

Instrumentation and Monitoring Strategies in Measuring the Performance of Sustainable Housing

Syed M S Rahman, Saman de Silva and Indubhushan Patnaikuni

RMIT University, Melbourne, Australia.

ABSTRACT: The present pattern of metropolitan development in Australia is one of spreading low-density suburbs, which is relatively affordable but environmentally unsustainable. The great bulk of new Australian housing stock is provided in the form of project homes in outer suburban areas. Between 1986 and 1999 the average size of new dwellings increased almost 30%, despite a decline in the average number of people per dwelling. It is anticipated that by 2021, Melbourne will need 420,000 extra dwellings. Similar trends observed in other major metropolitan regions are placing increasing pressure on our environment. An Australian Research Council and industry collaborative research project is currently underway at RMIT University to investigate sustainability and innovation in the outer-suburban housing developments. This project involves the construction of a typical suburban home, popular in the current Australian market place, with due consideration to the eco-features in design. This paper presents the outcomes and knowledge gained in developing a monitoring strategy including instrumentation and data acquisition to capture functional and incidental data which provides the research team with an indication of how a purpose designed eco-home would function over full duration of its design life.

1 INTRODUCTION

Australian housing industry is booming due to low interest rates, steady population growth as a result of substantial migration and a good overall performance in the economy. There is also an overall thinning in household sizes related to the increase in the single parent families and lone person households (ABS 2001). The Australian housing industry is currently building an estimated 140,000 new homes every year valued at A\$19 billion (HIA 2000) to accommodate this growing and thinning process.

New urban housing developments in Australia are characterized by high density inner city apartments and low density outer suburban housing estates. While there have been some shifts towards living in inner city multi-storeyed apartments, outer suburban single house developments still constitute the major portion of the new homes.

The great bulk of new Australian housing stock is provided in the form of project homes in outer suburban areas. In recent years, the Australian Model Code for Residential Development (AMCORD) has driven a reduction in average lot sizes, while consumer preferences have driven a simultaneous increase in dwelling size and higher thermal comfort expectations (Commonwealth of Australia 1995). This trend of low density housing and increase in dwelling size is not environmentally sustainable be-

cause of increasing energy and resource requirements for such housing trends.

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Substantial research is being carried out in Australia on housing sector for achieving sustainability and reduced environmental impacts. These include the smart housing project in Queensland, the eco-home project in Victoria, the Australian Housing and Urban Research Institute (AHURI) primarily in New South Wales and similar efforts in South Australia.

Blair et al., (2003) have argued that while there are many forms of land subdivisions and development, the master planned communities (MPC) have more freedom and prospects in achieving sustainability outcomes. MPCs consider many additional elements such as solar access, overshadowing, community facilities, landscaping, water sensitive urban design, minimum appliance rating and essentially water and energy conservation requirements.

2 THE ECOHOME PROJECT

The ecohome is located at the Cairnlea housing project, an housing estate development at western suburban; about 19 kilometers from Melbourne. The Cairnlea estate is 460 hectares and has 3000 housing units. The project began in 1999 and is expected to be completed in 2006. When completed, it will house 9000-10000 strong population. A key feature of this estate is implementing water sensitive urban design principles. The ecohome, which is currently on public display, is constructed by Metricon homes, one of the progressive volume housing builders in Australia.

The goal of the ecohome is to investigate ways in which we can minimize the impacts on the environment, while at the same time save energy and water bills for the dwellers. The knowledge gained through this pilot project will also be applied for sustainability outcomes of other development projects such as "Aurora", which comprises 8500 plots for housing at Epping located at the northern fringe of Melbourne.

The life cycle performance of homes we live in has significant impacts on the environmental sustainability, with dwellings estimated to contribute about 22% of Australia's green house gas emissions. In addition, Australian homes are among the largest per capita water users in the world.

The ecohome project is a major initiative which involves industry and research organizations in Australia. This collaborative research project has been funded by the Australian Research Council linkage grant and a number of industry partners including Building Commission of Victoria, Metricon, VicUrban, Sustainable Energy Authority Victoria (SEAV), City West Water, Melbourne Water, Hassel Architects and Origin Energy. The in-kind research expertise is provided by RMIT University and Deakin University of Australia which would produce three doctoral theses when concluded.

The ecohome has been designed specifically to discover how affordable and realistic solutions can be utilized to make a home more environmentally friendly. In almost every aspect of its construction, consideration to conservation has been given including water conservation through rainwater tanks, the use of recycling and recycled materials, conservation of energy through effective heat insulation etc. The result is that the home is accredited with a five star energy rating.

3 THE ECOHOME FEATURES

3.1 Solar panels

The ecohome is equipped with solar photovoltaic panels (Figure 1) that produce part of its own electricity needs. The system is also connected to the national grid and the electricity is supplied by Origin Energy only as a back-up supply. The benefit of grid connection is that when the system produces more electricity than is consumed in the house, the excess electricity is sold to the energy retailer cutting the bills. The other advantage of grid connection is that it does not require expensive storage system.

3.2 Solar hot water system

The ecohome has an "AquaMax" hot water system installed and connected to natural gas. The system was chosen because of its optional solar kit that boosts the stainless steel hot water unit by solar power. This causes an overall reduction in gas usage for heating water. The free solar energy warms the stored water. It is then brought up to the required temperature by a gas boost, benefiting the consumer and saving the environment.



Figure 1: Solar photovoltaic panels on roof of the ecohome.

3.3 Hydronic heating

Hydronic heating (Figure 2) works on recirculating water heated by a natural gas or LPG fired boiler. The water is circulated from the boiler into radiators, skirting board convectors or fan convectors located at different points in the home. Using natural convection the air doesn't dry out, cause unpleasant draughts or allergies. The hydronic system is also safe for children, pets and the elderly with the surface temperatures of the radiators well below other forms of heaters. The system is modular so that each radiator can be thermostatically controlled and turned off when not needed.



Figure 2: Hydronic heating system

3.4 Rain water tank

Australian homes use on an average 700-1100 litres of water each day. About 66% of it is used for indoor activities and the rest 34% for outdoor activities such as watering the lawn or a swimming pool. Indoor water usage includes 20% in the bathroom showers, 20% in toilet flushing, 12% in the laundry and the rest 14% in the kitchen sinks and basins (WSAA 2001).

The installation of a rainwater tank of capacity 1000 litres (Figure 3) will help conserve potable water. Although not recommended for drinking, the rainwater tank offers readily available water for using in flushing toilets, washing machines and for landscape irrigation.



Figure 3: Rain water tank (1000 litres) for roof runoff collection

3.5 Grey water recycling

The wastewaters from the kitchen, bathroom and laundry constitute the grey water. The kitchen grey water can be heavily contaminated with food particles and oil and hence not collected in the ecohome. However, bathroom and laundry grey water is less

contaminated and hence suitable for reuse after some treatment. The current legislation does not allow grey water to be used for surface irrigation but allow for subsurface irrigation in the garden.

3.6 Water efficient appliances

The ecohome uses AAA conservation rated water appliances throughout the house. These include Hansa Designo taps, Caroma Leda showerheads and dual flush toilets. Using these products does not create added work or inconvenience while cutting the cost of water bills and more importantly conserving potable water.

3.7 Insulation

Insulation is a critical energy and money saver. At ecohome, a recycled polyester fiber was chosen as a wall and ceiling insulator. It is hydrophobic meaning that it repels water and will not rot with exposure to moisture. It contains no harmful chemicals, pesticides or dangerous fibres. Due to its efficiency, relatively lesser volume of material is used saving the embodied energy component of external building envelope. It's effective insulation means maintaining thermal comfort both during winter and summer minimising the heating or cooling bills.

3.8 Low emission paints

Externally and internally, the ecohome utilizes the low emission paints such as Taubman's paint. These paints are water based, which makes them safer to handle during application. Due to lower amount of volatile organic compounds (VOCs), they reduce the potentially harmful chemical emissions that become airborne during drying and over the paint's lifespan.

3.9 Ventilation

Maintaining a healthy environment through indoor air quality is considered as a prime objective of the ecohome design. Poor indoor air quality can cause respiratory ailments, aggravating allergies and even cause persistent coughs. The ecohome uses a Venmar energy and heat recovery ventilation system. This system maintains a consistently good level of fresh air in the home by filtering out particles and controlling the humidity levels. The Venmar system also reduces its energy requirements by housing its exhaust and supply blowers in one cabinet, saving space and money.

3.10 Recycling

One of the major environmental challenges Australia faces today is the unnecessary growth of landfill waste. The lack of separation between recyclable

and non recyclable waste is a major cause of this growth. The ecohome addresses this challenge by incorporating two separate chutes (Figure 4) in the kitchen for recyclable waste and non recyclable waste. The wheelie bins are attached outside the kitchen just below the chutes. Thus the waste is separated first hand at home. This ensures the recycling and reduces the amount of waste going to the landfills.



Figure 4: Separate collection chutes for recyclables and organic waste from kitchen.

3.11 *Use of recycled and natural materials*

The concrete floor of the ecohome uses fly ash which is a byproduct of thermal power plants (coal). The structural roof truss and wall frames of the ecohome were constructed with wood of pine trees, specifically grown for the purpose of building, which is regarded as renewable resource. It also uses natural bricks and tiles. Wherever possible, recycled materials and materials containing low embodied energy were used.

3.12 *Passive Design Principles*

Ecohome has utilised passive design principles in its internal layout planning and the orientation of the building within the land. This would ensure optimum utilisation of natural sun light both in thermal comfort and natural lighting.

3.13 *Landscaping*

Landscaping surrounding the ecohome has taken in to consideration the strategic positioning of trees and shrubs to achieve natural shading and open areas. Low consumption of potable water in gardening was achieved through the careful selection of low water consuming native plants and subsurface irrigation.

4 MONITORING STRATEGY

One of the main objectives of the ecohome project is to monitor and document the performance of eco

features over a two years period of occupancy in order to develop whole of life sustainability performance prediction models based on the ecohome performance data. This would require instrumentation and a remote data mining capability during occupancy to minimize disturbance to the occupants. A remote log-in monitoring strategy has therefore been formulated to obtain data with respect to,

1. water consumption
2. energy consumption
3. indoor air quality
4. thermal comfort.

The effectiveness of waste reducing and recycling features such as chutes, a composting bin etc. will be qualitatively assessed. The performance of equipments such as photovoltaic cells and solar hot water system will also be qualitatively assessed. Data obtained from this monitoring will be compared to water and energy consumption in comparable but conventional homes in the region as well as to average industry data.

Monitoring is planned to be conducted in two phases – obtaining baseline data before occupancy and operational data during occupancy. The first phase, after the completion of the construction, the ecohome is currently being displayed to the public. At the time of writing this paper the baseline data are being collected. The house is expected to be occupied shortly and over the next two years the ecohome performances will be monitored for operational data. It is envisaged that the occupants will sign a memorandum of understanding, as a condition of the lease, that the occupants would allow remote data acquisition and participate in periodical interviews.

The next step of the research is to develop a long term prediction model to assess the performance of its sustainability outcomes. The intended model should be able to provide scientific understanding of how the passive design of the ecohome and other thermal features are contributing to the thermal comfort to its users by modeling the energy balance of the house. A separate prediction model will be able to predict the performance of the house using the baseline data and the data obtained during occupied period.

Currently the authors are considering using a computational fluid dynamics (CFD) model such as FLUENT to evaluate the thermal performance of the ecohome in comparison to a conventional house. For the long term prediction model, the authors are considering an Artificial Neural Network (ANN) approach to develop a model that can correlate monitoring data with the sustainability outcomes. The use of both CFD and ANN has been reported in a climate research program by Mahajan et al. (2005).

5 DESCRIPTION OF INSTRUMENTATION

Instrumentation and data collection incur significant cost and it is not feasible to install monitoring devices at every location of the house. Hence a choice has been made to optimize the cost and yet get data from strategic locations of the house.

Data is collected every 10 minutes interval and stored in a computer on site. During display period data have been downloaded from a computer located onsite during periodic visits to the ecohome by the research team. The current data acquisition system will be upgraded shortly to facilitate dial-up remote data mining to coincide with the occupancy of the ecohome.

5.1 Air quality monitoring

Figure 5 illustrates the air quality measuring device used in the ecohome. The air quality measurements include carbon dioxide (CO₂) and carbon monoxide (CO) measurement at upper floor and living room (Figure 7 and 8). The unit of measurement is particles per million.



Figure 5: Air quality monitoring device measuring CO₂ and CO

5.2 Temperature and humidity monitoring

Continuous measurements of temperature and humidity are obtained at strategic locations. The locations were selected to obtain data representing different utilization of space and to capture effectiveness of passive design principles adopted in the planning stage. The humidity is measured at (refer to figure 7 & 8)

- Outside
- Living Room and
- Upper floor

The air temperature data is taken more extensively from almost every significant place in the house such as (refer to figure 7 & 8)

- Outside
- Upper floor

- Kitchen
- Entry
- Master Suite
- Family Room
- Bed Room 4 and
- Living Room

5.3 Solar radiation

Incident solar radiation is measured to correlate this information with the performance of solar panels, solar hot water system and thermal performance of the passive design features (orientation and insulation).



Figure 6: Temperature and humidity measuring device

5.4 Qualitative monitoring

Qualitative monitoring will include performance of recycling and composting practices in the ecohome. This performance is subjective to the users of the ecohome and will be assessed through interviews.

5.5 Water and energy bills

Periodic monitoring of energy and water bills of the ecohome will enable us to assess the energy and water use reduction objectives.

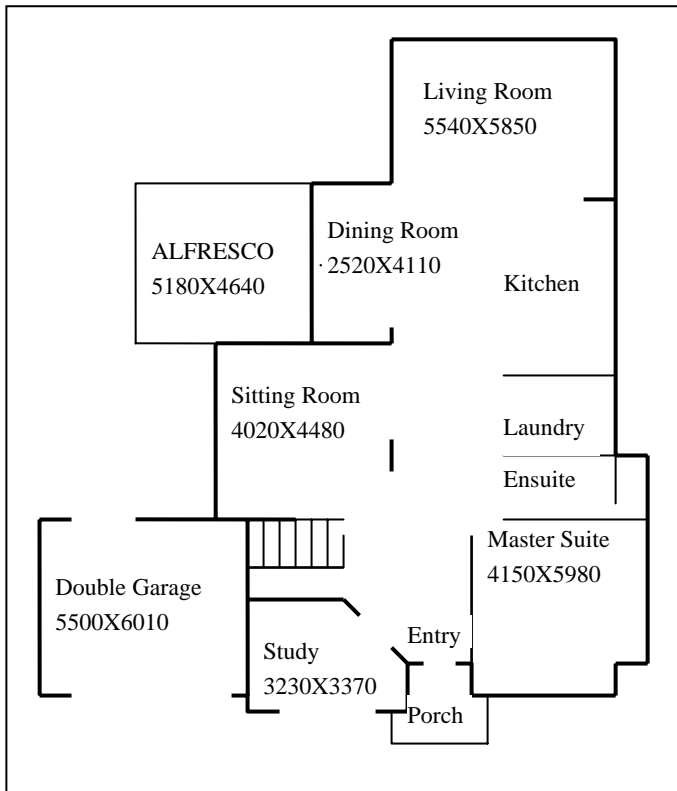


Figure 7: Simplified Floor plan of Ecohome (ground floor)

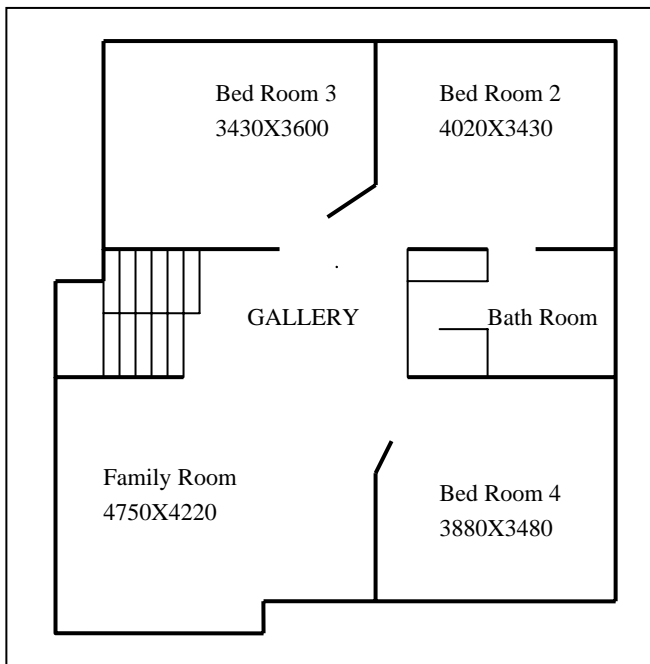


Figure 8: Simplified floor plan of Ecohome (upper floor)

6 CONCLUDING REMARKS

There is a growing understanding and acceptance in the housing industry that environmental sustainability is a major policy and market driver in the future. The release of Melbourne 2030: Planning for sustainable growth (State of Victoria 2002) and a planned implementation of 5 star energy rating requirement of all new houses in Victoria constructed after 01 July 2004 was a step forward in this direc-

tion. The housing industry will need to deliver more sustainability outcomes in years to come.

The ecohome project is an important step in this regard. A successful monitoring system will enable us to use short term data to develop and validate a long term prediction model of sustainability outcomes. The scientific basis of measured sustainability outcomes will help the urban planners and policy makers in their decision making.

ACKNOWLEDGEMENT

Public information booklet "Ecohome" printed by Metricon Homes.



Figure 9: The "Ecohome", Cairnlea, Melbourne, Australia.

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