Int. Journal for Housing Science, Vol.37, No.4 pp.239-248, 2013
Published in the United States

STRATEGIES FOR SUSTAINABLE HOUSING DEVELOPMENT – THE CHALLENGES FROM RENEWABLE ENERGY

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ABSTRACT

One-fifth of Australia's greenhouse gas emissions come from households. There are 7 million households in Australia and each is producing about 15 tonnes of greenhouse gas every year. Energy use, car use and waste are the largest sources of household emissions. Improving the energy efficiency of homes is one of the most effective ways of reducing greenhouse gas emissions and has been the main focus of the government's energy policy. In addition to the introduction of BASIX as mandatory to all new homes in NSW in 2004, the federal and state governments have introduced incentive schemes to subsidize Australian homes to install solar panels and other renewable energy technologies as a way to improve energy performance of existing homes since 2006. This paper examines the opportunities and challenges of renewable energy in improving energy efficiency of existing dwellings. The paper also presents the results of an economic analysis of renewable energy source in a dwelling in NSW. Finally a strategic direction of providing affordable and environmentally sustainable practices in upgrading existing homes to improve energy efficiency is also developed and discussed.

Key words: Sustainable Houses, Renewable Energy, Sustainability, Affordability.

Introduction

Climate change is one of the greatest challenges facing the world today. One of the initiatives to address climate change is to reduce greenhouse gas (GHG) emissions

0146-6518/04/239-248, 2013
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which are closed related to the consumption of fossil fuels. Australia is the 9th largest energy producer, accounting for 2.4% of world energy production and the world's 20th largest primary energy consumer [1]. Approximately 32% of the total energy produced was consumed locally with an annual growth of 1.7% for the next decade. The main fuels produced in Australia are coal (54%), uranium (27%) and natural gas (11%) and followed by crude oil and liquefied petroleum gas (6%), and renewable energy (2%) [1]. Energy production and use contributed about 68% of Australia's GHG emissions and is expected to grow to 72% by 2020 [2].

Buildings contribute to a large share of national and global GHG emissions. About 15% of GHG emissions from residential buildings are due to householders' heating and cooling usage [3]. In 1990, the residential sector contributed 43.4 mega tonnes of CO2 and by 2050 emissions from the residential sector will rise by 28.6 % to 55.8 mega tonnes of CO2 [1].The energy consumption required for heating and cooling in residential buildings is a function of both climate and thermal performance of the building envelope which can be addressed during the design stage. However new dwellings only occupy about 2% of the existing housing stocks and 98% of existing dwellings will continue to be inefficient. Therefore any energy efficiency improvements to the existing housing stocks will have a profound impact on the demand for fossil fuels and GHG emissions. In recent years the Australian Government has implemented renewable energy schemes to encourage alternative low emission energy sources such as the carbon trading scheme (CPRS) and renewable energy target (RET) [4].

This paper examines the opportunities and challenges of renewable energy sources in Australia. The paper also reviews the government policies and incentive schemes toward renewable energy use in households. An economic analysis was undertaken to demonstrate the potential of renewable energy on a standard Australian home. The result suggests that switching to renewable energy in home is feasible and beneficial only when sufficient government financial assistance is available.

Renewable energy potential and opportunities in Australia

Approximately 98% of the primary energy consumption in Australia is composed of fossil fuels and coal remains the main fuel for Australian's energy production [1]. The production of renewable energy has remained stable by about 2% of the total in the past few years. Australia has great potential and widely distributed wind, solar, geothermal, hydroelectricity, ocean and bio-energy resources. Australia has a well-developed hydroelectricity whilst wind and solar energy have grown significantly in the past few years. Other renewable energy is largely under-developed and could contribute significantly more to Australia's future energy supply [5]. TABLE 1 summarizes the production of renewable energy in Australian. Renewable energy production was dominated by hydroelectricity, bagasse, wood and wood waste of 85% in 2008/09 whilst the remainders were biofuels, wind and solar energy. Solar energy has become very popular for residential buildings in Australia in recent year [6, 7]. Approximately 7.6% of Australians have solar systems installed at home. Most of the solar energy is used for residential water heating which has increased by 61% since 2005 [1].

TABLE 1. Australian production of renewable energy [5].

Renewable Energy	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
	Energy (PJ)					
Bagasse	101.1	108.3	109.1	110.8	111.9	110.1
Biogas and biofuels	10.1	8.7	9.4	10.2	17.6	23.8
Hydroelectricity	58.8	56.2	57.7	52.3	43.4	44.3
Solar hot water	2.6	2.6	2.4	6.0	6.5	8.2
Solar electricity	0.3	0.3	0.4	0.4	0.4	0.6
Wind	1.6	3.2	6.2	9.4	11.1	13.7
Wood & wood waste	97.3	91.5	90.3	92.8	96 0	102.0
Total	271.7	270.8	275.5	281.9	286.9	302.7

Australia has great capacity of renewable energy which reflects on the climatic characteristics in each region. Hydroelectricity is mainly found in NSW, Tasmania, Queensland and Victoria. Wind farms are more popular in South Australia and Victoria. Bagasse fuel is associated with sugar production plants in Queensland whilst biogas mostly based on gas generated from landfill and sewerage across Australia [8]. Hydroelectricity has the greatest capacity in the production of electricity whilst the capacity of ocean and geothermal energy is yet to be developed. Renewable energy has tremendous potential in growth due to the development of renewable energy technologies and the increasing price of fossil fuel in the next decade. It is expected the growth to be between 20% to 42% by 2013/2014 [5].

Energy use and potential of renewable energy in the residential sector

Australians are high energy users and is currently the world's 20th largest primary energy consumer [1]. Energy consumption was around 5,688 PJ in the 2005/6 and is expected to rise to 6,479 PJ in the 2012/3, representing an increase of 14% [9]. Australia's total current residential household is expected to increase from 7.4 million in 2001 to 10.8 million dwellings in 2020, an increase of 47% [10, 11].Each household on average produces about 15 tonnes of GHG per year which contributes to approximately 20% of Australia's total GHG emissions [4]. The energy use of an average home includes heating/cooling (38%), water heating (25%), electrical appliances (16%), lighting (7%), cooking (4%), refrigeration (7%) and standby (3%) [12]. Heating/cooling, water heating and household appliances account for approximately 79% of total energy use. Energy demand for heating and cooling is projected to increase despite the introduction of minimum building shell performance standards. The main factors driving this trend include the floor area of the average new dwelling continues to exceed that of the stock average. The building shell performance standards only affect approximately 2% of the total stock per annum.

Existing housing stocks in Australia are not sustainable and the NSW government understands that home energy efficiency is the way forward. In July 2004 the NSW government launched a sustainability assessment tool called BASIX as mandatory to all new residential developments. The introduction of BASIX has a profound impact on improving energy efficiency of new dwellings [13]. However BASIX does not apply to existing housing stocks and new construction activity in the market averages less than 2%. The 98% of the existing housing stocks is now an important focus of the government's energy policy.

In response to the need for improving energy efficiency of existing housing stocks, a range of federal and state financial schemes have been introduced to encourage the adoption of renewable energy in existing homes [14]. These rebate schemes operate far more widely than compulsory buildings codes to encourage the owners of existing dwellings to adopt renewable energy. The Australian government has implemented the Renewable Energy Target (RET) which began on January 2010 to pursue a target of 20% electricity supply from renewable energy sources by 2020, aiming at producing 45,000 gigawatt hours per year. The scheme was implemented in two schemes since January 2011. The Large-scale Renewable Energy Target (LRET) aims at non-residential sectors whilst residential energy efficiency was implemented under the Small-scale Renewable Energy Scheme (SRES).

Renewable energy generation is a long-term strategy and the development is hindered because of higher production cost compared to conventional fossil fuel electricity generation. Under the SRES existing homes are provided with financial incentive to install solar water heaters or heat pumps for 10 years whilst solar panel system, small-scale wind and hydro systems are operated for 15 years [4]. Solar photovoltaic technology has become popular as it generates energy directly from sunlight and it is not relying on sources of wind and water. TABLE 2 summarizes the rebate schemes from the federal government and the NSW state in Australia.

TABLE 2. Summary of rebate and incentive schemes from the Federal and NSW state government [4].

Item	Details
Small-scale Renewable Energy Scheme (SRES)	- Solar water heaters & Heat pumps - Solar panel system - Small-scale wind systems & hydro systems
Small-scale technology certificate (STC)	- An online certificates for trading of electricity generated from renewable sources in megawatt hours
Feed in tariffs	- A premium rate paid to producers of renewable energy

Australian households began to install solar panels since 2006 with the incentive scheme of $8,000 from the government. Since then approximately 7.6% of Australians have solar systems installed but the program ended in June 2009 and replaced by the SRES [4]. Though many households have taken the advantage of the rebate system to install solar system and insulation, some households have difficulties in finding the extra fund to take up the incentive scheme and they cannot see the benefits of such an investment since the payback period can be as long as 10 years.

Research method

NSW is one of the largest states in Australia and has the highest growth in both population and energy consumption. NSW is experiencing increased residential construction activity as a consequence of continual urban growth coupled to the decline of average Australian household size and the increase in average floor space [9]. NSW is the largest energy consumer in Australia, accounting for about 28% of final energy consumption and it is expected to grow by an average of 2.3% each year to 2019/20 [3]. Residential energy consumption makes up 13% of total energy consumed in NSW and has risen approximately 20% across NSW over the last ten years [3]. Improving energy efficiency of existing housing stocks has become the main focus of the state government to achieve the RET. The purpose of the research was to explore the potential and benefits of renewable energy to homes in NSW. The study has selected a dwelling in Hornsby which is a suburb of Sydney about 21 kms from the CBD with a population of 18,703 and median age of 35 years of age [15]. The average household income is $1,139 per week [15]. The dwelling is a typical 4-bedroom brick veneered detached house with slab on ground construction and tiled pitch roof. The dwelling is single storey with a land size of 432m2 and gross floor area of 180m2. The house is occupied by a family of four people. The research was a pilot study to gain a better understanding of the total energy consumption in running a family home in comparison to switching to renewable energy source. At this stage only the operational consumption was assessed. The house has been initially inspected to assess the current conditions and to identify potential for renewable energy. Renewable energy for homes includes solar, small-scale wind and hydro-electricity. However the potential for small-scale wind and hydro-electricity system may not be suitable for the dwelling as it is neither located in a high wind area nor near to the water. Nonetheless the location for dwelling has an average of 7.5 hours of sunshine each day during summer which provides an ideal environment for developing solar energy. Therefore study has focused only on solar energy to provide household energy needs. The study included an analysis of energy bills for five years to evaluate trend of consumption and to develop strategies for energy efficiency improvements.

Results and Discussions

Operational energy analysis

Electricity bills were collected for the past five years from 2006 and details were summarized in TABLE 3. The table presents the electricity consumption on a quarterly basis and on average Q2 and 3 have the highest electricity consumption.

There is a clear cyclical and seasonal pattern characteristic of energy demand for heating during the winter months (Q2/3) and followed by cooling demand during the summer months (Q1/4). 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. The annual average electricity consumption was approximately 5241 kWh which was approximately 20% less than an average NSW home uses [16]. The analysis of energy consumption for the dwelling 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 3. Summary of electricity usage for 2006 to 2010.

Year	Quarter (kWh)				Monthly average (kWh)	Yearly total (kWh)
	Q1	Q2	Q3	Q4		
2006	1216	1221	1235	1176	1212	4848
2007	1241	1476	1203	1111	1258	5031
2008	1220	891	968	1035	1029	4114
2009	880	1725	1782	1355	1436	5742
2010	1240	1612	1890	1729	1618	6471

Potential use of renewable energy

In NSW approximately 90% of the energy used by homes is generated by burning coal and the efficiency is low [17]. NSW has a high potential for renewable energy, in particular solar energy as there are plenty of sunshine and has access to electricity grid transmission infrastructure. Therefore the case study focused on investigating solar energy and the associated upgrading to minimize heat gain and loss during operation. A sustainable upgrading strategy has been developed after initial building audit to improve energy efficiency of the dwelling. There are many initiatives can be done but more initiatives mean more expensive. Therefore the strategy used was based on the least cost and disturbance approach in order to restrain the upgrading to initiatives that government rebates are available so that the upgrading strategy are more attractive and viable. Key design initiatives proposed for upgrading include installing 1 kW solar panels, solar hot water, ceiling insulation and energy efficient light fittings.

The total upgrading cost (after government rebates) was approximately $10,210 based on current market prices. Each year the solar panels can generate approximately 1,276 kWh to offset the electricity required from the grid [18]. According to the literature installing solar hot water, ceiling insulation and energy efficient light fittings can save energy by approximately 60%, 20% and 60% respectively [12, 19]. With the proposed upgrading the total electricity saving will be approximately 2,680 kWh per annum, contributing to a saving of about 51%.

In considering the cost of upgrading, government incentives/rebates were calculated to demonstrate the effectiveness and affordability of renewable energy. An investment decision is based on net present value analysis (NPV), internal rate of return (IRR) and payback period. Table 4 summarizes the outcomes of analysis using the following formula:

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

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 4. Summary of analysis of energy efficiency upgrading.

Options	NPV ($)	IRR (%)	Payback (Years)
Base case (with government rebates) Current energy prices	3,489	7.113	13.5
Scenario 1 (with government rebates) Energy prices increase by5% p.a.	27,310	12.469	10.5
Scenario 2 (with government rebates) Energy prices increase by10% p.a.	142,280	17.824	8.5
Base case (without government rebates) Current energy prices	-2,641	3.921	21.5

The analysis was undertaken on a life span of 50 years at a discount rate of 5%. The initial analysis was established as a base case to compare with scenario 1 and 2 which have allowed for the increased energy price due to the government's clean energy policies and the introduction of carbon tax in October 2011. The base case was calculated based on current energy rates less the respective government rebates. According to the literature the energy prices will increase between 5.6 to 10% per annum in the next decade [20, 21]. The base case has allowed for an amount of $6,130 for the government rebates for the installation of solar panels and solar hot water. The NPV analysis suggests that the energy efficiency upgrading be accepted as the NPVs are all positive and the IRRs are greater than the required rate of return. The effect of increased energy prices has significant impact on the NPV and IRR results, contributing to approximately 8 and 41 times respectively higher than the base case for the NPV calculation and generally higher IRRs. The payback period also was reduced between 22% and 37% when increased energy prices were taken into account. The long payback period of the base case may eventually reduced the attractiveness of energy efficiency upgrading in the study. It is evident that government financial assistance and energy prices will play an important role in enhancing the use of renewable energy sources. Table 4 also presents the analysis of the base case without the government rebates and renewable energy source is not viable as NPV is negative, IRR is lower than the rate of return and payback is 21.5 years. A standard Australian family has tight budget for low to middle income earners [22]. To invest renewable energy without government rebates will be extremely difficult for homeowners, especially with the current market conditions.

Conclusions

The paper has examined the opportunities and challenges of renewable energy for homes in Australia, in particular solar energy. The study has revealed that upgrading existing homes with renewable energy source such as solar is an ideal and feasible solution to reduce electricity demand from the grid so as to reduce GHG emissions. The paper has also reviewed the Australian government policies and incentive schemes to promote the use of renewable energy sources. The research concludes that government policies on encouraging renewable energy by using incentive schemes have important impact to the uptake of renewable energy.

The paper has presented a case study to demonstrate the potential and benefits of renewable energy in homes using NPV analysis. The main focus for improving energy efficiency was to install ceiling insulation to optimize building fabric and mitigate heat loss and gains so as to reduce demand for heating and cooling. The study also included the installation of solar hot water, solar panels and energy efficient light fittings to reduce electricity consumption. The study has revealed that energy efficiency upgrading is achievable but with a cost that may eventually decrease the motivation to improve energy efficiency. The incentive to consider energy efficiency upgrading will largely depend whether the cost of upgrading can be offset by the potential savings, the available government financial assistance and future escalation of energy prices. The result has demonstrated that more government financial assistance may be required to facilitate switching to renewable energy sources. Benefits of dwellings to switch to renewable energy sources include:

- Installing renewable energy to existing homes help government to achieve the targets for reducing GHG emissions because the impact of 7 million households in Australia is significant;
- Using solar panels and other renewable energy systems may benefit from a stable demand and the cost may come down due to economies of scale and the development of new technology; and
- An increased in the use of renewable energy such as solar may change the market and homeowners perceptions on renewable energy for more switching in the future.

NSW has great potential for renewable energy, in particular solar due to its topography but the potential can only be fully utilized with sufficient government financial assistant. With the current incentive scheme homeowners switch to renewable is feasible but less attractive with the limited government financial assistance if the price of fossil fuel is not considered.

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