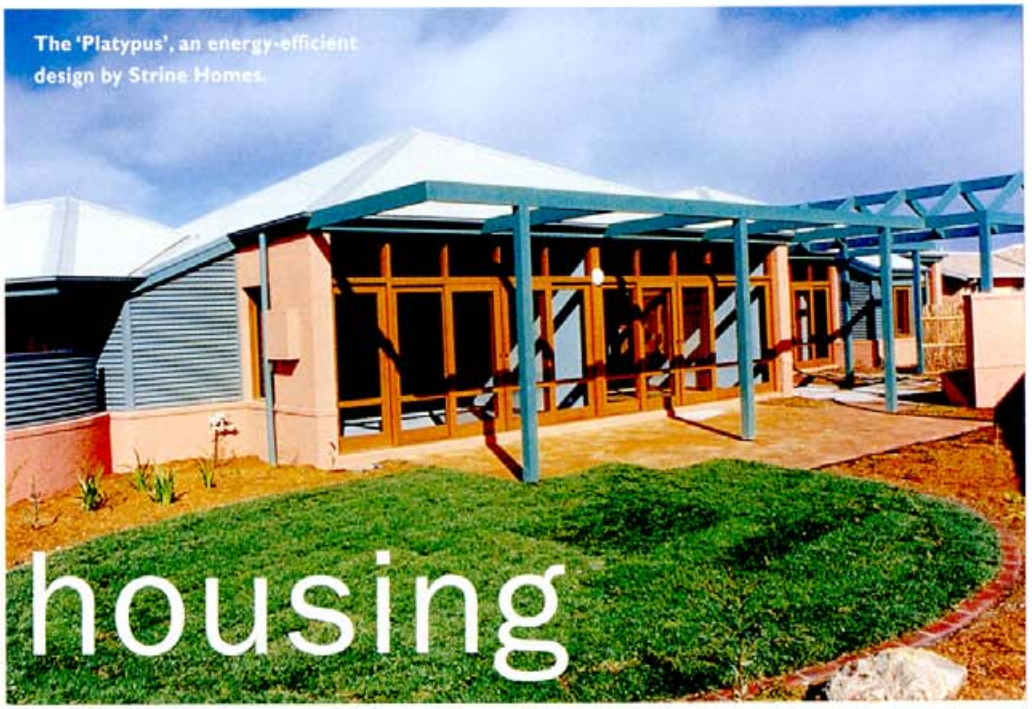
Energy-efficient homes don't cost the earth, so why aren't we demanding them? Australia's need to limit greenhouse gas emissions just might force a change. **Bryony Bennett** reports.



The 'Platypus', an energy-efficient design by Strine Homes.

Green housing

The basic tenets of energy-efficient design for Australian homes have been understood for decades. A flurry of research on the subject followed fuel price rises linked to the 1970s Middle East oil crisis. It was during this era that Ron Ballantyne and his colleagues at the former CSIRO Division of Building Research decided to put the principles of energy-efficient design to the test.

Ballantyne's team used computer modelling to measure the effects of building design on interior temperatures, and the subsequent need to heat and cool. Their findings quantified the value of elements such as insulation, orientation for solar access, window size, placement and shading, draught reduction, and the heat-storage capacity of floors and walls.

Continued development of the model led to the release in 1981 of a software package that Ballantyne envisaged would be used routinely to calculate the expected energy consumption of new home designs, and to improve their thermal performance. But it's taken a new challenge to our burgeoning energy use – global warming – for Ballantyne's vision to finally materialise.

Under the Kyoto Protocol to the Framework Convention on Climate Change, Australia has agreed to limit its greenhouse gas emissions to 108% of the 1990 level by 2008–2012. Some 13% of these greenhouse gases are emitted by houses, and about one eighth of that 13% comes from space heating and cooling.

This proportion is set to magnify as Australia's population – projected to reach some 21 million by 2010 – expands into new homes equipped with central heating and air conditioning systems. Australia's agreement to cap greenhouse emissions is absolute and has been made irrespective of population growth and changes to industry that occur during that period.

According to a study for the Australian Greenhouse Office by Victorian consultants Energy Efficient Strategies, space heating and cooling accounted for 39% of energy use in residential buildings and 15% of the sector's greenhouse gas emissions in 1998.

The study projected energy consumption and greenhouse gas emissions from 1990 to 2010 for four standards of home construction. It found that greenhouse gas emissions from space heating and cooling could grow as much as 40% in that period, depending on steps taken to improve energy efficiency (see graphs on page 26). This projected growth rate was considerably higher than for water heaters and household appliances.

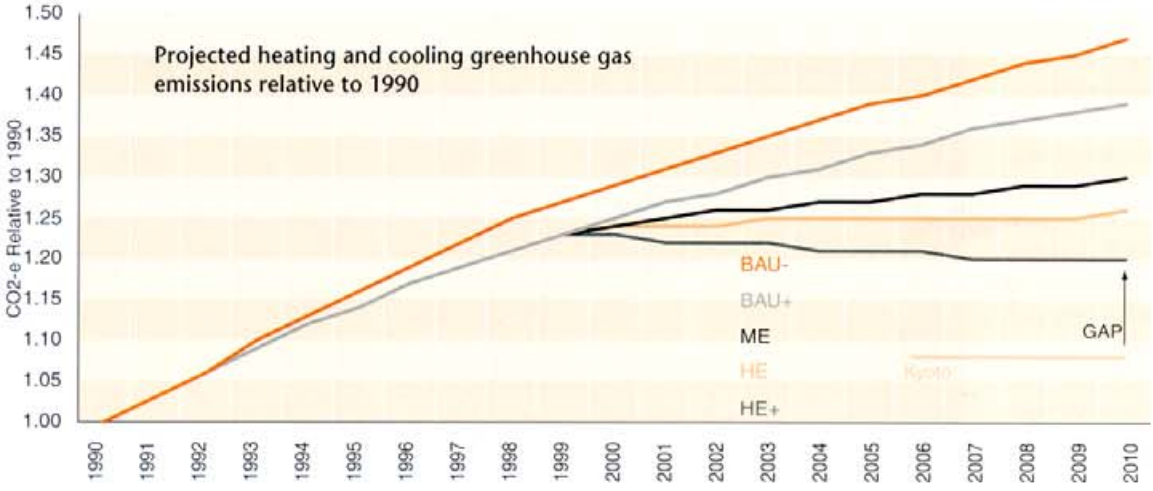
Energy Efficiency Strategies concluded from the study that by greatly improving the thermal performance of new homes from 2000 onward, Australia could go a significant way towards meeting greenhouse gas reduction targets for the residential building sector. These benefits would continue to accrue well beyond the Kyoto compliance period.

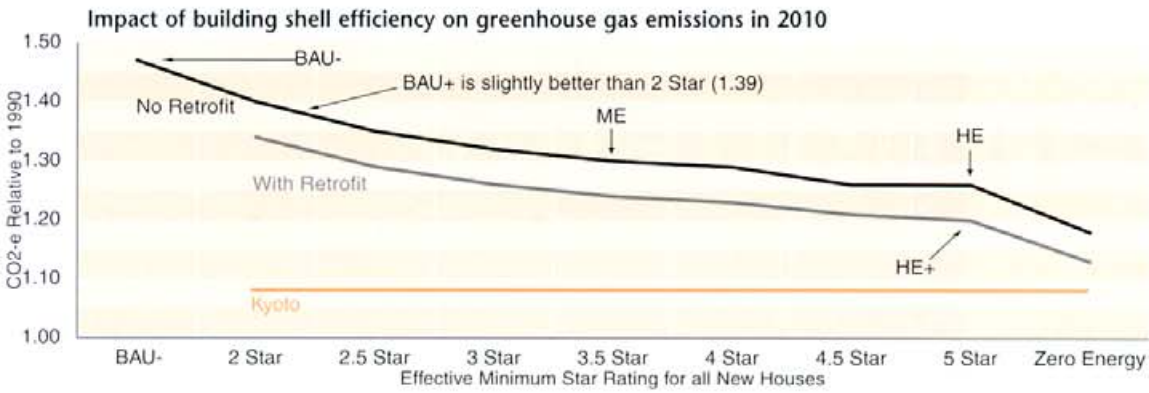
Australia established the voluntary Nationwide House Energy Rating Scheme (NatHERS) in 1995. Under the scheme, new homes receive a star rating of 0 to 5 according to the energy efficiency of the building 'shell'. The rating reflects the home's annual heating and cooling requirements, as projected by software also known as NatHERS (Nationwide House Energy Rating Software). The minimum-standard 5-star home uses 30% less energy for heating and cooling than a home rated 3.5.

The software, developed by Dr Angelo Delsante and his colleagues at CSIRO Building Construction and Engineering, builds on the pioneering work of Ron Ballantyne. For each home it assesses the effects on interior temperatures of design elements such as insulation levels, window orientation and size, building materials and ventilation, according to local climate conditions. As well as providing a star rating, it identifies areas of potential improvement.

The software is also employed at a broader scale to research the potential outcomes of energy-efficiency policies. Some 3000 runs of the model provided home-energy-use projections for the report by Energy Efficient Strategies, and in a study for Energy Efficiency Victoria will be used to optimise solar access in medium-density housing.

Tony Isaacs of Energy Efficiency Victoria says NatHERS provides a fundamental underpinning to all house energy rating schemes of Australia. 'Energy efficiency in





Scenarios projected in the study by Energy Efficient Strategies

BAU+ (business-as-usual with measures) – this assumes that dwellings continue to be constructed to today's standards.

BAU- (business-as-usual without measures) – as for BAU+, but without measures introduced from 1990-1997.

ME (medium efficiency) – as for BAU+ with the addition of a 3.5-star effective building shell requirement for all new dwellings from 2000.

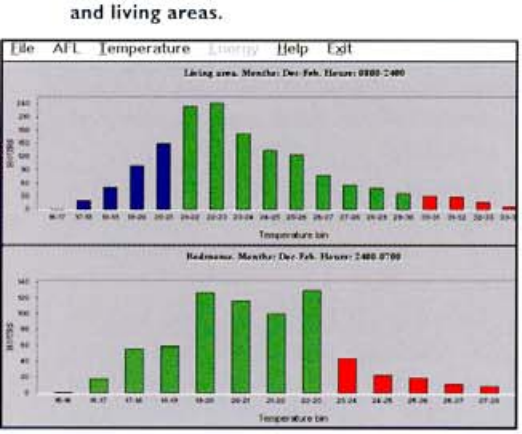
HE (high efficiency) – as for BAU+ with the addition of a 5-star effective building shell requirement for all new dwellings from 2000.

HE+ (high efficiency plus) – as for new dwellings, but also assumes improvements in the thermal performance of existing dwellings through a program to retrofit ceiling insulation.

Note: The term CO_2-e refers to the net carbon dioxide rom combustion of the specified fuel(s) plus the equivalent global warming potential of associated emissions (methane and nitrous oxide).

Above: The study by Energy Efficient Strategies simulated the impact of improved building shell thermal performance on greenhouse gas emissions for space heating and cooling in 2010. The 'with retrofit' option assumes ceiling insulation is installed in existing homes. The 'zero energy' option assumes all new houses from 2000 use zero net energy for heating and cooling. Even this optimistic scenario is unable to achieve the Kyoto commitment for Australia, mainly because of the limited proportion of housing stock affected between 2000 and 2010. With houses constructed in Australia at a rate of 2% per year, less than 20% of homes can be affected by energy-efficiency measures that target new buildings in the next 10 years.

Below: An output from NatHERS showing expected summer temperatures in bedrooms and living areas.



Australia would be set back years and years if CSIRO gave up on this research,' he says.

Star performers

Some governments have been quick to embrace the Nationwide House Energy Rating Scheme. In Victoria, which has had its own program since 1991, new homes must either be insulated to a specified level, or qualify for 3 stars. In NSW, five out of 177 local councils have a mandatory new-home rating of 3.5 stars under the state's Energy Smart Homes policy. All new homes in the ACT must achieve a 4-star rating, and since April this year, all homes for sale in the ACT have had to be star rated, with the rating included in all advertising.

To ensure the other states don't lag too far behind, the Australian Greenhouse Office, together with the building industry, is examining the possible inclusion of minimum energy performance standards – for non-residential and residential buildings – in the Building Code of Australia. A research team led by Robin Drogemuller of CSIRO Building Construction and Engineering is investigating the practicalities of such a change. Their findings will be presented to the Australian Building Codes Board for a decision on whether and how such changes would be implemented.

The team will identify building characteristics that affect energy efficiency, but are not covered in the existing code, and suggest ways of including them without compromising other code objectives. For example, the sizing of windows can affect natural lighting levels as well as energy efficiency. Also to be determined is the minimum mandatory standard for thermal performance, and the methods by which builders can comply.

According to the Australian Greenhouse Office, the aim of setting a mandatory standard is to eliminate industry worst practice. The advancement of best practice will be the bailiwick of the building industry. A possible scenario is a minimum mandatory rating of 4 stars, supported by incentive schemes which reward builders whose homes achieve higher ratings.

Tony Isaacs believes design awards run by the Master Builders Association and the Housing Industry Association (HIA) have provided a good beginning. Energy Efficiency Victoria has been energy-rating all award entries in that state for the past five years, noting an increase in the incorporation of energy efficient principles. 'We would like to think this process has helped to educate both builders and consumers about energy efficient design,' he says.

Isaacs says energy-efficient design can reduce heating and cooling costs by up to 40%. 'An energy-efficient house will be up to 5°C warmer in winter and 10°C cooler in summer than the average Victorian home,' he says. 'Over the heating season, a typical 5-star home could save some $400 in heating bills and reduce greenhouse gas emissions by four to five tonnes a year.

'Even at $2000 extra for an energy efficient home – and most do not cost that much extra – mortgage payments only increase by about $130 per year. A 5-star home would easily save its occupant $200 per year in energy bills meaning that even though the up-front price of the house is greater, it is actually cheaper than an energy inefficient home.'

But is this message reaching enough builders and homebuyers?

According to the report by Energy Efficient Strategies, there is generally little incentive for builders to increase the thermal performance of new homes. 'The buyers of buildings rarely specify measures that directly affect the energy efficiency of the building (such as orientation, glazing, insulation levels) and there is intense competition within the industry to minimise costs,' the report says.

'Builders do not pay the ongoing energy bills, so unless the ultimate occupant commissions the design, is involved prior to the construction and/or is aware of building shell energy efficiency issues, there is no direct market incentive to improve thermal performance. Given the relatively poor average thermal performance of typical new dwellings in Australia, it would appear that occupants exert little influence on these aspects.'

HIA national technical director, Graham Wolfe, acknowledges the industry has a role to play in meeting greenhouse gas emission targets. But he says its capacity to do so will rely on the benefits of energy-efficient design being sufficiently demonstrated to building industry participants and homebuyers.

'People are pushing themselves to the limit in buying their homes,' Wolfe says. 'An extra $500 up front can make a significant difference to their economic position. We need public education so that people can see the tangible benefits.

'For example, the benefits of insulation have been promoted for many years, but the benefits of orienting homes for solar access rather than outlook can be questioned. Telling homebuyers they can't orient their dream home on the site they want can be difficult for them to comprehend, particularly when the outlook is very important to them.'

Wolfe says the move towards higher standards of energy efficiency will also require some sections of the industry to 'retool', as energy efficient building products such as double glazing are not standard features

Cool designs for **northern** exposure

ENERGY-EFFICIENT housing in the tropics doesn't have to cost the earth, according to Townsville architect Ralph Power.

'Affordable houses that don't require air-conditioning can be built using conventional building methods,' Power says. 'It's just a matter of good planning and design.'

Power says maintaining air cross-flow and protecting walls and windows from direct sunlight are design priorities. This can be achieved using louvred, full height windows, shading of walls and windows through screening and overhangs, ceiling ventilation and the right garden plantings. Correct orientation, roof insulation and light-coloured exteriors are also important. Power applies these principles to eliminate the need for air-conditioning in both private and public housing.

Professor Richard Aynsley, UNESCO Professor of Tropical Architecture at James Cook University's Australian Institute of Tropical Architecture, says many new homes built in the tropics look much the same as those in Adelaide, Brisbane and Sydney.

'Builders copy these designs because they think that's what people want,' he says. 'But they can still incorporate some of the energy-efficiency principles of the traditional Queenslander.'

Aynsley agrees with Power on the importance of windows and ventilation. 'Windows are the weak link in Australian homes,' he says. 'Few of the new homes built up here have any form of window shading at all.'

He says in tropical, coastal areas such as Townsville, naturally ventilated houses work well in terms of energy efficiency.

'You get a cooling effect of 3.5°C for every metre per second of airflow,' he says. 'A well-designed home which relies on ceiling fans for cooling at the hottest parts of the day and at night when there is less breeze will use only 2% of the energy of a fully air-conditioned home.'

Aynsley says partial air-conditioning offers a way of reducing cooling costs in larger buildings such as offices and schools. In this system cool air is introduced to the lower two metres of the room, creating a 'cool pool' where people need it.

Such a system was installed in the old Townsville customs house, saving 85% of the cost of full air-conditioning, and 30% on annual operating costs. A similar effect could be achieved in houses by placing air conditioners lower on the wall.

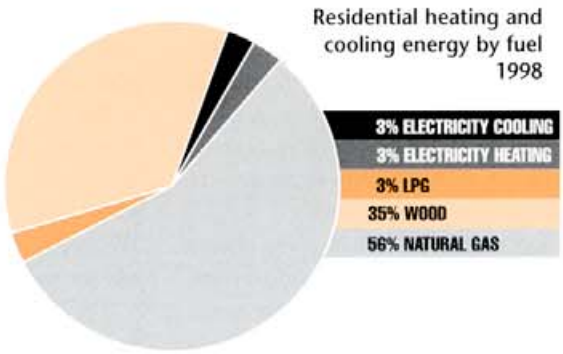
Aynsley says the Nationwide House Energy Rating Software, which was designed for 'closed environment' buildings, is currently not endorsed for use in Queensland as it does not account for the cooling influence of natural ventilation on building occupants.

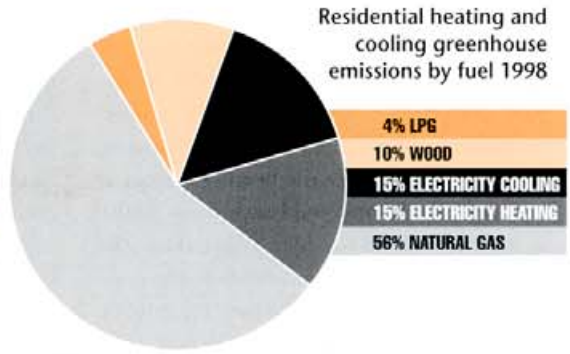
Ralph Powers incorporates energy-efficient design principles in both private and public housing. These units were commissioned by the Queensland Government.

There are plans to address this issue in later versions of the software.

'You need to be able to factor in physiological effect of air flow, which can't be measured on a thermometer,' he says. 'It will require a change of focus from energy use to comfort.'

Space heating and cooling accounted for 39% of energy use and 15% of greenhouse gas emissions from residential buildings in 1998, according to the study by Energy Efficient Strategies. The lower percentage for emissions reflects the extensive use of natural gas, a less greenhouse gas intensive fuel source than electricity.





and therefore tend to be more expensive. But there is an argument counter to this that the price of energy-efficient building products may fall as demand increases.

Experience in Victoria and the ACT has shown that energy-efficiency ratings of 3–4 stars can be achieved without radical changes to home design, or significant cost increases. The simplest way to improve thermal performance is to insulate floors, ceilings and walls, and, importantly, orient the building in the most favourable direction.

Trevor Lee, of the Canberra-based consultancy Energy Partners, trains and advises the assessors who use ACTHERS, a simplified, local version of NatHERS, to rate new ACT homes. Lee says the introduction three years ago of mandatory 4-star ratings has not led to dramatic changes in ACT building practices. But it has raised the thermal performance of new homes from 1.5 to 4 stars.

'The industry was uncomfortable with the idea at first, but because of existing compulsory insulation standards, we were already doing much better than the Australian average,' Lee says.

He says one change to building practices has probably been an adjustment in window sizes: larger facing north and smaller facing west. But where the windows face west for the view, protection from direct solar gain must be included in the buildings design.

A drawback of the ACT scheme is that it offers no special recognition for builders whose homes are so efficient they rate off the scale. 'It's quite feasible to design a 7–8 star performer in the ACT because of our benign, crisp sunny winter and mild summer,' Lee says. Such homes would use 70–80% less energy for heating and cooling than a home rated 3.5. Indeed, there are builders in the ACT who market homes they say need no heating at all.

Raising the standard

Given the ease with which ACT builders can meet the 4-star rating, should a mandatory national standard be higher?

Robert Foster and Lloyd Harrington of Energy Efficient Strategies believe it would need to be for the residential building sector to contribute its pro rata share of greenhouse gas reductions.

'It makes no sense for Australia to have such low standards,' Foster says. 'We talk about working smarter, the building industry needs to do that as well: not just faster and cheaper, but to be environmentally responsible.

'Our (AGO) study showed that unless we set a minimum 5-star rating, we won't go anywhere near limiting greenhouse gas emissions resulting from the heating and cooling of our homes to 108% of 1990 levels. I've yet to hear a good reason why we shouldn't go to 5 stars.'

Foster concedes that from an industry viewpoint there would be merit in phasing in such a standard. But it should be remembered that 'new houses will last 50–100 years so whatever decisions are made now will have an impact on Australia's greenhouse gas emissions for the next 100 years'.

He says that by overseas standards Australia's 5-star home rating would be considered to represent only a 'very mediocre' level of thermal performance.

Harrington says design factors such as orientation and window placement can have a large impact on thermal performance and can be included during the design process at close to zero cost. But responsibility for the orientation of housing lots extends beyond the building industry.

Warming ways

CANBERRA architect Rick Butt of Strine Homes says one of the keys to stimulating demand for low-energy homes is to make them look good. Butt, a former president of the Royal Australian Institute of Architects, designs homes with internal and external concrete walls that collect and store solar heat during the day and release it at night. Some designs feature a gently curved roof and ceiling which creates convection currents that assist the passive heating of the entire house. Butt says he has created homes that require no heating or cooling, even as far south as Hobart.

Some states have guidelines for the development of energy efficient subdivisions that provide for good solar access and facilitate correct orientation. In the ACT, residential subdivisions with more than 30 lots have to meet a minimum requirement for solar access. Harrington says government could play a stronger role in mandating energy efficient requirements for subdivisions, particularly in respect to orientation for solar access.

Tony Isaacs agrees that subdivision is 'an important part of the story'.

'It's much easier and cheaper to achieve a 5-star home rating on a block with good solar access,' he says. 'Victoria has subdivision guidelines designed to protect solar access, but I still see plenty of really bad developments. There's certainly a need to educate the people responsible for subdividing the lots: developers, local governments and surveyors.'

On some sites, adequate solar access is difficult to achieve. Overshadowing can occur due to sloping terrain, or in medium density developments. Some 30% of new homes in Victoria and the ACT are medium density. But Foster says this need only be a problem for the 'uninspired' building designer.

'You don't need perfect blocks, you just need to understand the principles of energy-efficient design,' he says. 'It may be a bit more expensive, but it's not impossible. If the 5-star minimum was implemented, house builders' priorities would start to include the need for good solar access and eventually land developers would have to start redesigning subdivisions.'

Deemed to comply

Builders are likely to be given at least two ways of proving the thermal performance of their homes. For the more adventurous among them, NatHERS and its local derivations will offer a route to design flexibility and the exploration of passive solar design.

'Even if you have no background in energy-efficient design, you can put in an initial design, see quickly where weaknesses are and take steps towards making improvements,' Foster says. 'It's an interactive learning tool. It offers pathways to getting good performance out of buildings and can help builders and designers to understand the economics of different design options.'

A prescriptive method that involves working through a checklist of building characteristics is also being considered. 'For energy efficiency to work, we have to provide multiple methods of checking thermal performance, depending on the level of sophistication of the users,' Drogemuller says.

NatHERS is being continually updated by its CSIRO creators. Future versions will address the treatment of home designs in warm-humid and hot-humid climates (see story on page 27), will account for the influence of home occupants on modulating heating and cooling levels, and may expand the star band to include a 6-star rating.

Another possible addition is the facility to predict household greenhouse gas emissions, which depend on fuel choice as well as energy consumption. 'Fuel choice has a significant impact on greenhouse gas emissions, Drogemuller says. 'For example, electric power measured at the meter produces four times as much greenhouse gases than burning natural gas.'

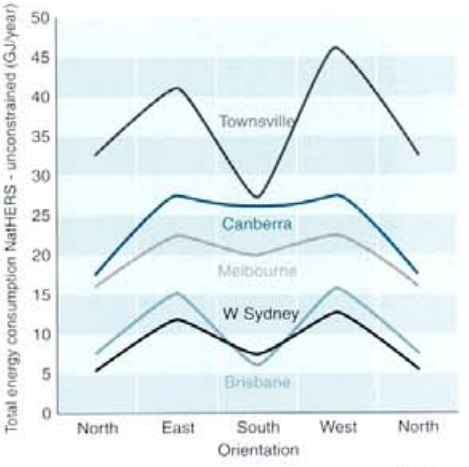
Then there's the emerging issue of embodied energy.

Embodied energy is the amount of energy required by all of the activities associated with the production process. The embodied energy of building materials varies widely, with concrete and steel at the higher end, and timber and stone at the lower end of the scale. Studies have suggested that the energy embodied in house construction is equal to about 15–20 years of its operational energy.

Consideration of the embodied energy of building materials adds a whole new layer of complexity to the energy-efficiency equation. That's because design changes that improve a dwelling's thermal performance might favour building materials with higher embodied energy. To steer a path through this apparent conflict, home energy assessments of the future may calculate the time taken for savings in operational energy to 'repay' the additional embodied energy inherent in its construction.

Prototype software for estimating the amount of embodied energy, and the greenhouse gas emissions generated through energy consumed in these processes, has been developed by Dr Selwyn Tucker and his colleagues at CSIRO Building Construction and Engineering. And there lies another story . . .

Effect of orientation on a passive solar design house by climate zone



Homes with predominantly east or west facing windows perform poorly in all climate zones. (Source: Energy Efficient Strategies, 1999.)

More about energy-efficient housing

Bell A (1983) Lessons from a solar house, *Ecos* 36, pp3-6.

Energy Efficient Strategies (1999) *Australian Residential Building Sector Greenhouse Gas Emissions 1990–2010, Final Report*. Australian Greenhouse Office.

King S Rudder D, Pradsad D and Ballinger J (1996) Site planning in Australia, Strategies for efficient residential planning. Department of Primary Industries and Energy.

Pears A (1998) *Strategic Study of Household Energy and Greenhouse Issues*. Environment Australia.

Prospects for solar air-conditioning (1977) *Ecos* 12, pp19-23.

Abstract: Insulation, orientation for solar access, window size, placement and shading, draught reduction, and the heat-storage capacity of floors and walls have been long accepted as important elements of energy-efficient design in Australian residential buildings. As Australia prepares to meet its commitments to greenhouse gas reduction, ways of promoting the incorporation of these principles in new home construction are being explored. This would reduce energy consumption and greenhouse gas emissions from residential heating and cooling. One option being considered is the addition of mandatory energy rating standards to the Building Code of Australia, supported by building industry incentive schemes. Nationwide House Energy Rating Software is a possible tool for demonstrating compliance with the code.

Keywords: energy efficiency, architecture, houses, interior temperatures, heating systems, cooling systems, energy consumption, Nationwide House Energy Rating Scheme (NatHERS).