Green revolution - A challenge to improve environmental performance of existing housing stocks

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Abstract

Climate change is one of the most pressing issues facing Australia today. This is a challenge and responsibility that is shared by all Australian households. Improvements to energy and water efficiency of houses can significantly cut greenhouse gas emissions and reduce utility bills. In July 2004 the New South Wales (NSW) government introduced the Building Sustainability Index (BASIX) to assess potential performance of a dwelling against a set of pre-determined criteria. Housing construction in NSW is the first in Australia to be subjected to mandatory sustainability requirements. BASIX is an online assessment tool which sets scores required to obtain development approval in new residential projects. BASIX is mandated only to improve environmental performance of new residential buildings and does not attempt to improve environmental performance of existing housing stocks which continue to consume natural resources and pollute the environment. Existing houses represent approximately 98% of residential building stocks in NSW and any improvement to these dwellings will have a profound impact on reducing the negative effects of the environment. This paper examines the sustainable upgrading strategies in improving environmental performance of three existing single dwellings in meeting the minimum BASIX requirements. This paper presents an economic analysis of sustainable upgrading using Net Present Value. The results suggest that sustainable upgrading of existing housing stocks is feasible and the scheme will be more attractive if the payback period is reduced with further government financial assistance.

Keywords

Sustainable upgrading, BASIX, sustainable house

1. Introduction

Environmental economics and sustainable development have become central concerns to people from all disciplines and in all countries (Cole, 1999). Many environmental discussions centre on the concept of ecologically sustainable development since the major oil crisis of the 1970s (Balderstone, 2004). Ecologically sustainable development, from a development point-of-view, is the efficient use of resources to meet the requirements and needs of present and future generations, whilst minimizing adverse effects on the natural environment. Environmental performance of new buildings has been the central focus of research. However new buildings represent less than 2% of the building stocks (Bullen, 2007; Power, 2008). With the current rate of rebuilding it would take approximately 50 to 100 years to replace the current stock whilst existing building stocks continue to contribute negatively on the environment and are harmful to the wellbeing of humankind.

Sustainable refurbishment and renovation of existing buildings has now attracted more attention. There are growing calls for the upgrading of existing building stocks and even the complete stop for new construction (Kohler, 1999). In countries such as Australia there is a significant switch from new buildings to the adaptation and rehabilitation of existing structure (De Valence, 2004). The importance of this trend refers to extending the useful life of existing buildings which supports the key concepts of sustainability by reducing virgin material consumption, transport and embodied energy, and pollution (Ireland, 2008; Power, 2008). The argument for reusing existing buildings is that they are relatively cheaper and is less environmental burdensome than to demolish and rebuild, if they are effectively upgraded (Bullen, 2007). Sustainable upgrading of existing building stocks will play a significant role in research and industry practices

This paper summarises the discussions and arguments, and attempts to clarify the direction towards major reductions in water and energy use in homes. The paper aims 1) to gain a deeper understanding on issues related to refurbishment of existing housings as opposed to new build, 2) to review the current situation of sustainable housing in Australia, 3) to assess and compare environmental performance of three properties of similar size but differing ages in New South Wales (NSW), Australia .4) to examine the conversion strategies in improving environmental performance in meeting the minimum BASIX requirements, 5) to present the research result.

2. Refurbishing or demolishing existing housings

With the fast growing of environmental building assessment tools, it is increasingly common for developers to make environmental claims the buildings that they produce. Demolishing an inefficient property may seem to be the best way of reducing energy use and to make way for more new buildings. Many support that demolition of existing housing and replacement with new is largely preferable in many cases to refurbishment since it is often expensive to upgrade and difficult to make them to meet sustainability standards (Ball, 2002; Boardman et al., 2005). A key foundation of this argument is that greenhouse gas emissions of highly efficient new housing can be far lower than the houses built in the past due to effective use of insulation and the latest technology. This is the underlying principle of the 40 percent house argument in advocating the demolition of a total of 3.2 million houses from 2005 to 2050 (Boardman et al., 2005; Power, 2008). Demolishing houses built in the past, somehow, is a way to improve the environmental efficiency.

An opposing argument however maintains that new buildings consume natural raw materials and energy in the development which could have been saved by reusing existing buildings (Bullen, 2007). In addition the carbon embodied in existing buildings, the energy required in demolition and dispose of waste, and the energy required for extraction, production, transport and use of new materials are enormous (Ireland, 2008). There have been research into the environmental value of existing housing and results have demonstrated that the maintenance and conservation of existing housing stocks help to achieve environmental gains as these buildings represent a major investment in natural and human resources (Martin et al., 2003; SDC, 2006; Ireland, 2008). Gunn (2001) states that heritage preservation is an important element in the move towards sustainability. Power (2008) further states that building, demolition and renovation waste make up about one-third of all landfill which is detrimental to the environment. Other argues that sustainable upgrading of existing homes is often substantial and costly (Ball, 2002). However, according to some research the cost of refurbishing is generally much less than the cost of new construction, since many of the building elements are already constructed (Martin et al., 2003; SDC, 2006). Martin et al. (2003) suggest that the cost of demolishing the existing houses and building and maintaining the new housing was double the cost of refurbishing and maintaining the existing houses over a 30 year period.

In considering the energy embodied in materials, Tucker (2008) states that the total embodied energy in existing housing stocks is equivalent to 10 years of the total energy consumption in Australia. Embodied energy of houses range from 4.5 GJ/m^2 to 5.5 GJ/m^2 and the reuse and recycling of building materials commonly saves about 95% of embodied energy which would otherwise be wasted. Total energy use (embodied and operating energy) is typically comparable only after 30 years. This means it will take about 30 years before energy savings will be realised by new houses rather than renovating an older house (Balderstone, 2004). In a research undertaken by the UK Government (Cabinet office, 2000), it states that the energy produced from non-renewable sources consumed in building accounts for about half of the UK’s emissions of carbon dioxide. Over 90% of non-energy minerals are used to supply the construction industry with materials. However in each year about 70 million tonnes of construction and demolition materials end up as waste in landfill sites. In another research undertaken by the Empty House Agency, they found that embodied energy constitutes 35% of the total CO_2 emitted over the estimated 50-year lifetime of new properties, whereas for renovation the embodied energy is 7% of the total energy over the lifetime (Ireland, 2008). It is questionable whether the decision to undergo demolition is justified for its energy-efficiency, given that the energy performance of renovated homes can improve significantly over time (SDC, 2006; Ireland, 2008). According to Power (2008) upgrading existing housing stocks can both reduce carbon emissions and environmental impacts of new building through implementing basic energy-efficiency improvement measures including insulation, double glazing, damp-proofing and condensing boilers for heating and hot water.

Despite the increasing recognition for sustainable refurbishment of existing housings there is still strong opposition due to economic constraints and the difficulty to match the sustainable performance of a new house. However despite this there is strong evidence that existing housing stocks has the greatest potential to lower the environmental load of the built environment significantly over the next few decades. The time to convert a building as opposed to new build will have an impact and the work to convert a building will take less time than demolition, site clearance and new build, unless extensive structural alterations or repairs are required.

3. Sustainable housing in Australia

Australia's total current housing stock is estimated to increase from 7.4 million in 2001 to 10.8 million dwelling, an increase of 47% (Australian Bureau of Statistics, 2009). Population growth and fewer people per household are the driving force behind housing demand. NSW is one of the largest states in Australia that has the highest growth. Table 1 summarises the population growth and residential energy consumption in NSW for 2001 and 2006. Table 1 shows that the population in NSW has increased from 6.6 million in 2001 to 6.9 million in 2006, an increase of 5% whilst the number of households has increased from 2.5 million to 3.4 million in the same period, an increase of 36%. The average person per household has reduced from 2.81 to 2.67 persons. The increase in the number of households coupled with reduction of average persons in each household has escalated the demand for dwellings. The estimated additional demand for dwellings for NSW is expected to be 335,000 in 2011 (McDonald, 2004).

Table 1 – Summary of population and households details in NSW for 2001 & 2006

	2001	**2006**	**% change**
Population (million)	6.6	6.9	4.6
No of households (million)	2.5	3.4	36.0
Persons in household (No.)	2.81	2.67	-5.0
Source: Australian Bureau of Statistics, 2009			

Australians are high energy users. Energy consumption was round 5,688 petajoules in the 2005-6 and is expected to rise to 6,479 petajoules in the 2011-12 year, representing an increase of 14% (Department of Climate Change, 2009). In Australia, about 95% of the energy comes from burning fossil fuels, causing greenhouse gas emissions (Energy Task Force, 2004). This energy production and use contributed 68% of Australia's greenhouse gas emissions and is expected to grow to 72% by 2020 (Energy Task Force, 2004). Approximately 25% of Australia's greenhouse gas emissions derive from energy consumption in the residential sector.

NSW is the largest energy consumer in Australia accounting for about 28% of final energy consumption, representing a total of 921 PJ in 2000/1, and it is expected to grow by an average of 2.3% each year to 2019/20 (Standing Committee on Public works, 2004). Residential energy consumption makes up 13% of total energy consumed in NSW and has risen approximately 20% across NSW over the last ten years due to population growth and the increasing demand of housing (Standing Committee on Public Works, 2004).

According to Reardon (2004), each household in Australia on average produces more than 15 tonnes of greenhouse gas per year, which contributes to approximately 20% of Australia's total greenhouse gas emissions. The largest source of greenhouse gas emissions from households is from energy used to heat, cool, cook, provide lighting and run household appliances, accounting for approximately 42% of total energy consumption per household (Reardon 2004). Hot water heating represents about 30% of home energy use (Blazey & Gillies, 2008). The high level of residential energy consumption is the consequence of inefficiency in the design and construction of Australian houses and it is also due to the lack of consumer awareness of energy savings.

Existing housing stocks in Australia are not sustainable and the NSW government is convinced that sustainability is the only way forward. In NSW sustainable housing is an important focus of the government's housing policy. In response to the need for sustainable housing the government launched a sustainability assessment tool called BASIX[1] in July 2004 as mandatory to all new residential developments. The introduction of BASIX has a profound impact on the environmental performance of new dwellings (Ding, 2007). All new residential buildings have become more environmentally friendly since the introduction of BASIX. The impact is not confined to building practitioners but has also raised awareness amongst home users. However BASIX does not apply its standards to existing housing stocks. BASIX has impacted upon the environmental performance of residential buildings but only affects about 2% of the total stock per annum (Blazey & Gillies, 2008). That means the existing housing stocks will continue to impact on the environment for the next few decades. More work needs to be done to sustainably upgrading the existing housing stocks so that it can progress to reduce negative environmental impacts. As discussed previously sustainable upgrading of existing housing stocks is a key foundation to achieving the goal of ecological sustainable development.

[1] http://www.sustainability.nsw.gov.au for full details on the BASIX assessment for new buildings as well as additions and alterations. In order to complete an assessment, log on to BASIX website and the website provides details of the proposed development as prompted by the BASIX tool. The project is assessed against the existing average and given a score. The project must demonstrate a reduction of 40% mains water, 40% energy and pass thermal comfort to qualify for a BASIX certificate.

In response to the need for sustainable improvement of existing housing stocks, a range of federal and state economic schemes have been introduced to encourage the adoption of sustainable building design features and construction strategies. These rebate schemes subsidize to a minor extent of the construction of new dwellings. They operate far more widely than compulsory buildings codes to encourage the owners of existing dwellings to adopt sustainability strategies. Table 2 summarises the rebate schemes from the NSW state and the federal government in Australia.

Table 2 – Summary of rebate schemes from the Federal and NSW state government

Item	Maximum rebate ($)	Sources	Details
Hot water system	1,600	Federal	Solar or heat pump system
	1,200	NSW	Solar or heat pump system
	300	NSW	5 Star rated gas hot water system
Solar panels	8,000	NSW	1 kWh solar panels
Water efficiency	500	Federal	Grey water system or rainwater tank
	1,500	NSW	Rainwater tank plumbed to toilet and washing machine
	150	NSW	4.5 Star rated washing machine
	22	NSW	to install water efficient devices e.g. shower heads, tap aerators
Insulation	1,600	Federal	Ceiling insulation
	300	NSW	Ceiling insulation
Others	35	NSW	Removal of domestic refrigerator more than 10 years old & with more than 250 litres capacity

In addition to the cash rebates a Renewable Energy Certificate (RECs) is implemented to increase the generation of electricity from renewable sources. RECs are a form of credit that can be traded, purchased or sold, thereby earning money to subsidise the installation of a solar or heat pump system.

4. Research Method

The purpose of the research was to explore how sustainable upgrading of existing housing stocks is a way toward achieving ecologically sustainable development. Three case studies were chosen in the northern suburbs of NSW. They were all detached family houses of roughly similar in size and layout but were built in different years using traditional construction methods. The research was a pilot study to gain a better understanding of the total energy and water consumption, and CO_2 emissions in running a family house. At this stage only the operational (in-use) consumption and CO_2 emitted in the everyday occupation of the houses were measured. The embodied energy and CO_2 emission in the materials will be included in the next stage of the research. Table 3 summarises the background information on the three case studies.

Table 3 – Summary of details for case studies

	House A	**House B**	**House C**
Location (Suburb)	Wahroonga	Pennant Hills	Hornsby
Land area (m2)	432	835	542
GFA (m2)	180	165	229
Type	4 Bedrooms	4 Bedrooms	4 Bedrooms
Age (years)	17	30	5
Construction details	Brick veneer with slab on ground, tiled roof	Brick veneer with suspended timber floor, tiled roof	Brick veneer with slab on ground, tiled roof
Family member (No)	4	3	3

The energy and water consumption were assessed for five years from 2004 to 2008. The environmental performance of the three cases will be evaluated using BASIX to assess the current performance and to propose a sustainable direction for upgrading the residences to comply with BASIX requirements. The additional costs for the sustainable upgrading will also be measured in conjunction with the available government rebates. The analysis highlights the minimum upgrades the property would be required to implement in order to comply with the BASIX benchmarks for new residential development.

5. Results and discussions

5.1 Operational performance analysis

Gas, electricity and water bills were collected for the three houses for the past five years and details are summarised in Table 4. The table presents the gas, electricity and water consumption on a quarterly basis. On average Q2 and 3 have the highest gas and electricity consumption. There is a clear cyclical and seasonal pattern characteristic of the increased demand for heating during the winter months followed by reduced demand during the summer months. The introduction of insulation to the subfloor, ceiling and wall cavities would mitigate the heat losses in winter and help to reduce heat transfer in the summer months.

Table 4 – Summary of gas, electricity and water usage for 2004 to 2008

Quarterly		Gas (MJ)			Electricity (kWh)			Water (KL)		
		A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
2004	Q1	4877	4135	3773	1216	959	912	49	75	28
	Q2	6045	8234	6074	1221	895	1357	50	64	31
	Q3	5948	9828	4694	1235	870	1481	41	64	75
	Q4	4443	5023	4015	1176	922	976	48	74	29
2005	Q1	4107	4429	4318	1241	1595	888	41	70	31
	Q2	5445	8643	5003	1476	701	1262	49	66	28
	Q3	5964	7625	5285	1203	726	1385	44	70	27
	Q4	4690	5767	3695	1111	1074	1142	41	83	29
2006	Q1	3824	5050	3053	1220	1070	970	40	79	31
	Q2	5016	11168	4948	891	1161	1503	38	68	33
	Q3	5501	12467	5124	968	1188	1132	42	67	20
	Q4	4511	6090	3514	1035	1231	1000	46	77	30
2007	Q1	4020	4810	3044	880	1189	954	54	73	28
	Q2	4955	13112	4604	1725	1384	1001	40	90	30
	Q3	5632	15718	5606	1782	1295	1115	43	76	37
	Q4	4874	6707	4364	1355	1103	1010	32	48	41
2008	Q1	5320	4998	4021	1240	1135	1003	38	51	51
	Q2	6542	12658	5924	1612	1119	1258	37	59	46
	Q3	3765	14848	6702	1890	1161	1503	50	58	44
	Q4	3365	11313	4803	1729	1129	1130	36	39	58
Yearly average		19769	34525	18512	5241	4381	4597	172	270	146
Monthly average		1647	2877	1543	437	365	383	14	23	12
Yearly average per person		4942	11508	6171	1310	1460	1532	43	91	49
CO_2 emission p.a. (kg)		384	672	360	5241	4381	4597	-	-	-
CO_2 emission per person p.a. (kg)		96	224	120	1310	1460	1532	-	-	-

The annual gas consumption of House B was the highest whilst the annual electricity consumption of House A was highest. The monthly total energy consumption and CO_2

emissions of the three houses were also presented in Table 4. The three houses consume 3220 MJ, 4191 MJ and 2922 MJ respectively for House A, B and C with House B having the highest energy usage. However the CO_2 emissions of House A outweigh the other two houses to be the biggest emitter of 5625 kg of CO_2 per year, approximately 11 to 13% more than the other two houses. Even though House B was the uppermost energy end user, approximately 69% were from gas and gas has much lower CO_2 emission than electricity. Nevertheless if the number of household members were taken into account House A has the lowest annual CO_2 emissions of 1406 kg per person whilst House B has the highest annual CO_2 emissions of 1684 kg per person, approximately 20% more than House A.

The water consumption as indicated in Table 4 has not revealed a clear cyclical or seasonal pattern. In annual water consumption House B was the highest which outweighs the other two by almost 40 to 50% more. The annual per person water consumption House B has outweighed House A and C by approximately 53% and 46% respectively. The three houses were generally above the benchmarks of energy and water consumption, and CO_2 emissions as set within the BASIX benchmarks.

5.2 BASIX Assessment

The three houses were assessed using BASIX to determine the performance of energy and water consumption, and thermal comfort. The outcomes from the BASIX assessment were used to determine the areas for sustainable upgrading. Table 5 summarise the outcomes of the BASIX assessment which reveals that all three houses passed the thermal comfort assessment but failed the water and energy efficiency appraisal. This indicates that all three houses were contributing negative environmental loads to the environment. House B has the worst water score which has only achieved 11% with a required score of 40%.

Table 5 – Summary of BASIX scores for House A, B and C

BASIX requirements	Target	Scores		
		House A	House B	House C
Water efficiency	40%	30%	11%	26%
Energy consumption	40%	25%	28%	23%
Thermal comfort	Pass	Pass	Pass	Pass

5.3 Economic analysis of sustainable upgrading

The analysis of energy and water consumption for the case studies was based on the utility bills which was only the secondary consumption. There may have wastage and loss in the delivery process from the production side to the side of the consumers where no information is available for consideration. The primary energy consumption can be approximately three times more than the secondary energy consumption as electricity in NSW is generated by burning coal. Therefore the outcomes from the analysis may be much worse than they appear to be.

Table 6 Summary of key sustainable design initiatives

Initiatives	Description
Water efficiency	
Fixtures and fittings	Upgrade of fixtures to bathroom and kitchen to 5 Star WELs rating
Rainwater tank	Installation of 3,000 litre rainwater tank to collect water from roof area. Collected water to be reticulated to toilets for flushing and to at least one outdoor tap to service the garden of the residence
Energy efficiency	
Solar or heat pump hot water system	Replace existing electric storage hot water system
Light fittings	Upgrade of existing light fittings to be energy efficient
Thermal Comfort	
Insulation	Installation of ceiling insulation, R-Value 3.0, including 2 No wind driven ventilators
Shading devices	All windows to have blinds to improve indoor comfort

Sustainable upgrading of existing housing stocks is important and essential. However it will only be acceptable to households if it is affordable. A sustainable upgrading strategy has been developed to improve environmental performance of the three houses to comply with BASIX requirements. Table 6 summarises the key sustainable design initiatives proposed for upgrading the three residences to comply with the three sustainability indices addressed by BASIX. There are more initiatives that can be done to further improve sustainable performance of these homes. However more initiatives will incur more costs which will make sustainable upgrading less attractive. Therefore the strategy used was based on the least cost approach to a minimum amount of upgrading that can fulfil the BASIX requirements. The improvements were also focused on the initiatives that government rebates are available so that the upgrading strategy will be more attractive and viable.

The cost of upgrading and savings due to improved efficiency and government rebates were calculated to reveal the effectiveness of sustainable upgrading. An investment decision is based on Net Present Value analysis (NPV), Internal Rate of Return (IRR) and payback period. Table 7 summarises the outcomes of analysis of sustainable upgrading using the following formula:

$$\mathrm{NPV}=\sum_{t=1}^{n}\frac{C_t}{(1+r)^t} \tag{1}$$

C_t = net cash flow expected at time period t

n = project life span

r = selected discount rate

t = the time of the cash flow

Table 7 – Summary of cost-benefit analysis of sustainable upgrading for the cases

	House A	**House B**	**House C**
Discounted costs $ (less government rebates)	11,500	10,400	10,500
Discounted benefits $	14,100	11,100	14,000
NPV ($)	2,600	700	3,500
IRR (%)	7.93	5.93	9.07
Payback period (year)	24	32	13

The analysis was undertaken on a life span of 50 years at a discount rate of 5%. The improvements have been calculated based on current market rates less the respective government rebates. The NPVs suggest that the sustainable upgrading be accepted as the NPVs are positive and the IRRs are greater than the required rate of return. Even though NPVs and IRRs demonstrate positive results, the payback periods were all more than ten years with House B even more than 30 years. The long payback period has eventually reduced the attractiveness of sustainable upgrading in the study. However the proposed sustainable upgrading has represented the least that need to be done to satisfy the BASIX assessment and more may be required to match the standards of new houses. The three projects were re-assessed in BASIX and amendments were incorporated into the original assessment. Eventually all three projects passed the three sustainability benchmarks addressed in BASIX.

6. Conclusions

The operational performance analysis of the gas, electricity and water usage over the past five years for the three houses draw parallel with the areas where the dwellings failed in the initial BASIX assessment. This paper has examined the direction for sustainable upgrading and has also presented an economic analysis alongside with the government financial rebates to pass the BASIX assessment. The study has revealed that upgrading to improve sustainable performance of existing housing stocks is an ideal and feasible solution to reduce greenhouse gas emissions and depletion of natural resources. The upgrading strategies for the three houses were developed using BASIX requirements as benchmarks. The main focus for upgrading was to install insulations to optimise the building fabric and mitigate heat loss and heat gains. The scheme also includes the installation of a solar or heat pump hot water system to reduce consumption of non-renewable energy. Energy saved will result CO_2 emissions through a reduced demand for heating and cooling. The water efficiency was improved through upgrading of fixtures and fittings, and the installation of a rainwater tank to reticulate harvested water for toilet flushing and irrigation.

The three houses represent a typical family in NSW. Even though a sample of three houses may be considered a small sample size, the results will provide an understanding on the current environmental performance of each household and its related style of living. Consequently a sustainable upgrading strategy to the existing housing stocks can be derived. The environmental impact of an individual house may be minimal but considering the effects of all the houses together they will make a significant impact to the environment. There are more than 7 million dwellings in Australia and the sustainable upgrading of existing housing stocks will have a significant impact on the environment. More work needs to be done to reduce the environmental impact of existing housing stocks. It will be fundamental if statutory requirements such as BASIX can be extended to existing residential buildings.

The study has also revealed that sustainable upgrading is achievable but with a cost that may eventually decrease the motivation to improve sustainably. The incentive to consider sustainable upgrading will largely depend on whether the cost of upgrading can be offset by the potential savings and the available government financial assistance. The long payback period of upgrading of the three cases has demonstrated that more government financial assistance may be required to encourage more sustainable upgrading.

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