Athens Institute for Education and Research
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ATINER's Conference Paper Series
CON2012-0248

Can Sustainable Housing Construction be Affordable?

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URL Conference Papers Series: www.atiner.gr/papers.htm

Printed in Athens, Greece by the Athens Institute for Education and Research.

ISSN **2241-2891**
19/09/2012

An Introduction to ATINER's Conference Paper Series

ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

Dr. Gregory T. Papanikos
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Athens Institute for Education and Research

This paper should be cited as follows:

Robson, K. (2012) "**Can Sustainable Housing Construction be Affordable?**" Athens: ATINER'S Conference Paper Series, No: CON2012-0248.

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Abstract

It is a commonly held belief that building sustainable houses is more expensive than using traditional construction materials. Given Australia's housing affordability crisis, the implementation of mandatory 5 and now 6 green star ratings has caused controversy due to the increased cost to buildings. There is a general trend in the literature that housing affordability and sustainable initiatives are mutually exclusive. In the context of ensuring that Australian housing in the future is both sustainable and affordable, there needs to be a focus on which practices contribute the most in terms of overall benefit, both financially and sustainably.

This research examines a number of construction sustainable technologies to determine which have the greatest benefit for affordable housing construction. The methodology provides an analysis of the qualitative data in the form of a questionnaire presented to industry professionals. The quantitative data will involve a comparison of a number of sustainable and standard technologies currently used in housing construction. The research analyses the current sustainable building methods and technologies available including: energy use in residential buildings, sustainable aspects of ventilation systems, sustainable facade/HVAC, double skin facades, rain water harvesting tanks and grey-water/black-water recycling. In addition, the materials used in buildings and building design and fit-out of buildings have also been examined in terms of sustainable benefits and the question of affordability.

The findings of the research indicate that some of the most likely cost/benefit technologies that can assist with sustainable construction include the use of double skinned facades and energy saving appliance technologies. When these are coupled with the relatively low costs of smart design and building orientation, it is possible to achieve significant benefits in heating and cooling at very small increases in the unit cost. Although there are many sustainable building innovations that can be installed in residential buildings it is still possible to make use of the cost effect ones, to ensure that new housing construction remains affordable.

Keywords: Sustainable, energy efficient, affordable Housing

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Introduction: The concept of sustainability in the building industry

The concept of sustainability is a major issue affecting Australian society. There has been phenomenal growth in sustainable development around the world, as a result of several environmental initiatives such as the Kyoto protocol and AGENDA 21 (Kato & Murugan 2010). The trend of sustainable development seems set to continue due to the benefits to society, the environment, economy and future generations. A major focus of sustainable efforts has focussed on sustainable development in the construction industry (Dimson, 1996). This is due to the fact that construction and its related activities are a large, if not the largest area of environmental damage in the world. Buildings consume 16 percent of the world's water and 40 percent of its energy (Dimson, 1996). Through sustainable initiatives however, society has the opportunity to improve on this record so that future generations can benefit. The Building Code of Australia (BCA) has taken steps to improve sustainable practices in Australian. Since 2003 they have mandated energy efficiency provisions across Australia, in order to achieve a 3.5 to 4 star rating. Victoria has implemented a 6 star House Energy Rating (HER) since 1st May 2011, mandating that every new home, alterations and addition will need to comply with the increased House Energy Rating (Australian Government, 2011). While the BCA has continued to increase the mandatory House Energy Rating's and focus on sustainable initiatives, there has also been a housing affordability crisis in Australia. A recent Master Builders Association (MBA) survey showed that "Victoria's five-star minimum energy rating added $7600 to the cost of a new house, and that six and seven-star ratings would add $10,000 and $14,000, respectively" (Craig, 2008, p1).

Green Star Ratings in Australia

The Building Code of Australia's Green Star ratings are derived from modelling a buildings required energy used for its heating and cooling. The star rating system currently operates on a 10 star system. A rating of 0 stars indicates that a building doesn't provide any meaningful insulating properties. A 5 star rating indicates that a building has a good thermal performance. A 10 star home would be unlikely to need require electrical heating or cooling (Australian Government, 2011). A 6 star BCA for housing now includes energy provisions for:

- **"Building Fabric:** installation of insulation and the use of light roofing colours
- **External Glazing and Shading:** Restricting maximum window sizes and/or using thermally improved glazing
- **Building Sealing:** Using seals around doors and windows
- **Air Movement*:*** Minimum opening areas and breeze paths to allow free cooling

- **Air Conditioning and Ventilation Systems:** Insulating and sealing ductwork and
- **Hot Water Supply:** Insulation of the unit and piping and for energy efficient hot water heaters (including solar, heat pump and gas systems)" (Technical Bulletin, 2010, 2).

While the move towards sustainable initiatives through increasing Green Star rating requirements does add to housing costs, the Green Building Council has advised that household costs over the long term would be reduced. They suggest this is a factor that is important, given the fact that the price of water and energy will increase in the future (Green Building Council of Australia, 2011).

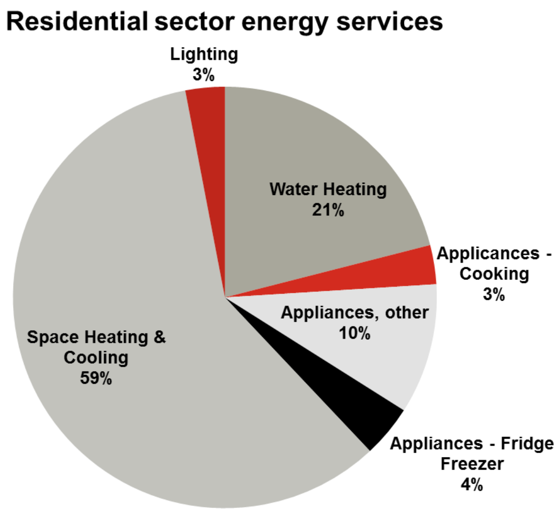
Housing Affordability

Australia has some of the most unaffordable housing market according to the Sixth Annual Demographia International Housing Affordability Survey published in 2010. Housing in Australia has risen due to a number or factors including; increases in construction costs, shortage of land supply and Government policies such as negative gearing and grants. In addition, lower interest rates and speculative investments in housing, has also helped to dramatically increase house prices across Australia in the last decade (Housing Affordability Trend, 2010).There is a general trend in the literature that housing affordability and sustainable initiatives are mutually exclusive. Indeed, defining affordability and taking both a short and long term analysis of these concepts will provide very different results. In addition, the issue of affordability and sustainability will be different for the variety of stakeholders involved such as the Government, developers, home owners, investors, tenants and environmentalists. The introduction of 5 and 6 Green Star ratings take into account sustainability from a holistic perspective. They do not, however, provide an analysis or additional weighting towards the most economical sustainable initiatives, in terms of a cost to benefit analysis. In the context of ensuring that Australian housing in the future is both sustainable and affordable there needs to be a focus on what practices contribute the most in terms of overall benefit. Housing affordability relates to a person's ability to pay for their housing. It is complex issue, impacted by the local housing and labour markets as well as larger economic, environmental and social forces. When people struggle to meet the cost of housing, researchers describe it as housing affordability stress. In Australia, the affordability of housing is generally defined as a percentage of income spent on housing. Housing affordability stress has been defined as those people spending more that 30 per cent of the income on housing (Housing Affordability 2011). In 2002-03 there were 862,000 lower-income households that were experiencing housing stress, comprising 15.8 per cent of all Australian households and 28.2 per cent of low-income households. Housing affordability stress is particularly acute for private renters, single-person households under the age of 65 and low-income home purchasers. The decline in house purchase affordability is a structural problem created by house prices growing faster than incomes over the last half century. AHURI finds that between 1960 and 2006 real house prices increased at an average of 2.7 per cent each year compared to 1.9 per cent growth in real incomes (Housing Affordability 2011).Although housing affordability is of growing concern to Australian residents the cost of a new home in green field developments is still cheaper than purchasing an existing home closer to the CBD of all major Australian cities. With correct advice many sustainable features can be implemented into new homes whilst still keeping costs down. The problem is that there is no consistent auditing system to monitor things like insulation use and grey water diversion. A builder can claim to have undertaken this work and may not actually have done it. In addition, many developers opt for the cheapest and easiest path to the 6 star green rating without regard to the overall long-term energy effectiveness of the house. Once the sustainable technologies that provide the most benefit from a cost-to-benefit perspective are identified, they could then influence the Building Code of Australia's mandates and assist in reducing the affordability crisis in Australia.

Energy Efficiency

Residential buildings account for approximately 20-30% of the energy used in OECD countries and energy reduction and innovation in this area is clearly an important issue (Rahman, Patnaikuni and de Silva, 2008). Energy usage by Australian residents is predicted to increase by up to 53% over the next 20 years. Horne et al. (2008) advises that one growth factor is the increased usage of appliances in the home using 'standby' power. Figure 1, below shows average residential sector energy usage in Australia.

Figure 1. *Residential sector energy services 2004/5 (Australian Government, 2011)*



The above diagram indicates which sectors consume the majority of the energy for residential buildings. Heating and cooling take up the most energy, whilst initiatives to improve the electrical efficiency of appliances will contribute partially to overall energy reduction, the impact is likely to be minimal. Lighting, heating, cooling and ventilation are the primary energy users in most buildings and reliance for this on current fossil fuel electricity is of prime concern to the nation in our bid to reduce our carbon footprint.

Life Cycle Costing

Life Cycle Costing adds all the costs of alternatives over their life period and enables an evaluation on a common basis for the period of interest. The Life Cycle Cost (LCC) of an asset is defined as " The total cost throughout its life including planning, design, acquisition and support costs and any other costs directly attributable to owning or using the asset" (Life Cycle Costing Guideline, 2004). By analysing increased upfront costs of sustainable energy initiatives over a life-cycle of use, a better judgment on its affordability can be made. When sustainable initiatives are not considered from a life-cycle costing model, however, many initiatives are considered “unaffordable”.

For example, researchers such as Zhu et al. (2009) argue that many aspects of sustainability over short term time frames are unaffordable. They conducted a study that compared and measured the actual energy savings for a zero energy house (ZEH), with various energy saving technologies, built side by side with a baseline house in suburban Las Vegas (Zhu et al. 2009). The study found that while the upfront costs were higher for all energy saving initiatives, that 80% of these initiatives has a payback period below 25 years (Zhu et al. 2009). This study indicates that it is important to analyse energy saving initiatives over a life-cycle to have a true understanding of their affordability and cost to benefit ratio. Horne et al. (2005) advances the view that the overall cost of implementing energy efficient technologies, are a marginal cost of a new house build, at about 0.5-1%. They suggest that the extra costs will generally be quickly recouped.

Sustainable Facade and HVAC/Ventilation Systems and Improving Technologies

Sustainable construction and affordability can be combined to provide excellent environmental benefits for communities. Design of buildings is a highly important factor when investigating the benefits of different types of HVAC and ventilation systems. This is because it costs much more to retrofit an existing building, than it does to implement effective technologies when constructing buildings in the first instance. Discussed below are technologies and systems that can change or improve on current methods. A review of non-air-conditioned buildings, natural ventilation, double skin facades and user behaviour are further discussed in relation to sustainability outcomes.

Non-Air-Conditioned Buildings (Multi-Zoned)

Designing the most efficient HVAC systems is of critical importance to increasing sustainability in buildings and also affordability. Majali, Prasad and Bhat (2008) have presented a computer model of heat transfer analysis of non air-conditioned multi-zone buildings. This model takes into account the effects of heat energy through a variety of building facades including: windows, air ventilation and infiltration, furnishings, and ground heat conduction. Using innovative technologies such as this computer model, architects are able to design buildings for better thermal properties in non-air-conditioned buildings. These results offer both sustainability and cost saving benefits which the researchers suggesting they using their model can save up to 15% more than standard construction models.

Double Skin Facades

Having been used for over 100 years double skin facades it was not until the 1970s that the skins heat transfers were measured. Common types are fully sealed skins, so air won't escape and it keeps heat in winter and this type of ventilated allows heat escape in summer. Investigation by Ji et al. (2008) found in a study examining standard residential two storey houses with double skin facades that they reduced the energy use by 15% in summer and 30% in winter.

Water and Waste Management Systems

There are various components to examine when reviewing water and waste management systems, however, the two main components are water supply and wastewater disposal. Water supply can be either from the mains water system or from rain water harvesting tanks that can be located on rooftops or adjacent to the building. Wastewater disposal management systems include using the main sewerage system, greywater and blackwater. It has been suggested that water management solutions for new developments should be based on sustainability considerations due to the current social, economic and environmental implications, rather than just the additional costs and what the developer desires (Makropoulos et al., 2006). Of all the options Rain water harvesting tanks and by-pass grey water are the most cost effective options (Zhang et al 2009).

Construction Method

The method of construction has a significant impact on affordability. Kelly and McCarthy (2008) suggest that as a construction material steel allows for flexibility in construction. Using steel can enable buildings to facilitate adaptability through structural extension, strengthening, internal flexibility and flexible building services. The quality of construction also has an impact on the *overall sustainability. Additionally, research shows that poor construction can lead to leaking building envelopes that cause a number of problems that need to be avoided to ensure sustainability is maintained. Possible problems include: condensation, water damage, draughts, layers of cold air right above the floor level and elevated energy consumption, thus there is a greater importance on the air-tightness of the building envelope (Schnieders and Hermelink 2006).*

Super Structure Materials

To further enhance a building's sustainability, the selection of durable materials is an effective way of extending the life a building, with the additional benefit of reducing material consumption. Thereby reducing any natural resources that would be required for manufacturing and also the amount of capital spent on installation. Durable materials also need less maintenance, thus reducing the operating budget of the building (Sev 2009). Additionally the selection of inappropriate materials can be expensive, but more importantly, the sustainability goals may not be achieved (Mora 2007).

Fit-Out

The fit-out of a building has a large impact on the building's sustainability, given that the operational period of a building has the largest life-cycle impact on a building's sustainability (Schnieders and Hermelink 2006). Cost effective improvements include; using low energy electrical fit out items such as ceiling fans, type of HVAC system, reducing the building envelope infiltration via air sealing measures, increasing the R-Rating of the ceiling insulation, the use of programmable thermostats and even using white or light shades for external finishes (McIlvaine et.al. 2008).

Recycled Construction Materials

As all building activities involve the use, redistribution and concentration of some components of the earth's resources (Sev 2009), reusing building materials can provide a high level of sustainability within the construction industry. This results in the reduction of embodied energy of constructed buildings. This can be extended through smart design and planning to re-use existing infrastructure. Current research shows that the use of renewable materials in building construction is useful, both for the environment and economically (Medineckiene et al 2010). It has been said that the renovation of dis-used buildings could be considered the ultimate form of recycling (Sev 2009).

Aspect & Location of Building

Smart planning and architecture can provide real benefits to a buildings' sustainability. By locating the building on the correct aspect this can have a significant impact on how much energy a building will require for heating and cooling. In the southern hemisphere a northward orientation is beneficial. Clearly, in Australia, if a reduction in heat is required, an increase of shading would be require to ensure the benefits of passive heating and cooling through orientation maximises the use of renewable resources from the site (Sev 2009).

Design of Building

When designing a sustainable building, attention must be paid to the greater environmental impact and contextual implications of the building in relation to the site. In addition, the building must be oriented according to the sun path for maximisation of passive solar gain and daylight (Sev 2009). Simplicity of design can be a cost effective mechanism of increasing sustainability. By optimising and improving the efficiency of the necessary components of a building: the building envelope, the windows and the automatic ventilation system, the sustainability of a building can be increased (Schnieders and Hermelink 2006). The size of a building has an effect on both the sustainability aspects and its affordability. Larger spaces require more heating and cooling to maintain temperature. Additionally larger spaces require more material and labour costs during construction, consequently decreasing the affordability. By reducing material use by properly sizing buildings, savings of both materials and labour will result. A building that is oversized for its design purpose, or has oversized facilities, consumes excessive materials (Sev 2009). These issues can be resolved at the design stage. Limiting the amount of glazing within a building can also decrease the future energy use of the building. Where glazing is deemed essential for ventilation or natural light, the type of glazing used will impact the sustainability of the building. The use of standard laminated glazing may increase the affordability; however, the offset is that the sustainability is decreased. Conversely, double glazing or other glazing treatments will decrease affordability and increase sustainability.

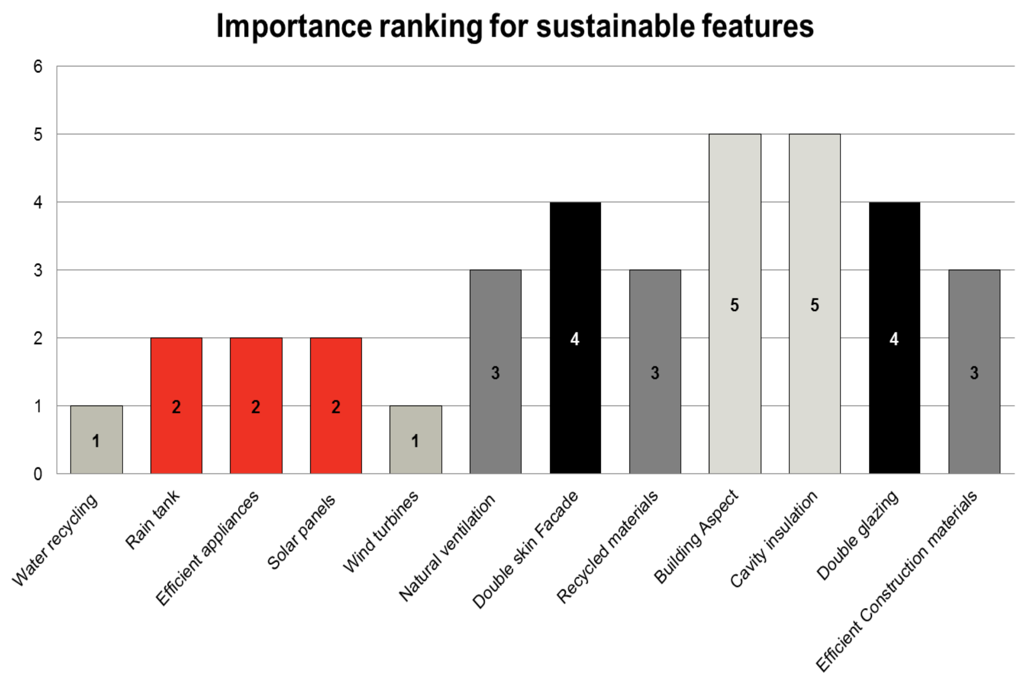
The design of the roof also has a large impact on sustainability and cost. Wide eaves produce a large amount of shade that is able to maintain the buildings temperature against the outside temperature. The cost implication of wide eaves throughout the buildings' perimeter is substantial. Effective design through the use of veranda's and other similar building elements, at strategic locations can provide the added benefits at a reduced cost. Even the colour of the roof can produce small energy efficiencies, however, there is typically no incremental cost associated with it (McIlvaine et.al. 2008). The research has revealed that there are many possible benefits for the environment using modern technologies and sustainable methods. However, the research of these technologies and cost to benefit ratio is currently not comprehensive. The aim of this research thesis is to address this problem and provide a detailed analysis of sustainable, affordable and innovative technologies that result in excellent life-cycle cost to benefit outcomes, so that both sustainability and affordability can be achieved for housing communities.

Methodology

This paper uses “Mixed-Method Research”. Mixed Method Research can detect recurring patterns or consistent relationships in data, and being from quantitative and qualitative they are two separate sources of data (Abowitz & Toole 2010). They are totally independent of each other, and this can cancel out weakness in the collection of the data. The advantages of Mixed Method are the strengths and weaknesses are able to be assessed and show different perspectives on the topic, and each method’s limitations can be compensated via the other method.

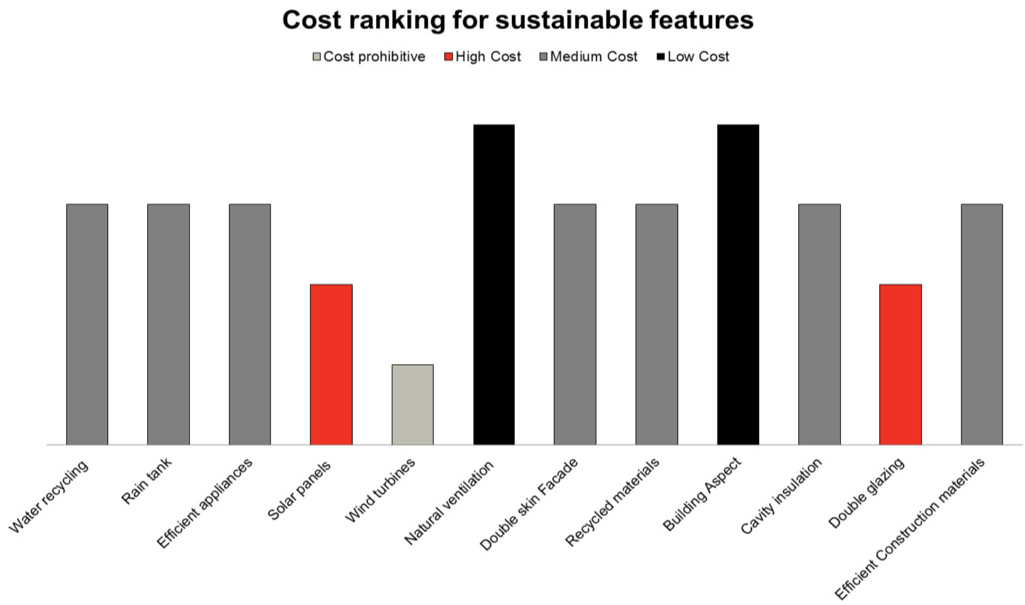
Interviews were conducted with four construction practitioners to develop a questionnaire **Appendix A.** This questionnaire was then sent to 50 professionals who specialised in residential construction. 33 surveys were returned and the following graphs illustrate the findings from this research. The responses from the surveys correlated perfectly with the cost effective components discussed in the research.

Figure 2: *Classification of sustainable feature on the basis of importance for the environment*



When the completed questionnaires were analysed the respondents found wind turbines and water recycling to be the least important features to be used in sustainable housing and cavity insulation and the aspect of the building to be most important , closely followed by double glazing and double skinned facades.

Figure 3. *Evaluation of the cost effectiveness of sustainable features in housing construction*



Similarly there was agreement with regard to the most cost prohibitive item being wind turbines, followed by double glazing and solar panels, however all remaining nine features were ranked as medium or low cost and if all these were implemented into new construction they would make very little difference to the overall cost of a home.

A case study was also undertaken to examine the sustainable features that are possible if a client is determined to make an environmental difference with their home. This property is a 9 star rated property in a Northern suburb of Melbourne. The sustainable features in this home are benchmarked as typical of where Australian residential construction should be if we are going to substantially improve our global footprint. A 9 star house uses 80% less energy to heat and cool than a 6 star house (the current standard), and 1/10 of the energy of average existing housing stock. The features of the house include:

- Passive Solar design. House orientation & layout to bring sunlight deep into all living spaces Eaves designed to let in the winter sun, and keep out the summer rays

- Double glazed low emissivity coated casement windows & bi-folds to maximise ventilation
- Thermal mass provided by polished concrete floor and recycled & bagged Reverse Brick Veneer walls to store the heat in winter and cool in summer
- Solar Lord Evacuated Tube Solar hot water system with instantaneous gas boost
- Highly insulated, tight building fabric
- Stairwell door and internal louvre windows to regulate thermal stratification.
- Louver vents to all exhaust fans (eliminates unwanted air leaks)
- Reversible ceiling fans to provide summer cooling
- Ventilation designed to take advantage of sea breeze
- LED and compact fluorescent lighting throughout
- Greenswitch to turn off standby loads before going to bed/leaving the house.
- 2.3kW grid interactive Photovoltaic system
- Curved roof to help maximise neighbours northern solar
- Rainwater collected from entire roof via a charged filtered system
- Rounded gutters to enhance self cleaning
- 2x3000-litre Rainwater tank to run laundry, flush toilets, & water garden. Mains backup
- Redwater valves to direct 'cold' hot water, normally wasted, to the watertank
- Nylex greywater gravity diversion system to underground garden distribution
- Water efficient tapware throughout; 7.5 litre per minute shower roses; & 3/4.5 litre flush
- Low Embodied Energy Polished Concrete floor made from Ecoblend concrete (60% cement replacement) with recycled aggregate and steel
- Plantation hoop pine timber windows, with recycled Karri door frames
- Plantation or Salvaged timber used throughout.
- Modwood decking and ramps
- Recycled content Ecotech tiles to upper bathroom
- Low VOC GECA certified Marmoleum to stair treads and upper floor
- Recycled brickwork to bring mass to upper floor
- Low Embodied energy cladding materials. Rough sawn battens, Ecoply and Zincalume 4) Health
- Zero VOC (Volatile Organic Compounds) paint throughout
- E0 (minimal formaldehyde off-gassing) cabinetry and trims throughout.
- Undyed, Low VOC Willaura carpet and underlay to bedrooms

- Easy to clean surfaces to living spaces throughout
- Bright, natural light filled rooms throughout (Sustainable House Day, 2011)

As global warming, energy consumption and the ever growing price of electricity and other services increase, the topic will become more main-stream and demand for the above type of building could hopefully be standard practice in future. (Pilkington et al. 2011).

But why is Australia still lagging much of Europe in so many renewable energy sources and design techniques? Considering the fact that Australia has a greater degree of sun exposure than much of the world and the same technologies at our fingertips, it needs to be questioned why Australia is not more focused on implementing renewable technologies. Perhaps the main point of future research is much bigger than we anticipate. Based on the high demand of new homes, urban sprawl of outer suburbs and the projections of the current population in Melbourne potentially doubling, it is reasonable that these issues should be looked at more in depth. The issue of affordability and sustainable housing construction is still a complicated one that with further research can be addressed if the political will is there and people implement the sustainable technologies that provide the most benefit from a cost to benefit perspective. The research has found that there are a number of cost effective sustainable elements that can be used in housing construction, but currently this is at the discretion of the individual. It is clear from the research that industry professionals are aware of the cost effective initiatives, but the sad fact is that the majority of the 150,000 homes built each year in Australia are project homes constructed by large scale developers, many of whom continue to take the easy path. Often choosing sustainable features that they often do not deliver and which they know will not be checked. It is only homes built by concerned individuals like the case study discussed where any substantial sustainable construction items are installed. Until government regulations pursue a more stringent rating value and a consistent audit process, Australian housing will continue to be unsustainable.

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APPENDIX A: What are the most cost effective sustainable elements for housing in Australia? This questionnaire has been designed with both closed and open ended questions and will be used to collect primary data for this qualitative research based on the above topic. The researcher would be very grateful if you could find time to complete it and return to the person who gave it to you or scan and send to: Kathryn.robson@rmit.edu.au Many thanks for your participation.

Q1. Profession	Builder
	Architect
	Engineer
	Consultant
	Other
Q2. What type of Design/Construction do you specialise in?	Low Density Housing
	Medium Density Housing
	High Density Housing
Q3. How do you rate the information presently available in relation to sustainable/green building methods and materials/elements?	Excellent
	Good
	Fair
	Poor
	Very Poor
Q4. When considering the sustainable features of a home, how important is the aspect of the building?	High
	Medium
	Low
Q5. How important is fit out in the overall sustainable effect?	High
	Medium
	Low
Q6. Which of the following features have been incorporated in any building or development you have worked on in the last 2 years?	
Grey or black water recycling system	

Rain harvesting tank or tanks system	
Energy efficient appliances	
Solar panels	
Wind turbines	
Non air conditioned or natural ventilation	
Double skin Facade	
Use of recycled construction materials	
Correct building aspect	
Cavity insulation	
Double glazing	
Energy saving construction materials	

Q6. If you have used any of these features rank them from highest to lowest in sustainable importance in the columns to the right of the feature.

Rank Importance	1 Least importan t	2	3	4	5 Most Importan t
Grey or black water recycling system					
Rain harvesting tank or tanks system					
Energy efficient appliances					
Solar panels					
Wind turbines					
Non air conditioned or natural ventilation					
Double skin Facade					
Use of recycled construction materials					
Correct building aspect					
Cavity insulation					
Double glazing					
Energy saving construction materials					

Q7. Rank "Up Front Cost" as a proportion of overall cost	Cost prohibitive	High cost	Medium cost	Low Cost	Don't know
Grey or black water recycling system					
Rain harvesting tank or tanks system					
Energy efficient appliances					
Solar panels					
Wind turbines					
Non air conditioned or natural ventilation					
Double skin Facade					
Use of recycled construction materials					
Correct building aspect					
Cavity insulation					
Double glazing					
Energy saving construction materials					

Thank you for completing this survey. Kathryn Robson