A Canberra renovation has transformed a dark and cold house into a livable and family-friendly home that is more energy efficient and responsive to the environment. The clever renovation has also made the house more adaptable to fit the long-term needs of its occupants.

When the family of four moved into the poorly designed two-storey brick and weatherboard house they faced some tough questions about what to do to improve it — should they knock it down and start again, remove the top storey and extend outwards or build a bungalow at the back?

Environmental considerations and cost made them settle on an extensive retrofit of the existing house, making it far more habitable and suitable to the climate while keeping an eye on the family’s future requirements.

The house in Curtin, an inner suburb of Canberra, has good access to bike paths, parkland and public transport. Temperatures on winter mornings can fall below zero; summers are usually dry and warm. The house was built as a single-storey dwelling by previous owners in the 1960s; a pitched roof ‘Cape Cod’ second storey was added in the 1980s.
Case studies
Curtin, Australian Capital Territory

Design brief
The owners wanted a house that was warmer in winter and had more access to light. A desire for environmental sustainability meant passive heating would be the key. The house would need to open to and connect with the environment.

They were also keen that the house be subtly designed so that in future, when their two children moved out, the upper storey could become a separate rental property. The couple were looking for flexibility and were happy to accept smaller living space in years to come — the renovation was to make the house smarter rather than bigger.

Design response
The worst element of the old house was the central staircase, which allowed heat to escape up the stairs and left the ground floor bitterly cold in winter. It also divided the living areas of the house and made family interaction difficult.

In the renovation the old staircase was demolished and a new one built at the east side of the house — so that the house could effectively function as a two-apartment residence in the future.

A new laundry and garage are also in the home’s eastern end. The once small and pokey laundry was in the way as people passed through the house to the backyard. Now, it is tucked underneath the staircase and clothes can be dried under cover in the garage.

The kitchen, once in the south-east corner, is now part of a large kitchen—dining area in a central, north facing position. Double glazed doors bring light deeply into the area, making it a warm, social family space.

The lounge, where the kitchen once was, faces south to the backyard, with a double glazed sliding door allowing easy access to the garden and beyond.

Upstairs, the three bedrooms and living area were left largely as is, though a terraced garden was constructed on the roof of the garage to provide more outdoor space.

A crucial aim of the renovation was to ensure the home was well sealed in a tight building envelope, with no unnecessary ceiling penetrations and few gaps in the house through which heat could pass. This would ensure that passive heating and cooling could be most effective.

Study nooks and a purple glass splashback were additional design features used to bring a sense of life and character to the house.

The fridge is hidden behind joinery but ventilation from the subfloor space to the eaves ensures its efficient performance is not compromised.
A terraced garden provides outdoor space on the second storey.

**Solar hot water and solar power**

The owners installed an evacuated tube solar hot water system, north facing at a 55-degree pitch, to replace the old electric hot water service. The efficiency of the new system has meant the family rarely uses its electric booster.

The steep, Cape Cod pitched roof made the installation of solar panels difficult. The owners decided against a solar power system, instead focusing on improving the home’s overall energy efficiency to reduce heating and cooling costs.

**Passive heating and cooling**

Good window design and location maximise natural lighting. Bright, naturally lit homes promote health and well-being and reduce the need for electric lighting. To maximise the effectiveness of passive heating in this house, north facing double glazed windows and doors were installed. All windows and doors are tilt and turn with flexible opening mechanisms — assisting natural cross-ventilation for cooling.

The windows and glazed door frames are made from lead-free uPVC, a material with good insulating properties similar to timber.

**Active heating and cooling**

Canberra’s cold winters mean a form of active heating is a must. In this house, an energy efficient hydronic heating system works through a gas-fired boiler and radiator panels. The hydronic heating has replaced an inefficient heater downstairs and a reverse cycle split system upstairs. Energy efficient ceiling fans provide the only form of active cooling in the house.

**Building materials and insulation**

In parts where bricks were removed, reconstituted timber weatherboards have been used as cladding. Timber cladding has low embodied energy and generally low environmental impact.

Insulation acts as a barrier to heat flow and is essential to keep a home warm in winter and cool in summer. In Canberra’s cool temperate climate, the main priority of insulation is to reduce heat loss. As part of the renovation, the existing walls were insulated with R3 rated recycled polystyrene and the timber floors with R2 polyester batts; the ceiling was topped up to R5+ with wool cell insulation.

**Energy saving lighting**

Efficient LED lighting has been fitted throughout, sourced from an electrician and a local lighting store. The owners made creative use of a range of LED lights, in strips for pelmet lighting, wall-recessed hall and stair lights, and unvented/airtight downlights that give excellent light while using just 8W.
Case studies
Curtin, Australian Capital Territory

Materials reuse
The old staircase, kitchen, bathroom and curtains were given away free to anyone who could come and collect them. All the original whitegoods in the house were reused, as were old pavers in a new driveway.

Water saving
Canberra’s annual rainfall of just over 600mm is modest compared with most other Australian capital cities. It means that capturing rainwater and using it in the garden and home is an important environmental consideration. In this house two 5,000L rainwater tanks were installed, plumbed to the ground-level toilet and the laundry.

Draught sealing
Draught sealing around doors and windows can save up to 25% of heat loss and gain. The owners paid close attention to keeping as much heat in as possible through the installation of tightly sealing windows and doors. All exhaust fans in the house were fitted with effective dampers.

Paints, finishes and floor coverings
The new floor of the house is made of bamboo, and the carpets are of pure wool. Low VOC paints and finishes were used throughout the home.

Design for the future
An outstanding aspect of the renovation is the way it has made the house more adaptable. The staircase situated at one side means the upper storey could be separated as a second dwelling in the future. The laundry, with ample undercover clothes drying in the adjacent garage, can be shared by a number of occupants. With future mobility and wheelchair access in mind, a ramp has been built to the front deck as has a low-threshold entry.

Evaluation
The house’s energy rating is now an overall 7.5 stars, up from the original 2.5. The ground level has a rating of 8 stars, the upper storey 7 stars. Electricity consumption has halved. The house is now much brighter and more open to the environment, which the owners say has dramatically improved its livability and enhanced family life. It has a good balance of thermal efficiency, aesthetics, practicality, functionality and cost.

The plan now is to do more work on the upper storey so that it can function properly as a separate dwelling. A major change flagged for within the next 10 years is the addition of a kitchen to replace the current small kitchenette.

Author
Alternative Technology Association, 2013
Sydney North Shore, New South Wales

Case studies
Sydney North Shore, New South Wales

These townhouses were developed to increase the housing density of the local area while maintaining the local architectural aesthetic in a framework of environmentally sustainable design.

Through this project, the mother-and-daughter development team demonstrate that sustainability and profitable development can go hand in hand. These townhouses showcase the reduction of carbon emissions and resource consumption as well as improved indoor air quality — and they were very well received by the buyers’ market.

Site, location and climate

The site is located on the lower north shore of Sydney. This warm temperate climate zone enjoys warm to hot summers, mild winters and a low diurnal (day–night) temperature range. The site enjoys cooling breezes from the south-east over summer. The prevailing winter breezes come from west to south-west, and from the south. (see Design for climate)

The 2,584m² L-shaped site has one street frontage and very little overshadowing. It is within walking distance of a large shopping centre and bus transportation. The principal designer describes the site as encompassing ‘a moderate cross fall which required all the floor plates to be stepped across and up the site’.

Design brief

The main objectives of the project were to showcase sound environmental building principles combined with commercial feasibility in a challenging economic environment. These objectives were principally achieved by selecting conventional materials and applying conventional construction techniques wherever possible to ensure cost efficiencies. Each floor plan is similar to increase efficiencies across the project.

The design concept balances conventional lightweight timber frame construction for cost efficiencies with high-mass party walls and floors for good thermal performance.

- Six new townhouses
- Medium density
- Climate zone: 5. Warm temperate

Topics
- Passive design
- Reducing mains water use
- Waste reduction
- Recycled/renewable material use
- Embodied energy reduction
- Greenhouse gas reductions
- Renewable energy production
- Indoor air quality

Thermal comfort rating
6 stars
Heating 35–58MJ/m²/year
Cooling 16–33MJ/m²/year
Total 51–91MJ/m²/year

Sustainability features
- Double glazing
- Solar hot water
- Solar power system
- Insulation
- Lighting
- Rainwater harvesting

Project details
Principal designer: James Cooper, Sanctum Design
Project architect: Len Farrugia, Sanctum Design
Interior designer: Foster and Associates
Builder: Carty Property
Developer: Evergreen Living
Size: 166–175m²; four 3-bedroom and two 4-bedroom houses
Size of land: 2,584m²
Cost: Medium to high
Case studies
Sydney North Shore, New South Wales

Design response
After a number of design responses were explored, the final solution was four three-bedroom and two four-bedroom townhouses, ranging in size from 166m² to 175m². Each home has an average strata title of approximately 350m². The common space of the site is 473m².

Passive design
Each townhouse has an outdoor living terrace to the north with adjacent indoor living, dining and kitchen areas. Bedrooms and amenities are on the southern side wherever possible. North facing living areas make the most of solar gain, allowing winter sun to penetrate the concrete thermal mass and double brick party walls through expansive glazing and clerestory windows. (see Thermal mass)

During summer, the terrace is covered to provide shade to the thermal mass with an operable louvre roofing system. It can be opened to allow sun to penetrate in winter, or closed to keep the internal mass of the living and dining room shielded from the sun. (see Shading)

Temporal climates require less cooling than warmer climates. In summer, cooling breezes coming from the south-east are drawn through the townhouses’ entry passages and upper floor balcony doors. Cross-ventilation through the first floor rooms is provided through 100% operable louvre clerestory windows to maximise convective ventilation. (see Passive cooling)

West, south and east facing windows are few in number and small in size to reduce solar gain in summer.

Fixed awnings for shading have been fitted on west and east facing windows to provide extra protection.

Reducing mains water use
The townhouses have rainwater tanks with a capacity of 10,000L plumbed to the toilets, washing machine and at least one garden tap. This potentially reduces mains water use by a total of 60,000L. Highly efficient fittings were selected to conserve water: showerheads (3 star), kitchen and bathroom taps (all 6 star) and toilets (4 star). (see Rainwater)

Waste reduction
Demolition waste makes up 40% of all landfill. Waste was controlled throughout demolition and construction by the use of recycling bays constructed on site for steel, aluminium and other metals, plasterboard, masonry and timber. Offcuts were used wherever possible. All trades were briefed throughout the project as to its sustainability aims. (see Waste minimisation)
Reclaimed timber has been used extensively throughout the project, including reclaimed ironbark for external decking, jarrah for weatherboard feature cladding and blackbutt for internal timbers. Plantation and Forest Stewardship Council (FSC) certified timbers are used as structural timbers. Timber that is FSC certified has been recognised as meeting international environment and social standards for responsible forest management. (see Lightweight timber)

The project uses Good Environmental Choice Australia (GECA) certified plaster board throughout. GECA certification ensures good environmental performance benchmarks throughout the life cycle of the product.

**Embodied energy reduction**
A combination of high thermal mass and lightweight building construction, which is lower in embodied energy, is an effective solution for this warm temperate climate. (see Embodied energy)

**Greenhouse gas reductions**
The reduced need for electricity use throughout the development helps reduce greenhouse gas emissions. Reversible ceiling fans are installed throughout to aid in cooling; for heating, 5 star natural gas heaters are installed in the living and dining room only. Low energy LED and CFL lighting is installed throughout, with clerestory windows bringing natural light into the home and reducing the need for artificial lighting. External lighting is controlled by sensor.

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**Water heating**
Water heating is supplied by solar systems with instantaneous gas boosting.

**Energy efficient appliances** — such as stovetop, oven and dishwasher — were specified throughout. (see Appliances)

**Exhaust fans**
Exhaust fans have a self-closing lid to prevent heat loss and gain and are wired so that they can be manually switched on and off.
Case studies  
Sydney North Shore, New South Wales

Renewable energy production
Each townhouse is equipped with a 2kW grid connected solar power system. At time of build these systems would have received 60c per kW feed-in tariff, offsetting electricity bills.

Indoor air quality
Consideration was given to the indoor air quality of the townhouses through the selection of products and finishes that reduce indoor air pollutants. These include:
- adhesives with zero formaldehyde, to reduce the health effects of exposure to formaldehyde, which can include eye, nose and throat irritation
- E0 MDF joinery, i.e. very low levels of formaldehyde emissions
- low volatile organic compounds (VOC — chemicals that evaporate or ‘off-gas’ into the atmosphere and can cause eye, nose and throat irritation and headaches; a standard new building project would off-gas considerable levels of VOCs, mostly directly after installation) and 100% wool carpets installed throughout the first floors of each townhouse
- low VOC paints.

Good home design is also one of the most effective ways to reduce indoor air pollutants. The design of these townhouses ensures the homes are naturally ventilated, encouraging breezes for air exchange. (see The healthy home)

Double glazing
All windows and external doors are timber framed with clear double glazing — apart from the clerestory windows which have the addition of a low emissivity (low-e) coating on the inside face of the glass to reduce solar heat gain during summer and heat loss through winter. (see Glazing)

Solar hot water
Solar hot water units with an instantaneous gas booster have been supplied to all townhouses. A gas booster usually produces fewer greenhouses gases than an electric booster. (see Hot water service)

Solar power systems
At time of build, the solar power systems would have received 60c per kW feed-in tariff, offsetting electricity bills.
**Insulation**

Insulation acts as a barrier to heat flow in and out of a house. In this warm temperate climate zone, reducing heat loss and gain are equally important. Each townhouse is fitted with a combination of reflective foil and GECA-approved wool polyester blend bulk insulation to R2.5 (walls) and R3.0 (ceilings).

**Lighting**

Internal natural daylight levels are high, reducing the need for artificial lighting. Light fittings have been selected for their low energy use: light emitting diodes (LEDs) and compact fluorescent lamps (CFLs) are used throughout. Outdoor lights have been fitted with sensors to reduce energy use. (see Lighting)

**BASIX certificate**

The NSW Government introduced the Building Sustainability Index (BASIX) from 1 July 2005 to establish minimum standards for all new homes in the state. BASIX takes into account the thermal comfort as well as the water and energy use of the home. The BASIX certificate score for the townhouses was 59% for water (target 40%), pass for thermal comfort (target pass), and 101% for energy (target 40%).

**Evaluation**

Many of the owners cited sustainability as a reason for purchasing the townhouses and the project was well received in the market — all six townhouses were sold.

According to the principal designer, the main limitation on the approvals process was resolving the driveway configuration to cater for council’s specifications about the location of parking spaces.

Post-occupancy analysis is difficult, given the nature of this project, but anecdotal feedback from homeowners suggests the homes generally perform very well thermally. Energy bills have been as low as $7 a quarter. The fundamentals that have worked in this project are orientation, external shading, passive solar gain and using significant thermal mass to stabilise internal temperature. The inclusion of the 2kW photovoltaic system has also contributed to these low bills. The central townhouses enjoy more stable temperatures throughout the seasons, which is to be expected given that they are ‘insulated’ by the neighbouring townhouses. Some owners have elected to install a heat pump reverse cycle air conditioner in the upper bedrooms to make summer heat waves more comfortable. The principal designer adds, ‘If we were able to provide more thermal mass in the upper floor rooms we may have achieved better summer performance. However the cost of embodied energy in the mass may have taken some time to pay off, against the low cost and low usage requirements of the heat pump air conditioner.’

**Additional reading**

For additional information about the challenges and opportunities for the design of multi-residential developments see Buying and renovating an apartment.

This project has been commended for and won a number of awards including the Building Product News (BPN) Sustainability Award for Multi-Density Residential.

**Author**

Alternative Technology Association, 2013
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 understory 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.
Case studies
Darwin River, Northern Territory

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 greenhouse 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)
Shower and toilet rooms are designed for disabled access, and all doorways are wider than standard.

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

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.
Case studies
Darwin River, Northern Territory

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
Alternative Technology Association, 2013
This Sunshine Coast display home is designed to meet Australia’s highest house energy rating of 10 stars. A local building company, specialising in sustainable small lot homes, set out to produce a modern, affordable energy saving home to suit the property market. The home’s net zero energy use is a key selling point, appealing to home buyers looking to cut energy bills.

The dwelling, part of a housing development display village, showcases the benefits of energy efficient design to a broad range of consumers. The builder has aimed to meet the market’s needs, deliberately blending the home in with the 20 others on show.

### Site, location and climate

The builder found an ideal site in the Bells Reach Display Village at Caloundra West, 90km north of Brisbane in the midst of the Sunshine Coast. It’s an urban area close to the beach with a temperate year-round climate averaging around 21°C in the winter months. Most days are warm and humid especially in summer with hot averages around 28°C. The temperature can drop on winter nights to around 10°C and rainfall peaks in summer. Thermal mass would work well in the home, storing heat on winter days and releasing it on cool nights.
Case studies
Caloundra, Queensland

The site was picked for its almost north–south aspect conducive to good passive design. It was determined that a 10 star house could be built on the block. However, designing for small lots requires overcoming several restrictions, width being one of them. The lot is only 10m wide x 32m deep with houses sitting tightly on either side. Once essentials such as a garage and entrance are placed at the front of the block, the layout still needs to address passive design principles, flow-through ventilation and optimisation of the aspect.

Design brief
The builder set three high goals for the display home that would make it a benchmark for sustainability and energy efficiency. The new home needed a 10 star house energy rating to make it a showcase design. It needed to achieve net zero energy use by producing more electricity than it consumed over a year, demonstrating the environmental and financial benefits to living there. And the design needed GreenSmart Accreditation from the Housing Industry Association (HIA), to further assess and endorse its environmental performance. Good passive design would help meet these goals.

The builder wanted the construction to be environmentally sustainable, so used locally sourced, recycled and recyclable, renewable and low volatile organic compound (VOC) materials as much as possible.

The layout and design had to appeal to consumers and demonstrate that sustainable and energy efficient homes are affordable. Visitors had to feel comfortable enough to imagine living there while recognising the sustainability and financial benefits. A contemporary, relaxed design was essential.

The proposed home had to adhere to the developer’s Minimum Architectural Requirements which give guidelines on everything from landscaping to external wall finishes. A certain look and feel is expected in these homes. These requirements must be followed before any other features the builder wants to showcase, including energy efficiency measures, can be implemented.

Design response
The contemporary design is for a small family home with three bedrooms, two bathrooms and a single lock-up garage, all on a narrow block. It has tiled living areas and epoxy finished bedroom floors. The master bedroom features a large en suite, and minor bedrooms are in a separate wing with their own bathroom.

Low-VOC paints and laminates throughout reduce greenhouse gas emissions and provide healthier air for residents.
The north facing living area is open plan and opens to a rear alfresco area that faces the yard. The 2.55m ceilings add to a feeling of spaciousness.

Mains water use is kept to a minimum with all taps having a high WELS rating.

A 10 star house energy rating was secured with good northern orientation, high levels of thermal mass, ceiling and wall insulation, and careful consideration of window size and position. These elements were adjusted in the design until the target rating was achieved with house energy rating software.

The site’s near north–south aspect was advantageous, offering perfect orientation for a 10 star home. The dining and living areas have a northern aspect for best solar access and natural light; and the low pitch roof helps efficient operation of the solar photovoltaic system to achieve a zero net energy goal. (see Orientation)

The home was initially designed using the builder’s regular construction methods, with more thermally efficient materials added to achieve the 10 star rating only where needed. Reverse brick veneer was specified for the northern living room wall to increase thermal mass — not a first choice by the builder due to its added expense. In addition, masonry block walls, some painted and others coloured and honed during manufacture, were used elsewhere to provide additional thermal mass while acting as a feature wall in the main living area.

Other features essential for gaining a 10 star rating and thermal efficiency include light-coloured exterior walls to reduce heat gain, weather strips for draught proofing, ceiling fans to ensure good airflow and low-e glass to reflect radiant heat.

Waste was kept to a minimum by altering the design where needed to optimise material size. Changing the size of a room by 100mm could save an entire sheet of construction material, such as external cladding, with the builder implementing this during the design and following through during construction. (see Waste minimisation)

The house is built with new materials that contain recycled materials as well as materials that can be recycled. Most of the house can be broken down or reused at the end of its life, including insulation made from recycled glass bottles and cladding made partially from pinewood pulp. The steel roofing contains up to 25% recycled materials and can be completely recycled again at the end of its service life. The concrete slab is recyclable as is the plasterboard and numerous other components.

A renewable energy system was essential to achieve the net zero energy use goal. The home was independently assessed for its energy efficiency to determine what size solar photovoltaic system would generate more electricity than the household would consume in a year. The display home is not carbon neutral for greenhouse gas emissions as it has a gas hot water system, but anyone buying this home can elect to have a solar hot water system installed. (see Renewable energy)

Indoor air quality was important to sustainability goals, with low-VOC paints and laminates used throughout, reducing greenhouse gas emissions and being healthier for residents.
Case studies
Caloundra, Queensland

Concrete slab
The right combination of horizontal and vertical mass was needed to achieve a 10 star rating, with a concrete slab providing horizontal thermal mass. The concrete sits on and around a series of waffle pods, thus the slab is mostly resting above the ground and is less susceptible to changes in ground temperature. The air pockets created by the pods form an insulating layer between the structure and the ground. (see Concrete slab floors)

Reverse brick veneer
Reverse brick veneer provides vertical mass in the north and west facing living area to achieve the 10 star rating. A layer of brickwork facing into the living area on the internal wall absorbs and releases heat. Next to it is a thick layer of insulation designed to minimise heat intrusion from the outside or heat loss from the inside, thus stabilising the internal temperature. The external cladding is painted in a light colour to assist in reducing heat absorption through the outside wall. (see Brickwork and blockwork)

Lightweight construction
The home is built using composite construction. In addition to reverse brick veneer and masonry construction, lightweight building materials such as sustainably sourced timber are used, reducing embodied energy.

Insulation
High levels of wall and ceiling insulation were needed to achieve a 10 star house energy rating. The ceiling has thick R3 batts as well as a layer of R15 glasswool roofing blanket underneath the actual metal roof sheeting. The external walls have R1 insulation wrap on the outside with R2 batts in the wall cavity. (see Insulation)

Energy saving windows
All windows and doors have low-e glass. A thin film coating helps reflect radiant heat, reducing heat loss in winter. Double glazing was not necessary to achieve a 10 star rating.

Windows are strategically placed, especially in the living areas, to allow good ventilation, and are sized to provide best natural light to reduce energy use.

Solar photovoltaic system
A 1.5kw solar photovoltaic system helps to counter power bills. This in effect gives the home a net zero energy rating as the system generates more electricity than projected household consumption.

Energy efficient appliances
A whole of house fan in the ceiling operates like an extractor fan, drawing air through the windows into the home and exhausting it through roof vents. This creates a cooling breeze in summer by virtue of an evaporative effect on the occupants. The system doesn’t need to operate long to have an effect, and helps minimise air conditioner use, thereby saving energy consumption.

Rainwater tank
Mains water use is kept to a minimum. A 5,000L poly rainwater tank collects water for reuse in toilets, laundry and gardens. All taps have a high WELS rating to save more water. (see Rainwater)

Evaluation
On paper, the Bells Reach 10 star home meets all the builder’s benchmarks and goals for an energy efficient dwelling. Currently there’s no thorough analysis of what it is like to live in, as it is a show home, although it maintains stable indoor temperatures at its exposed display village site and is meeting energy use expectations. A comparison with a real 7 or 8 star home would be useful to test the benefit of building to higher house energy ratings.
The builder took a very systematic and scientific approach to creating a 10 star home in what turned out to be a very successful project. They adjusted the design and materials only where necessary so the home could be constructed as economically as possible, in turn dispelling the idea that energy efficient homes are necessarily expensive. It also shows that a modern sustainable design can be achieved on a small lot.

The project demonstrates that the highest performing homes can be made affordable, with the Bells Reach 10 star home able to be replicated for approximately $244,000, excluding land, and ready to be rolled out in the housing development.

**Author**

Alternative Technology Association, 2013

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The open plan, north facing living area opens to a rear alfresco area facing the yard.
Clad in Zincalume steel, the environmentally responsive, modern design of this portside dwelling ties itself to the area through the use of building materials used in the area historically.

After six years of living in a poorly insulated early 1900s stone villa in Adelaide, where winter temperatures inside the building were colder than outside, the owners were ready to build a more climate-responsive dwelling.

Although at 125m² the two-bedroom home is small by Australian standards, it is more than sufficient for the occupants. The design embraces the owner’s love of entertaining, and features a good-sized open plan kitchen/living area leading onto a large deck, a much-used indoor/outdoor living space. The hallway wall doubles as a display area.

Site, location and climate

The two-bedroom dwelling is in Birkenhead on Adelaide’s northern beaches. Adelaide has very hot, dry summers with heatwaves often exceeding 40°C, and cool to cold winters requiring heating. A well-sealed building fabric, insulation and thermal mass are priorities in this climate, to keep heat in during winter and out during summer. It’s also important to remember that it’s practical to design for the normal conditions rather than the few really hot weeks.
Case studies
Birkenhead, South Australia

Design brief
The main objectives of the project was to build a passive-designed house that heats and cools itself on a reasonable budget, situated on a modest-sized block in the Adelaide suburbs. The owners were often told that an ‘eco house’ is expensive, and were determined to prove it did not have to be. They felt strongly that anyone could achieve good passive design outcomes by thinking about orientation, material selection, local climate and designing to the site location before starting a build.

Design response
While designed for two people, the building layout is flexible and can be zoned. Clever location of doors is used to aid zoning so the most used areas of the home receive optimal heating and cooling benefits.

As with all builds, some challenges presented themselves. The local council required two off-street parking spaces with at least one under cover. The house was sited at the southern end of the block and the car spaces to the north-east, allowing for future extensions and to maximise solar and winter heat gain. A window was inserted on the northern wall above the carport roof to ensure maximum winter sun.

The designer worked hard to maximise the limited space. At 4.2m x 8m, the large, north-facing deck makes the home ideal for entertaining. The size of the home is suitable for a couple, either just starting out or downsizing later in life. The third room is currently being used as a TV room but could be used as a study or guest bedroom.

The owner regrets that he wasn’t able to install thermally broken windows. ‘The window supplier wasn’t helpful at all. Even double-glazing was an issue, as the glass
had to come from Melbourne. Overall, asking for high-performing windows was difficult—some suppliers wouldn’t even give me a quote on it.’

This issue may be resolved in the future as the market becomes more interested in high-performing windows.

Monitoring performance
Several monitoring systems in the building are tracking internal temperature, humidity, energy consumption and solar energy production.

A weather station on the roof monitors external temperature, humidity, wind direction, speed and rainfall. Additional data loggers (Hobo MX1011) are located in the kitchen/living area and bedrooms to track internal temperature and humidity (readings are taken hourly).

These simple devices connect to a smartphone via Bluetooth, making downloading data very easy. Data is then plotted in spreadsheet or graph format, allowing easy comparison with the temperature graphs generated by the NatHERS software.

Thermal mass
Internal thermal mass keeps a house warmer in winter and cooler in summer. In this home, a strong emphasis has been placed on passive solar design and thermal mass.

Internal thermal mass in the form of two recycled brick walls in the kitchen/living area was created on the western wall. The reverse brick veneer helps the home minimise heat gain in summer. The section (from inside out) is 90mm brick / 30mm air gap / 11mm OSB / 93mm EPS / 11mm OSB / breathable membrane / 15mm air gap / Zincalume. By using recycled red bricks with a very subtle American bond pattern worked into it, and cut-and-struck lime mortar, the walls not only add thermal performance but look great.

Reverse brick veneer
The reverse brick veneer walls provide an extra layer to the building fabric on the western façade reducing heat build-up during the long summers. Many more temperate areas may only require the SIP to achieve a comfortable home, an issue worth discussing with an experienced accredited NatHERS assessor (www.nathers.gov.au).
Insulation

The R3.2 insulation in all walls and R6 bulk insulation in the ceilings boosts the home’s thermal performance.

Windows

North-facing windows in the kitchen/living area allow passive solar gain in winter while clear-eave calculations keep the sun out in summer. There is no western glazing to the thermally conditioned zones. Bedrooms are in the cooler part of the house, with windows located to the east allowing the occupants to wake up to the sun each day.

The windows are double glaze alu-minium 6/12Arg/6 with the sliding door glass at 6.38mm for easy handling (double glazing can be heavy). This size also helps maintain a higher solar heat gain coefficient, and is a factor in determining whether you are trying to maximise winter warmth or exclude sun from a design.

Window location was calculated on the site’s prevailing wind patterns in summer to assist with cooling. Breeze paths have been created and window heights allow for stack cooling.

The SUHOstudio YouTube channel has a video showing the winter solstice solar gain through the north-facing lounge room doors and windows of the house.

Floor treatments

Sisal carpet covers the floor in the two bedrooms with exposed concrete floors throughout the rest of the house. These were sealed with a no volatile organic compound (VOC) oil. No VOC, natural paints, primer, undercoats and sealers were used on the ceilings, walls and woodwork to eliminate toxins and maximise air quality.

Wall construction

The owners were keen to ensure their new home was built well, reasoning that a well-designed building is irrelevant if it’s not built properly.

The speed and ease of construction impressed both owners. The structural insulated panels (SIPs) come with a pre-chased hole running horizontally at 300mm, 450mm and 1200mm to run electrical cables. The couple put the panels together themselves, running a chasing string through the holes. This meant that when the electrician arrived on site to install the cabling, all that needed to be done was to tie a wire to the string and pull.

Sealed building fabric

Thermography analysis on the final building fabric and an air-pressure test showed the house achieved 3.6 air changes per hour (ACH) at 50 pascals. Given that the average project home in Australia rates at around 19 ACH, this puts the Birkenhead home in the category of best-sealed houses in the country. However, designers need to be aware that if a house is too well sealed it may require a mechanically forced air system, as in European-style passivehaus designs.
Case studies
Birkenhead, South Australia

**Heating and cooling**
Ceiling fans have been installed in the bedrooms and living area. There is no other mechanical heating or cooling for the house.

**Solar photovoltaic system**
With a 3.5kW grid-connected solar PV array on the roof, the family produces more energy than it uses, making this an energy-positive dwelling.

**Heat pump hot water system**
A 325L heat pump provides hot water. Choosing not to run gas to the dwelling allows for the possibility of running the whole house on solar storage batteries in the future.

**Energy-efficient lighting**
Lighting was carefully considered at the design stage. There are no downlights as these can compromise the effectiveness of ceiling insulation, and in general, the fewer holes in a building’s envelope, the better it will perform. By building the house to maximise good natural light, the need for artificial lighting was kept to a minimum.

**Water saving**
The homeowners installed two rainwater tanks around the property with a total capacity of 7,000L. The tanks are plumbed together and service the whole of the house and garden. The water supplies for house, garden or both can be manually changed from the tanks to the mains if required. There are also low-flow taps and showerheads along with 4.5 star WELS (Water Efficiency Labelling and Standards) toilets.
Questions and answers

Your Home (YH) asked designer and owner Mark Clayton (Mark) about some of the choices he made on the build:

YH: Why did you choose SIPs (structural insulated panels)? Were they easy to source, and did you have any concerns about the foam insulation used in them?

Mark: We chose SIPs as they delivered many benefits:

1. They are an air-tight building fabric with a quick build time. As SIPs are pre-fabricated it really is just a job of fitting them together. Completing the full structure took just two weeks work.

2. SIPS are structural, so I didn’t have to worry about the engineering specs. It’s all been pre-calculated, including things like the lintels over openings. This also meant I didn’t have to learn the timber framing code on how to build structural stud walls—a timesaver.

3. Because SIPS don’t have thermal bridging, the solid state insulation will not fall into cavities or compress on its own weight over time. I knew we were getting something that would last.

4. Price-wise, the product was about the same but the thermal performance was much better.

There are several SIP suppliers entering the market, I chose this one as many of the SIP’s use metal frames and I prefer to work with timber.

I have no concerns about the foam insulation.

The no VOC oil was supplied by Livos and the slab was burnished. This was done for several reasons:

1. We were after a warehouse feel to the build and I liked the finish the copter leaves on a slab. The concrete team was aware of this and they spent several more hours than normal coptering the slab to make it smoother (seven hours in total, I understand two is normal). A 32MPa (megapascal) mix was used which is harder than concrete used under carpets (this is normal for exposed slabs).

2. By not grinding the slab we made significant cost savings. Slab grinding or polishing costs about $80–$110 per square metre.

3. By leaving the slab as it was and sealing it with oil, there was no need for tiles and a tiler, again reducing costs.

YH: Did you do anything special or different in the build, like extra sealing tape at the top and bottom of the SIP? Some have suggested that you need forced air once you are below 6 air changes per hour. Did you consider this or is opening windows all you need to do? What about fresh air in winter?

Mark: Most of the benefit was because we used SIPs. I also made sure that when we installed the windows they was installed well and silicon was used to seal up gaps.

1. By not having downlights we minimised ceiling penetrations.

2. The SIPS are pre-chased for the electric ring main and therefore not opening into the cavity as per usual in brick veneer construction. All switches have been located on internal walls (which are insulated) therefore reducing holes in plasterboard that connect to outside or ceiling space.

It has been suggested that forced air is required, we leave both bathroom windows open all year round, in winter this helps minimise moisture in the building. As the building heats up the slab and internal thermal mass inside, we find that opening a window or the sliding doors for 10 minutes each day provides effective air change.

As the heat is stored in the thermal mass, the fresh air is quickly heated and the internal comfort is not affected. I would agree if no windows were ever opened then indoor air quality could be an issue; again, it’s about understanding how to ‘drive’ the house and using common sense.

Evaluation

The owners’ focus now is to educate others in what they have done, and how and why they have done it. They are very happy with their home and want to encourage others to learn from their approach and build in keeping with the home’s local climate, while showing that outstanding results can be achieved on a small budget.

Their main advice for anyone keen to undertake this kind of build would be to plan well, understand the work flow and be prepared. They advise keeping contractors in the loop about where you are heading; the last thing you want is to get too far ahead and make their job harder.

The owners also found that recommendations were invaluable. If a good contractor recommends someone, chances are they will share the same quality of work. The owners stated that they were very lucky with the contractors they used and have recommended them to others looking to build.

Author

Mark Clayton, Sustainability House
Case studies
Parkside, South Australia

Parkside, South Australia

- New build using some structure of the old house
- Medium density
- Climate zone: 5. Warm temperate

Topics
• Passive design
• Reducing mains water use
• Adaptive reuse
• Embodied energy reduction
• Greenhouse gas reduction
• Renewable energy production
• Indoor air quality
• Adaptation

Thermal comfort rating
Not available

Sustainability features
• Trombe wall
• Rainwater tanks
• Mechanical dry indirect evaporative cooler
• LED lighting
• Reverse block veneer
• Rammed earth internal walls
• Greywater diverter
• Solar photovoltaic panels
• Evacuated tube solar hot water
• Double glazed windows
• Ceiling fans
• In-floor heating through gas-boosted solar hot water

Project details
**Designer:** John Maitland, Energy Architecture
**Builder:** Adelaide Prestige Homes
**Size:** 220m²
**Size of land:** 790m²
**Cost:** $900,000

The new emerges from the old as sustainable design creates a bright, thermally efficient and environmentally in-tune home that incorporates a property’s heritage past.

The occupants of a stone villa in Adelaide found over the years that it needed major improvement: its thick walls and small windows meant it was dark and cold in winter but it needed robust air conditioning to cool after a run of hot days in summer. It was also subsiding on one side. They called in sustainable designers who came up with a radical plan to transform the house.

The sustainable design also incorporates the property’s heritage past.
Site, location and climate

The three-bedroom stone and brick house is in Parkside, an inner southern suburb of Adelaide. Hot and dry for long periods in summer, Adelaide is also subject to ‘cool changes’ when temperatures can drop suddenly from high 30s to low 20s degrees Celsius. Winters can feel cold despite relatively mild conditions. Insulation and thermal mass are priorities in this climate, to keep heat in during cold weather and keep heat out when it’s hot outside.

Design brief

The owners wanted the design team to demolish the house and produce a new building, but were persuaded to keep the front stone gabled façade and ironwork veranda. There would be a new enclosed garden and more space inside, while energy and water efficient features would be incorporated to improve comfort and overall livability. The home’s poor orientation — northern elevation close to the site boundary restricting natural light — also needed to be addressed.

The owners had thought of a standard new home, but the designers came up with a bold idea that at first surprised, then inspired them.

Design response

The roof was taken off, the house hollowed out and a garden courtyard built in its place. An entirely new house was then built around it. The historic front façade and other stone walls were retained because of their beauty, heritage value, high embodied energy and excellent thermal mass.

The aim of the design was to get the house’s orientation right. The new home was pushed towards the property’s southern boundary to open up to the north, with the new front courtyard capturing winter sun. The house’s three bedrooms, two living spaces, study, loft and kitchen were built over the driveway and into the large backyard, to the south and west of the courtyard.

Insulation — Trombe wall

A fascinating aspect of the home’s sustainable design is the Trombe wall installed on the north facing stone wall of the new living room. A steel frame sits slightly off the rendered and painted old stonework and is clad with polycarbonate panels to create a warm cavity, which in winter transmits heat through vents into the living room. In summer, the vent at the top of the Trombe wall can be opened to let the warm air out. A large, retractable shade protects the courtyard and the Trombe wall from the sun. The old stone wall is protected from weathering at the same time.

The Trombe wall makes an insulating layer on the outside of a thermally massive wall. Without it there is nothing to stop the heat flowing out through the wall in winter and in during summer.

Passive heating and cooling

Thermal mass keeps a house warmer in winter and cooler in summer. In this home, a high emphasis has been placed on passive solar design and thermal mass. Much of the incorporated thermal mass comes from the bluestone walls retained from the existing house, as well as concrete slab floors, 300mm-thick rammed earth internal walls and reverse block veneer construction.

Much of the thermal mass comes from the original bluestone walls, as well as new concrete slab floors.
Case studies
Parkside, South Australia

The reverse block veneer consists of 90mm concrete blocks on the inside, and timber cladding with rendered and painted fibre cement sheeting on the outside. The concrete blocks are solid, to maximise on thermal mass, and the external ‘skins’ are fitted to the insulated timber frame.

The home’s internal rammed earth walls in the living areas and bedrooms provide a warm aesthetic and a good sound break between rooms, and hold a large volume of thermal mass that helps to moderate the internal temperature. Rammed earth is a specially designed mixture of sand and rubble from a quarry, mixed with cement and a little water. It has low embodied energy and is very durable.

Rammed earth walls provide a necessary sound break between living areas and bedrooms.

The R2.5 insulation in all walls and R5 bulk insulation in the ceilings boost the home’s thermal performance.

North facing windows in the new section of the house allow passive solar gain. The windows are double glazed with 12mm argon and a 6mm clear inner pane, in combination aluminium and timber frames. Clerestory windows bring north light into the bedrooms on the southern edge of the property.

A controlled skylight (adjustable solid louvres within the skylight close out the sun when unwanted) is fitted along the passage and living room bluestone wall — part of the original house that has been retained.

For passive cooling, a large retractable shade protects the courtyard and the north facing wall of the house from the summer sun. The house’s living areas open out to a patio covered with adjustable roofing louvres, and eaves shade the north facing windows of the loft.

Active heating and cooling

Solar heated (gas boosted) water is delivered through pipes for in-floor heating and into vertical radiator panels in rooms that don’t have a slab.

To control indoor temperatures during Adelaide’s long hot spells, the owners installed a Climate Wizard indirect evaporative cooler. It uses a modified...
evaporative cooling cycle incorporating a heat exchanger that brings cooled, dry air to the home. The cool air is delivered through a series of underground pipes and enters the house through vents in cupboard kickers and some walls at floor level.

This system is more effective than a regular evaporative cooler and can work at higher levels of humidity without making a house uncomfortably humid or excessively dry, as it doesn’t extract or add water to the incoming air as it is cooled. It is particularly efficient in this house. By delivering cool air at floor level and driving warm air up and out through the ceiling vents and clerestory windows, this system maintains lower temperatures in thermal mass during a hot day, so that mass can do the work when the unit is switched off at night. It draws less than 300W running on idle, and less than 6L of water per hour, retaining temperatures of 24°C or less throughout extreme summer conditions. Windows and doors do not need to be open as with evaporative coolers.

Mechanical evaporative coolers are common in low humidity climates. They use less energy than refrigerated air conditioners and work better with doors and windows left open.

Ceiling fans have also been installed in the bedrooms. On still days, mechanical fans can be useful to create breezes. The maximum useful air speed for comfort is about 7.5m/sec.

Water saving

The homeowners installed six rainwater tanks around the property with a total capacity of 60,000L. All tanks are plumbed together and feed the whole of the house and garden. The water supply for the house or garden or both can be manually changed from the tanks to mains. There are also low-flow taps and showerheads.

A greywater diverter delivers bathroom and laundry water for subsurface irrigation to the extensive vegetable garden and fruit trees. Reusing wastewater outdoors can reduce a household’s potable water use by 30–50%. Subsurface drip irrigation systems spread water evenly around the garden, and are safer for spreading untreated greywater.

Solar power and solar hot water

With a 2.6kW grid-connected solar photovoltaic array on the roof, the family produces about half the energy it uses. For hot water, they installed an evacuated tube (array of 60) solar system that heats a 500L custom-made tank, boosted by a gas-powered hydronic boiler.

Energy efficient lighting

Most homes could reduce the amount of energy they use for lighting by 50% or more by making smarter lighting choices and moving to more efficient technologies, such as the light emitting diode (LED). The benefits of LEDs include lifetimes of up to 100,000 hours and potentially very high efficiency levels. The homeowners installed LED lighting throughout the house.

Evaluation

The owners of this home had a realistic budget for the scale of the work and were prepared to prioritise sustainability. This allowed their designers to come up with an integrated system of features for overall energy and water efficiency.

The couple say they could not be happier in their home, even as the house’s unusual façade draws curiosity from passers-by. A lot of people stop and talk to them, giving them encouraging comments about the design.

Comfort levels with temperature, ventilation and light have improved dramatically in the new abode. Lights are now hardly needed during the day and the couple are pleased with the new configuration of spaces, including the courtyard. Before they had a large backyard that was difficult to manage; now the new outdoor spaces are smaller, more purposeful and easier to use.

Author

Alternative Technology Association, 2013
A renovation to a brick inner urban terrace has creatively maximised limited space, opening it to light and passive energy while incorporating the home’s history and heritage.

The centrepiece of the renovation is a new kitchen and living room, an extension that has added just 15m² to the original building while incorporating a high degree of environmental sustainability. The owners wanted the back of the house to open and connect with the environment while improving the home’s livability for themselves and their two young children.

The renovation demonstrates how much can be achieved with a limited budget used in the right way.

Site, location and climate

The house is in the inner Melbourne suburb of North Fitzroy where the climate is mild temperate. Winters can be cold and damp; summers are usually punctuated with long spells of hot, dry weather. The long, thin, east–west facing block of 190m², typical for terrace dwellings in the area, gave the designer the constraint of limited space and — as one owner described it — a ‘fiddly’ job. Another challenge was to improve the overshadowing by the block of flats next door.
An extension sits at the back of the 1870s-era semi-detached brick terrace.

**Design brief**

The owners moved into the house several years before the renovation when it was in a very run-down state, with an asbestos lean-to bathroom at the back of the house. They knew that it was overdue for a makeover but wanted to get to know the house properly before they renovated. Built in the 1870s, the two-storey terrace had undergone many transformations in its long history as a working class residence.

The chief problem, they noticed, was a lack of light because of the high-density surroundings. They wanted to increase light and space without encroaching too far into the small garden at the back of the property. The extension had to be environmentally sustainable, with energy efficiency, passive heating and cooling, materials choice and reuse being important considerations.

The owners wanted to maintain and connect with the property’s heritage and history as far as possible. Their wish was a renovation that did not give their home a wholly contemporary look.

**Design response**

The owners project managed the renovation themselves because of their small budget and strong feel for what they wanted. They engaged an architect to draw up the concept plans, with a second architect coming on board to draft them into working plans and give the owners guidance.

Much of the original house was retained as is, including the whole of the second storey. Originally on the ground floor, a short corridor ended with a living room on one side and a small kitchen on the other. The living room remained largely untouched, but the kitchen was replaced with a bathroom. The back of the house was opened and extended to a new kitchen–dining area to gain the sought-after light and space.

**Passive heating and cooling**

North facing clerestory windows with eaves were designed to bring light deeply into the extension and give passive thermal control. The original brick wall at the side of the house, spattered with cement and old mortaring, is now a prominent feature of the new kitchen–dining area. It gives thermal mass as well as a striking sense of history juxtaposed with the contemporary look and feel of the extension.

The floor plan has been zoned to minimise lighting and heating requirements, while screened windows have been strategically positioned to help cross-ventilation and night purging during summer. Plants in the garden and external blinds help with sun control.

**Sustainable materials use**

The kitchen benchtop and most of the cabinetry were reclaimed from another demolition. The shelves are recycled Oregon timber. The builder put it all together, with some additional new cabinetry, in three days.

A reclaimed and refurbished clam-shaped basin is a feature in the bathroom. The concrete porch pavers laid in the back yard are reclaimed from the builder’s excess stock.
Case studies
Fitzroy North, Victoria

The pale colour of the extension’s new steel roof reflects heat and improves the home’s energy efficiency. The external walls are made from plywood, while the frame is radiata pine with plasterboard internal lining.

The slab is made of concrete with 30% cement replacement and 60% recycled aggregate. According to the owners, the cement replacement saved more than a tonne of carbon dioxide in the 14m³ of concrete poured for the extension. The slab edges were insulated to prevent thermal bridging.

Concrete is an excellent source of thermal mass, but the owners chose a slab floor because in their tight, hemmed in site they couldn’t excavate deeply enough for a timber one.

Windows and glazing

Argon-filled double glazed windows and a bi-fold door with western red cedar frames open onto the property’s long, narrow garden.

A double glazed skylight with toughened low-e glass lets natural light into the new bathroom. It makes the small 2.2 x 1.6m room seem larger as light bounces off the floor-to-ceiling mirrors on the rear wall.

Water saving

As part of the renovation, the owners installed a 2000L slim steel rainwater tank that fits into the tight space of their backyard. Its water is plumbed to the toilet, laundry and garden.

Mindful of the need to conserve as much water as possible, the owners installed a 4 star water-efficient wall-hung toilet suite in the bathroom, as well as 3 star taps in the bathroom and kitchen. Thanks to these measures, they save about 100L of mains water a day.

Rainwater captured in the slimline 2000L steel tank provides water for internal and external use.
Flooring and paints

The owners chose all-natural and renewable rubber tiles with low-VOC adhesive for the kitchen-dining area and the new bathroom. With concrete underneath, the rubber tile floor has a significant amount of give, and is more forgiving on the feet than vinyl or linoleum. A change in tile colour helps to conceptually divide the kitchen from the dining area.

Zero VOC paints were used in the renovation.

Energy saving

All appliances in the renovation are correctly sized and highly energy efficient, including an induction cooktop, a 4.5 star 350L refrigerator and a 6 star LED television. Appliances are wired to accessible relay switches to save stand-by power.

A small, secondhand energy-efficient power flued gas heater is the only source of active heating in the extension, providing radiant and convective heat during Melbourne’s chilly winters. The owners chose it rather than a more energy efficient reverse cycle air conditioning unit because such a unit would not give radiant heat and be a temptation to use in summer over existing passive cooling methods such as shading and opening windows for cross breezes.

Solar energy and hot water

The existing 835W grid-connected solar photovoltaic system was upgraded to 1.185kW with the addition of two 175W solar panels on the roof of the extension. The upgraded system is almost sufficient to meet the family’s net household demand.

A solar hot water system, consisting of 30 evacuated tubes and a stainless steel tank with instantaneous gas booster, was installed as part of the renovation.

Lighting

Light emitting diode (LED) lighting was installed in the extension and replaced inefficient halogen downlights in the existing part of the house. Two 12W screw-in dimmable globes went into the dining room, two 10W screw-in bulbs in the hallway, one 16W downlight in the bathroom, a 2m LED medium intensity strip light with 10W driver for kitchen bench lighting, two 10W downlights as halogen replacements for the stairs, and one 30W floodlight for the garden.
Insulation

The roof, ceiling and walls of the extension have been insulated with highly effective glasswool batts (80% recycled content) and foil sarking, with an R4.0 insulative rating in the roof and ceiling and R3.5 in the walls. An insulative paint additive was applied to the living room walls and kitchen-dining room ceilings to further improve the insulation quality of those rooms.

Evaluation

The owners are very happy with their renovated home. The most pleasing aspect was the shared vision they had with the tradespeople, who were prepared to work with their particular demands and requests. The job required working with an old house in confined, small spaces and the tradespeople accepted the nature of the work with little fuss.

The rubber floor tiling has proved to be one of the best aspects of the renovation. It’s comfortable and environmentally sustainable. The owners do warn that because the tiling they chose was imported from France, it required a much longer lead time than vinyl — sea freight takes up to three months; air freight is quicker but expensive. Such products need to be ordered as far in advance as possible, and slightly over-ordered to prevent a tile shortfall at installation and an air freight of tiles to finish the work.

Author

Alternative Technology Association, 2013
Perth, Western Australia

The Green Swing small-scale development features small building footprints for its two townhouses and two apartments, and large communal outdoor spaces. Two couples took the initiative to promote sustainable urban living on a site just 5km from the Perth CBD.

The dwellings’ impressive energy and lifecycle assessment results include a 10 star energy rating for one of the two-storey townhouses.

### Site, location and climate

The 837m² site in the Perth suburb of Lathlain met the developers’ needs for reduced car use. The site is within walking distance of the city, and shops, restaurants and entertainment. It is well serviced by public transport.

### Thermal comfort rating

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Heating</th>
<th>Cooling</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse brick veneer townhouse</td>
<td>0MJ/m²/year</td>
<td>3MJ/m²/year</td>
<td>3MJ/m²/year</td>
</tr>
<tr>
<td>Strawbale townhouse</td>
<td>4MJ/m²/year</td>
<td>7MJ/m²/year</td>
<td>11MJ/m²/year</td>
</tr>
<tr>
<td>Double brick apartment 9 stars</td>
<td>10MJ/m²/year</td>
<td>4MJ/m²/year</td>
<td>14MJ/m²/year</td>
</tr>
<tr>
<td>Double brick apartment 8 stars</td>
<td>14MJ/m²/year</td>
<td>16MJ/m²/year</td>
<td>30MJ/m²/year</td>
</tr>
</tbody>
</table>

### Sustainability features

- Insulation
- Double glazing
- Recycled materials
- Straw bale
- Low embodied energy
- Reverse brick veneer
- Solar hot water
- Solar photovoltaics
- Energy efficient appliances
- Energy efficient lighting
- Rainwater
- Greywater

### Project details

**Architect/designer:** Solar Dwellings  
**Builder:** Right Homes  
**Size:** 60m² to 75m² (One–two bedrooms) per dwelling  
**Size of land:** 837m²  
**Cost:** Total project costs including land acquisition $1.9–$2 million

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The Green Swing small-scale development features small building footprints for its two townhouses and two apartments, and large communal outdoor spaces. Two couples took the initiative to promote sustainable urban living on a site just 5km from the Perth CBD.

The owners have also rejuvenated the adjacent vacant land with a community garden.
Case studies

Perth, Western Australia

being just 400m from a train station, and is on a bike path to the city.

The neighbouring vacant land, containing a stormwater drainage pit, was a key factor in deciding to buy the property. The developers requested and received council permission to build a community garden and revegetate the site for use by residents and the neighbourhood.

Solar access is best at the rear of the long and narrow site. Orientation is good, being 35° off north, yet consideration was needed to get the best orientation for multiple properties. A goal of 60% outdoor space in the development also presented a challenge when fitting several buildings on the narrow block.

The local climate is hot and dry in summer, but benefits from a cooling southerly sea breeze, the ‘Fremantle Doctor’, on most afternoons. Winter is relatively mild with an average daily temperature of 18°C but temperatures can drop to below 10°C at night.

The development includes two townhouses and two apartments surrounded by edible and waterwise gardens. The owners wanted zero emission homes, or at least very low energy use, meaning careful consideration of passive design principles to allow natural heating and cooling as well as solar access for renewable energy systems. (see Carbon zero, carbon positive)

Design response

The design presented two townhouses and two apartments surrounded by edible and waterwise gardens.

Increasing the number of dwellings from three to four met the developers’ goals for a community feel. The intended third townhouse became two apartments, one downstairs and one upstairs.

Three main building materials were chosen for their thermal efficiency and insulating properties. One townhouse is reverse brick veneer and the other straw bale combined with reverse brick veneer; the two apartments are insulated double brick. The reverse brick veneer and double brick are high in thermal mass, helping achieve passive design and energy efficiency goals.

Design brief

The developers’ clear goal was to create a sustainable urban environment. They wanted a showcase for increased density housing that set new precedents for townhouses and apartments close to the city. The development needed to incorporate at least three dwellings including one for each party (a couple and a family of five.)

The three very important elements in the design brief were to create a design that encouraged a sustainable community, have a small footprint for the dwellings and limit car impact. All are related to an overarching goal to maximise shared outdoor space.

Straw bale was specified for one townhouse because it is a renewable building material and provides a high level of insulation.
Each building occupies a small footprint of around 60–75m². However, building on two levels has opened up available floor space in each townhouse to 120–150m². The floor space in each apartment is around 60–65m² with a 45m² loft expanding the space in one. The small floor areas reduce building waste and help achieve a goal of 60% outdoor space.

To keep the dwellings small, the size needed for each room has been carefully considered. The children’s bedroom in the reverse brick veneer townhouse can be converted to two bedrooms in the future. Lofts create more storage or living space in otherwise unused ceiling and roof areas. Usual indoor activities, such as watching movies, can happen outside in the shared communal space.

Car parking to the front of the property makes a short driveway possible and ensures more open space elsewhere; it also allows all living areas to face the northern rear of the block. The development benefits from a shared undercover area, outdoor kitchen and communal gardens where a driveway might have been.

The design encourages residents to see each other, creating a stronger community. The dwellings cannot be accessed from within the garage; residents must walk outside the garage and use the front door. The entrances to all three buildings face a communal courtyard.

The dwellings require no mechanical heating and cooling due to their energy efficient design. This is achieved with concrete slabs-on-ground combined with thermal mass in walls, high levels of insulation and double glazing, and windows to the south-west for cooling sea breezes and natural ventilation. A common bike storage area on the western wall of the strawbale dwelling doubles as extra protection from the hot summer sun. Breezes from the surrounding garden help cool the homes.

The buildings are designed and orientated for renewable energy systems so that zero greenhouse gas emission goals can be met. The homes are orientated 15°C off north and the pitch of the roofs are maximised for solar photovoltaic panels.

The design was revised to ensure the homes met low greenhouse gas emission goals. Elements such as window size, differences in orientation and wall type were improved to increase the home energy rating. The strawbale dwelling has a 9 star rating, the reverse brick veneer a 10 star rating and the double brick apartments rate 9 and 8 stars.

Insulation
The strawbale walls have an estimated insulation benefit between R5.5 and R8.5. Other walls and ceilings in the strawbale townhouse are insulated with a local product made from up to 85% recycled materials including plastic bottles. The upstairs and downstairs ceilings have high-rating R4 insulation for maximum effect; the reverse brick veneer walls are insulated with R2.5 batts.

The reverse brick veneer townhouse has R2 wool insulation between the wall framing and in the upstairs ceiling. The external cladding is 75mm R2.5 polystyrene, giving the wall an estimated R-value of 4.5. The downstairs ceiling is designed without insulation to enable a thermal connection between the downstairs bedrooms and upstairs living area. (see Insulation)

Double glazing
Double glazed windows with FSC-certified hardwood frames are installed throughout. The windows are imported from the Netherlands (see Glazing). Louvred awnings on the northern façade shade the windows.
Case studies
Perth, Western Australia

Recycled materials
Most of what would normally go to landfill has been recycled or reused. The gable ends of a loft have been insulated with insulation offcuts. The clients asked the builder to use chipped bricks ordinarily thrown out. Waste minimisation has been a success due to negotiation between the clients and the various tradespeople.

Materials from a demolished house in Perth were used extensively, including recycled jarrah timber for the solar and louvred awnings. The loft in the reverse brick veneer dwelling is made from recycled floorboards and the flooring is made from granite bench top remnants. (see Waste minimisation)

Straw bale
Straw bale was specified for one townhouse because it is a renewable building material with a high level of insulation. The east and west walls are constructed from around 250 straw bales and have a clay and lime render which provides some thermal mass. (see Straw bale)

The north and south walls are reverse brick veneer, providing additional thermal mass to help with passive heating and cooling. The stud-framed walls upstairs are filled with loose straw and also rendered, limiting the use of plasterboard.

Reverse brick veneer
The other townhouse is reverse brick veneer, selected for its high thermal mass and insulation. The wall structure includes an internal wall made from new face bricks with a structural, insulated timber frame and is clad with an external rendered polystyrene layer, making it thermally tight. (see Brickwork and blockwork)

Low embodied energy
Several measures implemented from a life cycle analysis help to reduce embodied energy. The slabs are poured from a more environmentally sustainable concrete made with recycled aggregate and fly ash. Some dwellings have a lightweight timber structure. Some face brick is used instead of a rendered and painted finish. (see Embodied energy)

Solar hot water
All dwellings have flat plate solar hot water systems. The systems in the apartments have a tank capacity of 180L making them efficient at heating water for a smaller household. The townhouse tanks have a 300L capacity. (see Hot water service)

Solar photovoltaic systems
Each apartment has a 1.5kW solar photovoltaic system on the shared roof, the strawbale townhouse a 3kW system and the reverse brick veneer townhouse a 2.7kW system. The 3kW system has strong returns with bills showing that it covers more than the household’s electricity usage.

Energy efficient appliances
The dwellings have electric induction stoves, considered efficient because they only heat what they come in contact with. The owners prefer induction cooking to gas cooking because gas is non-renewable, and gas fumes can have a negative impact on indoor air quality, particularly in small, well-insulated homes.

Rainwater
Each townhouse has a 4500L metal rainwater tank; the apartments share a 4000L poly tank. Rainwater is plumbed to the entire strawbale townhouse while the other dwellings have rainwater plumbed to the toilet and washing machine.
The apartments share a 4000L poly tank. The developers wanted all outdoor areas, except the private courtyards, to be commonly owned, but planning policies stated that each grouped dwelling needed an exclusive use area of 200m². The developers had to produce a map showing this was achievable but never used it for strata titling purposes: it could be used for future strata arrangements.

Plans to place dwelling entrances away from the street and garages close to the street — important design features for car access and community — did not fit with planning regulations. Placing windows on the roadside, introducing eaves and gables, and facing the garages inward, softened the garages.

The WA Department of Health granted its first ever exemption under conditions from standard health guidelines that prohibit shared rainwater tanks and the dispersal of greywater over common areas. The owners pursued this exemption so that other developments could have shared water saving systems.

The Green Swing is a success because the developers persisted with negotiations on these policies and regulations. They set new sustainable design and building standards in the area. The development is a constant work in progress for residents, particularly revegetating and rejuvenating the adjacent land for community use. Future plans include another development in the same street.

Author
Alternative Technology Association, 2013

Greywater
All dwellings are greywater ready with dual plumbing to enable wastewater to be reused. Currently, the costs of a filtration system and government regulations mean only one property can disperse greywater over the common gardens.

Evaluation
The developers negotiated resolutions to several planning issues and other regulations so they could implement important sustainability features.

The proposed mixed development exceeded minimum site requirements for the space allocated to each home, so the size and layout of the dwellings had to be adjusted.