable. Lightweight (low mass) materials are preferred: they cool down fast when temperatures drop and they don’t retain heat. The focus in this climate is on passive design strategies to achieve optimal comfort by excluding sun year round, and by utilising passive cooling principles such as maximising exposure to cooling breezes and encouraging air movement and evaporation.
Reducing mains water use
There is no connection to mains water. Rainwater is collected from the shed roof and stored in three above-ground rainwater tanks. The total storage capacity is 100,000L. Water is filtered for drinking.

Embodied energy reduction
Due to the high risk of termite and ember attack no timber has been used in the construction of the house. Instead the house is constructed entirely of steel, cement sheet and slate. While the embodied energy of concrete and steel is relatively high, the design of a long-lasting building in these conditions will ultimately reduce the impact of the embodied energy of the materials. Significant savings from the recyclability of steel will also reduce the life cycle impact of the material.

Greenhouse gas reductions
The greenhouse gas emissions of this home would be significantly less than those of the average household. Renewable energy sources produce no greenhouses gases in operation — solar power supplies most of the home’s energy needs. By minimising demand through energy efficient design, greenhouse gas emissions have also been reduced. The gas cooktop and oven are the only appliances that use non-renewable energy sources.

Renewable energy production
The house is off-grid with a solar power system to supply all electricity needs. Solar panels are roof mounted on arrays at the back of the shed away from the house site for ease of cleaning. The inverter and batteries are housed in a well ventilated and insulated (to reduce heat gain) part of the shed to keep them from overheating and to reduce noise interference with the house.

Food production
Water from the wastewater treatment system is used to irrigate an orchard and vegetable patch, including elevated no-dig garden beds. Produce grown in this garden helps supply the owners’ food needs.

Indoor air quality
Careful consideration was given to indoor air quality through the selection of products and finishes that reduce indoor air pollutants. This home avoids the use of plastics, fibreboards, paints and chemically treated surfaces to minimise volatile organic compounds (VOCs), chemicals that evaporate or ‘off-gas’ into the atmosphere. Kitchen benches are commercial grade stainless steel, internal walls and ceilings are unpainted, and floors are cement sheet on steel bearers, surfaced with slate from Kununurra. The floor joists are closed channel steel to prevent accumulation of pests, moisture, embers and dust. Interior lights are outdoor designs with open bases so they do not accumulate insects during the wet season. (see *The healthy home*)

Good design in this home ensures it is naturally ventilated, encouraging breezes for air exchange. (see *The healthy home*)

Adaptation
The design of this home gives consideration to the changing needs of residents over its lifetime. The shower and toilet rooms are designed for disabled access, and all doorways are wider than standard. There is provision in the design for a lift to be installed if required at a later date. (see *The livable and adaptable house*)
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Solar power system
This home is not connected to the electricity grid, unlike many of its neighbours. Its 6kW stand–alone power system includes solar panels, an inverter, control equipment and a gel-based storage battery (to reduce corrosive fumes). This system does not have a backup generator because the owners wanted to minimise non-renewable energy use in the home. (see Photovoltaic systems)

A gel-based storage battery, combined with a photovoltaic array, provides a reliable power source.

Wastewater management system
Sewage from the home is treated with a commercial wastewater treatment system that uses worms and other organisms to turn the sewage into garden irrigation water.

Solar hot water
Hot water for the home is heated by 100% solar power. The owners have not needed to install a booster system.

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Plans: David Bridgman, Mode Design.
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Evaluation
The house has now been inhabited by its owners for nearly four years. They say the passive cooling–air flow aspects of the home are so successful that for the cooler months of the dry season they are considering installing a heater!

The owners have also made the following comments:

• We have experienced a bushfire near the house, a cyclone and at least three, possibly four, earth tremors since moving in, not to mention numerous storms that are a feature of the wet/dry tropics. The house has sustained no damage from these. Tiny ants have, however, caused serious damage to the electrical systems on two occasions, necessitating replacement of expensive components. Termites have not colonised nor harmed the building.

• Because the house is in a private conservation reserve and has large open window areas with natural airflow, living in it is like camping. You can lie in bed and look at the stars. Frog calls are so noisy in the wet season that we have to watch subtitled films as the TV can’t be heard on 100% volume setting (this is not considered to be a bad thing).

• It was important to choose a relatively high breezy site. This paid off in the Cyclone Carlos 1-in-500-year flood levels when we were able to help flooded neighbours because our house was on dry land and still with power (the grid shut down). Twenty houses along the same river were flooded.

• As the batteries (for the solar power system) age we may supplement the panels with a small wind-powered generator to compensate for seriously cloudy days during extended monsoon periods (there is usually a breeze even at night during the monsoon).

• The success of the project was very much due to the builder’s willingness to take on something out of the ordinary and to understand the principles of sustainability embodied in the design. It took a four year search to find the right builder, someone willing to build the home without wanting to make major modifications to the design.

The home won a 2009 NT and 2010 national HIA GreenSmart award for Energy Efficiency.

Author
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