RETROFITTING EXISTING HOUSING STOCK: CASE STUDY OF A HOUSE IN QUEENSLAND, AUSTRALIA

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ABSTRACT
In the wake of global energy crisis and paramount concerns of greenhouse gas emissions, building sector is identified as one of the major energy consumers and greenhouse gas contributors. Although some considerations are given to energy efficiency in new constructions, the existing building stock remains a major problem. With existing dwellings accounting for around 98 percent of the total building stock, the problem is clearly visible. Although buildings do not last forever, regular maintenance and retrofitting can prolong the life of buildings. Retrofitting is often done to meet the variety of changing demands of the household. Retrofitting also provides an opportunity to make changes in the existing housing stocks planned and designed without due consideration to energy efficiency. Recently, Australian Government has announced direct financial incentives for the households to upgrade the energy efficiency of the existing housing stocks. This paper takes a case of a typical building from Queensland in which different retrofitting options are tried and tested with an aim to make the building more energy efficient. These retrofitting options are simulated using the *BERS Pro*, a house energy rating software. Climatic design guidelines help to identify the problem areas which are addressed in retrofitting by enhancing ventilation, introducing thermal mass, upgrading windows and installing shading devices. Additional energy and water efficient measures such as, introducing energy efficient lighting fixtures, high performance appliances, solar water heating options and rainwater harvesting are also incorporated.

KEYWORDS: energy efficiency, thermal mass and ventilation, retrofitting, climatic design, greenhouse gas, house energy rating.

INTRODUCTION
Climate has always been a major factor in building design in the past. With the invention of modern technology and climate modifying techniques, designers opted for mechanical appliances instead of using natural energies in building design, isolating buildings from their environment. Globally, around 30-40 percent of all primary energy is used in building sector (UNEP, 2007). Recent research has shown that 40 percent of this energy consumption could be saved, provided that energy is used efficiently (Çakmanus, 2007). Moreover, reduction in energy-usage has a significant influence on environmental protection and CO_2 emissions. In the new millennium, people have become more concerned about greenhouse gas emissions and are

attracted towards efficient use of energy. Environmental consciousness has also encouraged designers to make climate responsive designs by utilising natural energies, such as sun and wind, to maintain a comfortable living environment. A report on *Technologies, Policies and Measures for Mitigating Climate Change* has identified that improvements in the building envelope have the economic potential to reduce heating and cooling energy in residential buildings (Watson, *et al*., 1996). Building professionals are the key players in reducing the building's operational energy by producing more energy-efficient buildings and renovating existing stocks to meet the modern sustainability criteria (UNEP, 2007).

This paper explores the retrofitting options of the existing housing stock with reference to a typical house in Brisbane, Queensland, Australia. A house energy rating software, *Building Energy Rating Scheme – Professional (BERS Pro)*, is used to simulate the performance of the house while incorporating various changes step by step. The software provides star rating to the house. Higher the stars, lesser the energy needed for heating and cooling, making the house more energy efficient. Enhanced ventilation and incorporation of thermal mass induces higher ratings in simulation. Some additional retrofitting options are also mentioned which helps in reducing operational energy of the house.

NEED TO ADDRESS THE EXISTING HOUSING STOCK

In many countries, efforts have been made to introduce energy efficiency regulations for new building constructions, but the quantity of new constructions are very low i.e. only about two percent of the total building stock. Among them, only 10% of the new buildings in the 'developed' nations are 'green' (Birkeland, 2008). Every year approximately two percent of the new homes are added to the existing housing stock in Australia (Karol, 2008). There are approximately 7.5 million existing residential dwellings in Australia which have adopted no or very little energy efficient measures. However, Commonwealth and local governments have imposed regulations to ensure minimum energy efficient criteria to be met in approximately 150,000 new residential dwellings built each year in urban areas (Dalton, *et al*., 2008). It means that immediately there is very little immediate impact in energy conservation in the building sector. Whereas, if the existing housing stock is retrofitted with energy efficient options, the impact on energy conservation can be enormous. The United Nation's Intergovernmental Panel on Climate Change (IPCC) also acknowledged building improvements as one way of reducing global warming pollution with "net economic benefit" (Scientific American, 2008).

The world currently relies predominantly on fossil fuels for most of its energy, and a large portion of this energy is wasted through inefficient use. For example, the generation and distribution of electricity is only 25 percent efficient. This means that by saving one unit (kWh) of energy actually contributes to a fourfold saving in environmental damage done during the production of that energy (Campbell, 1984).

It has been estimated that 8.5 percent of Australia's greenhouse gas emissions are from household energy use (Mullaly, 1998). If existing house owners were to become aware of the energy reductions that can be achieved by making some simple changes, the savings would be significant both environmentally and individually (Campbell, 1984). Thus, there is a necessity to address the existing housing stocks which are poorly designed without due considerations given to the aspects of energy efficiency. Since the operational energy is the major cause for greenhouse gas emissions in residential or commercial buildings to be renovated, this should be the first aspect to be taken into account when considering the improvement of the energy efficiency of building stocks (UNEP, 2007). However, retrofitting also improves condition of all the building elements, while prolonging the lifetime of a building. It makes possible a considerable reduction in building maintenance costs and investments in the repair and replacement of worn-out elements, which would be inevitable in the future.

According to the survey conducted in 1999 by the Australian Bureau of Statistics, 58 percent of owner occupiers were living in renovated dwellings, with renovations carried out during ten years previously (Australian Bureau of Statistics, 2008). Australians move or renovate on an average every seven years and over 50 percent of home owners plan to renovate at some stage (Safer solutions, 2008). The motivation for renovation ranges from repair to increasing comfort and living space (Voss, 2000). Regardless of the reasons, renovation presents both special challenges and the opportunities to apply energy efficient technologies to buildings.

AUSTRALIAN INITIATION

The Australian government made announcement to incorporate minimum energy performance requirements into the Building Code of Australia in the year 2000 (Commonwealth of Australia, 2000). Improving energy efficiency in buildings is an important part of Australia's program to reduce greenhouse gas emissions. Recently, Australia has ratified the Kyoto protocol promising the country's liability in reducing the greenhouse gas emissions. The newly elected government is committed towards fulfilling its promise; as a result, the Department of Climate Change was established on December 2007.

The Department of Climate Change, Commonwealth Government of Australia is helping households through direct financial incentives. The incentives include $10,000 low interest loans for Australian households to implement energy and water savings, rebates for energy-efficient insulation for 300,000 rental homes, $8,000 rebates for rooftop solar power panels, $1,000 rebates for solar hot water systems, $500 rebates for rainwater tanks and grey water recycling, improved cost-saving energy and water efficiency standards for new homes and appliances (Department of climate change, 2008). In addition to this, State and Territory Governments are also providing additional incentives to encourage energy efficient measures in the household sector. In the recent years, State and Territory Governments are formulating their own standards for energy efficiency in new building construction. Victoria was the first state to introduce the five-star energy standard for new homes in 2005, with more than 100,000 homes built to the five-star standard in Victoria since then (The Age, 2008). Queensland Government has made an announcement to upgrade the minimum star rating for new residential dwellings from the existing three and half star to five star energy standard, effective from March 2009. They have also decided to introduce a sustainability declaration as part of the sale of a house or unit in Queensland effective from January 2010. It will not form part of the contract of sale, but rather serve to inform prospective buyers about the sustainability features of the dwelling (Queensland Government, 2008a). This type of declaration is already mandatory in Canberra, Australian Capital Territory since 1999 (NatHERS, 2008).

METHODOLOGY OF THE STUDY

This paper takes the case of a building designed and built by a local developer from Brisbane, Queensland, Australia. The study is carried out in three steps:

- Firstly, a brief climatic study illustrates the local climate and opportunities to explore the available natural energies in the building design.
- Secondly, the selected house is evaluated “as it is” using energy rating software “BERS Pro” which is popular in Australia.
- Thirdly, retrofitting measures are undertaken as per the recommendations from the climatic study. The retrofitting measures include upgrading insulations, adding thermal mass, putting more efficient windows, enhancing ventilation as needed. At the end, the retrofitted houses are evaluated with the same energy rating software to understand the enhanced performance due to the alterations made on the houses. The benefits of using energy efficient lighting fixtures, high performance appliances, solar water heating options and rainwater harvesting are also discussed briefly.

CLIMATIC DESIGN FOR BRISBANE

Brisbane climate

Brisbane is hot, humid in summer and cool in winter. These seasons extend to autumn and spring months, which are transitional periods between the two main seasons. The average maximum air temperature ranges from 29°C in February to 21°C in July. The highest temperature ever recorded is 40.2°C in February. The average minimum temperature ranges from just 9°C in July to 21°C in January and February. The lowest temperature ever recorded is 1.6°C in June. Humidity is high in summer and the early autumn months, but then gradually reduces from April to remain in the comfortable range for the rest of the year. In total, Brisbane has got 12126 heating degree hours and 2885 cooling degree hours[*]. If night time and early morning heating requirements are ignored considering most people do not turn the heater on while sleeping, heating degree hour is reduced to 2100. Cooling is required for seven months in a year (October to April) and heating is required for only three months (June to August) while for the remaining two months May and September, the requirement of heating is negligible which can be ignored.

Summer months get substantial rain, the sky in summer is cloudy for about 12 days in a month. In winter, the sky is clear for almost 15 days per month. Of the annual rainfall of 957 mm, which is approximately 83 days of rainfall, about 50 percent usually fall between November and February. Rainfall in summer months is the highest while it is the lowest in winter months. The wind in Brisbane changes its direction in each season. In summer, it comes from the north to south-east. The autumn wind comes mainly from the south; it ranges from the south – east to the south – west. The winter wind pattern is also similar to the autumn. Night and morning wind in autumn is strong and comes from the south-west. The afternoon and evening wind is dispersed and weak. The spring wind basically comes from the north. The afternoon wind blows from the north – east and night wind from the south – west.

[*] Heating degree hour calculated with base 18^0C and Cooling degree hour calculated with the neutral temperature (T_n) = 17.6 + 0.31*T_{av}, where T_{av} is average monthly temperature.

Design strategies

Design strategies are formulated based on the climate analysis using Bioclimatic charts and Mahoney tables. Among number of design strategies, some of the key strategies which are specific and more relevant for this study are discussed below:

- **Insulation in roof, walls and floors**

Brisbane experiences seasonal and diurnal variation in temperature. Brisbane needs cooling for seven months and heating for five months. The heating demand is much higher due to lower winter temperature. To keep the building well protected from fluctuating temperature, insulation in roofs, walls and floors are very important. Insulation helps to stabilise the fluctuating temperature and minimise air infiltration through building envelope. Un-insulated floors, walls and roofs contribute significantly in air infiltration. An energy efficient building in winter should be able to prevent air infiltration when doors and windows are closed thus minimising heat loss from the house. In summer, it should have the facility to capture cooling breezes when doors and windows are opened.

- **Thermal mass and ventilation**

It has been established that thermal mass together with a well ventilated system are beneficial for all types of climates. Climate like that of UK and other hot humid regions are also benefited by the use of thermal mass combined with an intelligent ventilation strategy (Roberts, 2008 and Givoni, 1994). Use of thermal mass is necessary in Brisbane because it introduces a time-delay between changes in the outside temperature to the internal room temperatures. At night, the building fabric is cooled using the relatively cool night-time air (night cooling) and during the day it acts like a thermal sponge, soaking up heat from the interiors. This concept can also be extended to daytime operation, by increasing ventilation during cool breezes while reducing the ventilation to a minimum during heat waves. If potential of natural ventilation is weak due to lower wind speed, some design features or being wind shadowed by nearby structures, forced ventilation, such as fans can be used to enhance the performance locally where needed.

- **Windows and shading**

Brisbane has both heating and cooling requirement so building should utilize solar radiation and wind effects, as well as, protection from them. Windows are always critical in buildings. If they are appropriately placed, sized and shaded, they enhance the quality of the building and can also reduce the heating and cooling demand. Large windows on the north façade are beneficial for winter solar heating, but night time insulation should be considered and appropriate shading is needed to protect from summer sun. Windows on the east façade are mainly to catch the cool breezes, but should be well shaded, especially during summer mornings. If possible, windows on the west should be minimized to avoid summer afternoon heat and to block cold winter wind. Daytime living areas can have double glazing to minimize winter heat loss through the windows.

- **Arrangement of activities in building**

Energy efficiency of a building is related with the location of different activities in a building. For Brisbane, daytime living areas should be kept on the north, as much as possible, to get benefit of winter solar heating potential. Bedrooms should be placed on the east; Kitchen should be placed on the south / east. Utilities and garage can be placed on west / south. These arrangements allow harnessing the natural energies for heating and cooling the buildings.

HOUSE ENERGY RATING USING BUILDING ENERGY RATING SCHEME (BERS) PROFESSIONAL

Building thermal performance alone does not tell us how comfortable a house will be or how much heating and cooling energy a house will use. It only tells us the heating and cooling loads needed to keep a house at a given temperature. It is just one of the factors that influence household heating and cooling energy use (ABSA, 2006).

The BERS is developed and maintained by Solar Logic. The mathematical "engine" at the heart of the BERS program is the same as thermal simulation engine used by *Accurate* developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO). *Accurate* is the benchmark software for the Nationwide House Energy Rating Scheme (NatHERS). The thermostat settings and time periods for space conditioning are different according to the uses of the rooms, which is set by the Building code of Australia. Heating thermostat settings for living room uses 20^0C between 0700 and midnight. In sleeping zones, the heating thermostat has been set to 15^0C between midnight and 0700 and 18^0C between 0800 and 1600 (ABCB, 2008). Beyond the specified times any heating or cooling requirement is discarded. Cooling thermostat setting has been set to thermal neutrality, which varies with the daily and monthly temperature profile. The software assumes that building occupants will open the windows during warm weather, when ventilation would improve their thermal comfort (Bureau of Meteorology, 2008).

House has to be divided into several zones as per the use. Sleeping, Living, Kitchen, and other daytime and nighttime zones are conditioned while remaining zones such as garage, corridor, and wet areas remain unconditioned. Thermo-physical properties of materials have been already defined in the software; user has no access to alter it.

Australian Building Code has set NatHERS star criteria (annual energy loads in MJ/m^2 for the conditioned floor area). The energy loads varies with the location which takes account of climatic variations. The output of the software is in total energy load with corresponding star rating. For Brisbane, if total heating and cooling loads are greater than 245 MJ/m^2, the star rating will be zero; 3.5 star is equivalent to 83 – 71 MJ/m^2, 5 star is equivalent to 55 – 48 MJ/m^2 and less than 10 MJ/m^2 is equivalent to 10 stars (NFEE, 2008).

SIMULATION OF A TYPICAL HOUSE IN BRISBANE

A typical house designed and constructed by a local builder has been selected to understand its energy performance. The performance is evaluated using the house energy rating software. This house represents general house design and construction practice in Brisbane. The lot is elongated towards north – south and access to the lot is from the north. The house plan is elongated towards the long axis on the north – south. There is minimum setback of 1.5 meter on the east and the west. A small backyard of 6 meter is on the south. At present, the house is not overshadowed by other buildings and trees at any time.

Additional information for simulation

1. External walls are 220 mm thick brick veneer with R1.5 insulation which is a minimum specified by the Building Code of Australia.
2. Internal partition walls are 70 mm cavity panel.

3. Ceiling height is 2400 mm.
4. Plaster board ceiling is insulated with R2.5 which is a minimum specified by the Building Code of Australia.
5. Concrete tiled, hipped roof at 25^0 slope angle.
6. All windows are single glazed in aluminium frame.
7. Roof is extended 450 mm beyond the external wall.
8. Bedrooms and the living room have carpet cover on the concrete floor and rest of the rooms have tile cover except the garage which has bare concrete floor.
9. It is assumed that all the windows have Holland blind as an internal furnishing.

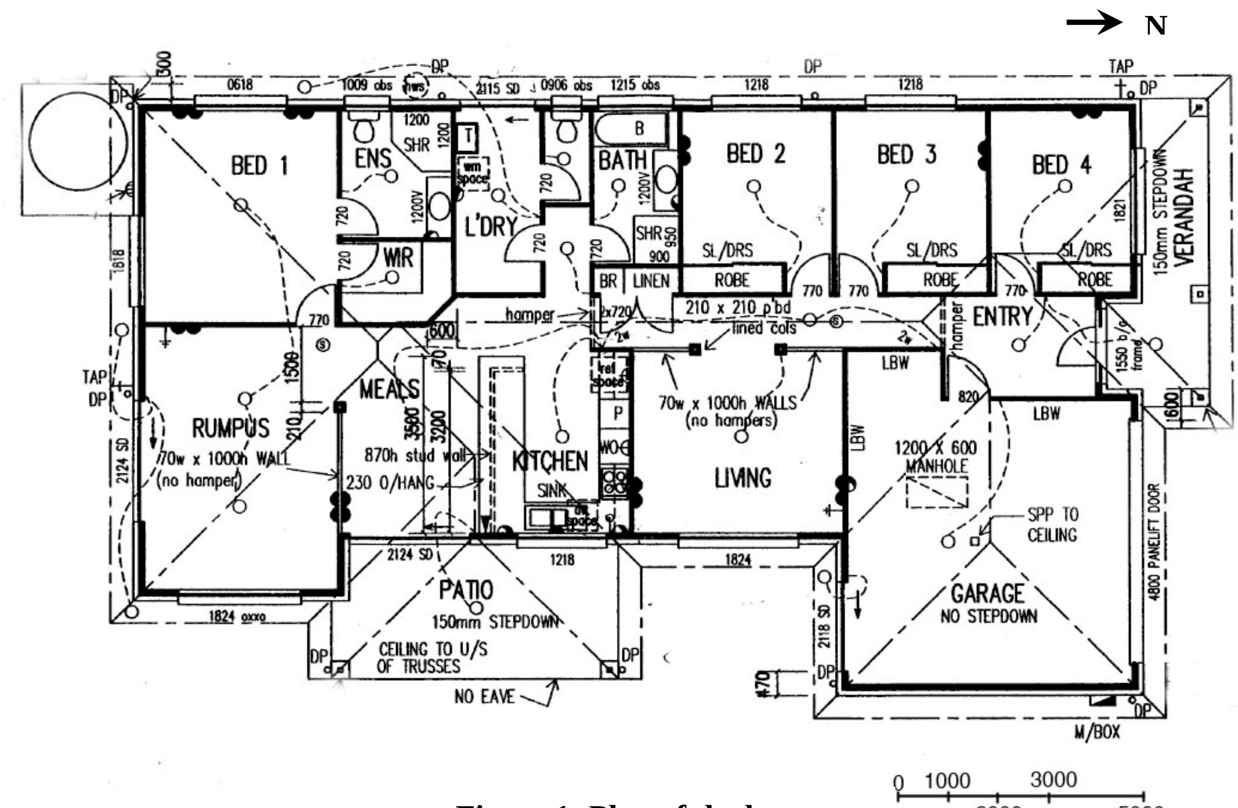

Figure 1: Plan of the house

The above mentioned house is simulated using the BERS Pro software as it is built. The house requires total 60.5 MJ/m^2 of energy for heating and cooling, it corresponds to 5.0 star rating. To maintain the recommended temperature in conditioned areas, the house requires annual cooling energy of 44.5 MJ/m^2 and heating energy of 16.0 MJ/m^2. Cooling is required from December through March and heating is required from June through August. Individual star rating of conditioned areas are as follows:

Table 1: Star rating of rooms – as built

Conditioned Rooms	Stars	Conditioned Rooms	Stars
Bed 1	7.5	Living	2.0
Bed 2	7.0	Rumpus	3.0
Bed 3	6.5	Kitchen	4.0
Bed 4	6.0		

This house has achieved 5 stars rating which is well above the energy standard set by the Queensland Government. From March 1 2009, all new houses and units in Queensland must achieve a minimum 5 stars (out of 10) energy equivalent rating under the new sustainable housing regulations (Queensland Government, 2008b).

RETROFITTING OPTIONS

There are number of retrofitting options tried to enhance the performance of the house. The retrofitting options are divided into two parts. The first part aims to enhance the thermal performance of the envelope which can be quantified in terms of star rating of the house. The second part aims to reduce the operational energy by incorporating energy efficient features such as, energy efficient lighting fixtures, high performance appliances, solar water heating options and rainwater harvesting. These retrofitting measures can not be modelled through the software but the changes will certainly help in reducing the energy use in buildings and thus reducing greenhouse gas emissions.

In the first part, step by step modifications have been carried out starting from addition of insulation in the ceiling. There is a very small reduction in heating energy observed as a result of increasing insulation from R2.5 to R4.0 so the ceiling insulation is left to R2.5. Following changes have been made on the top of the previous ones:

1. **Ceiling fans are added in bed and living rooms –** Ceiling fans are easier options to enhance the ventilation in buildings. They can be easily installed and are low cost, low energy consuming system but are highly effective in room cooling. A lot of energy can be saved through fans in comparision to the centralised cooling system such as air conditioning and can be used only where needed. Ceiling fans create a wind chill effect which increases the band of thermal comfort limit, thus giving comfortable feelings. It is quite interesting to see the energy rating jump to 6 stars after incorporating ceiling fans in the living and the bed rooms. Cooling energy has been reduced by 13 MJ/m^2 to 31.6 MJ/m^2 while heating energy remains the same at 16.1 MJ/m^2. The total amount of heating and cooling energy requirement comes down to 47.7 MJ/m^2. Star rating of rooms are as follows:

Table 2: Star rating of rooms when ceiling fans are added in bed and living rooms

Conditioned Rooms	Stars	Conditioned Rooms	Stars
Bed 1	8.5	Living	3.0
Bed 2	8.0	Rumpus	4.0
Bed 3	8.0	Kitchen	4.0
Bed 4	7.5		

2. **Thermal mass are added in rooms –** This building has no internal thermal mass in Bed and Living, Kitchen, Rumpus and corridor have ceramic tiled floors. Adding thermal mass in building fabric is relatively a complex process. But to prolong the life of a building, major renovation needs to be carried out and addition of thermal mass should be given a high priority. For the simulation, an additional (single) layer of brick is added

from inside to the external walls and all plaster board partitions are replaced by single brick thick walls. Total energy requirement to condition the house is reduced to 35.2 MJ/m^2 which is equivalent of 7.0 stars. With this improvement, cooling energy requirement dropped to 22.5 MJ/m^2 and heating energy to 12.7 MJ/m^2. Star rating of rooms are as follows:

Table 3: Star rating of rooms when thermal mass is added in rooms

Conditioned Rooms	Stars	Conditioned Rooms	Stars
Bed 1	9.0	Living	5.0
Bed 2	9.0	Rumpus	4.5
Bed 3	9.0	Kitchen	4.5
Bed 4	9.0		

3. **Windows are double glazed in living areas –** Double glazing windows have low thermal conductance (U-value) which helps in reducing both heating and cooling loads. The cost associated with the double glazing is higher than the single glazed windows. Since the bedrooms have performed relatively better than the daytime living areas – living and rumpus rooms, the windows in living and rumpus have been replaced with double glazing. Main intention is to enhance the performance of those rooms while saving cost at the same time. This change has improved the performance of those rooms with the increasing star rating to 6 stars. Overall, the house is now rated 7.5 stars with the above mentioned changes. Cooling energy has dropped to 21.4 MJ/m^2 and heating energy to 10.3 MJ/m^2, totaling energy load of 31.7 MJ/m^2. Star rating of rooms are as follows:

Table 4: Star rating of rooms when windows are double glazed in living areas

Conditioned Rooms	Stars	Conditioned Rooms	Stars
Bed 1	9.0	Living	6.0
Bed 2	9.0	Rumpus	6.0
Bed 3	9.0	Kitchen	4.5
Bed 4	9.0		

4. **Shading devices on the east and west windows are installed –** Shading is very important in reducing the cooling load. It is much easier to shade the windows facing north. In summer, sun attains higher altitude angle so eaves projection is enough to shade windows in the north. The east and west orientation windows are vulnerable from shading perspective so additional measures need to be taken to ensure they are shaded during summer months. Individual awnings are installed on the living and rumpus windows facing towards the east, Bed 2 and Bed 3 windows facing towards the west. The improvement is reflected in the star rating of the individual rooms. Each room has got additional one star with this improvement. This change has made the overall house rating to 8 stars with a total energy requirement of 27.4 MJ/m^2 comprising of cooling energy of 17.1 MJ/m^2 and heating energy of 10.3 MJ/m^2. New star rating of rooms are as follows:

Table 5: Star rating of rooms when shading devices are installed

Conditioned Rooms	Stars	Conditioned Rooms	Stars
Bed 1	9.5	Living	7.0
Bed 2	10.0	Rumpus	7.0
Bed 3	10.0	Kitchen	4.5
Bed 4	9.0		

The energy use in residential sector is the largest source of greenhouse gas emissions. Figure 2 shows the typical Australian breakdown of energy consumption within the dwelling and shows that space heating/cooling and water heating dominates the energy use profile (Reardon, 2008). Energy use in Queensland is drastically different than the national figures. Figure 3 shows that large amount of energy in Queensland is used for water heating. The installations of air-conditioning units are increasing (Miller and Ambrose, 2004). This will obviously contribute towards increasing space heating cooling. Reducing a dwelling's need for such energy or seeking alternative renewable means of energy for these areas will greatly reduce Australia's overall environmental impact and greenhouse gas emissions.

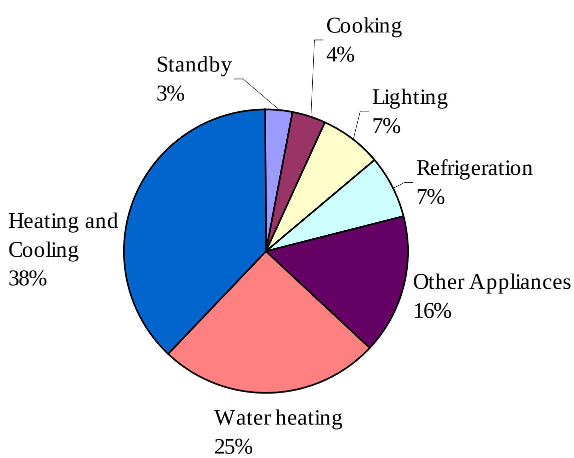

Figure 2: Australian household energy use, Baseline energy estimate (Reardon,

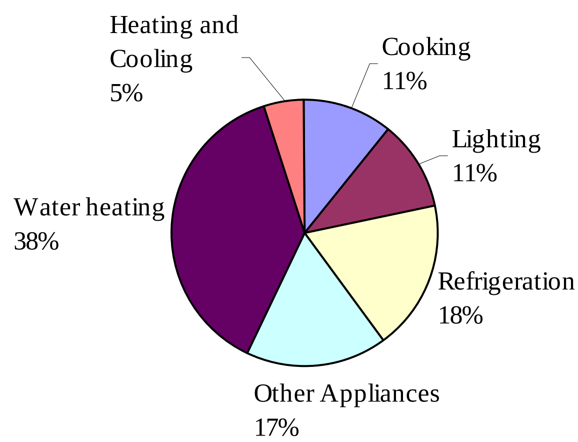

Figure 3: Queensland household energy use (Miller and Ambrose, 2004)

Queensland Government has been promoting sustainable living which is use of less water and energy around the houses. They have recently launched *Climate Smart Home Service* which includes an energy audit, the wireless energy monitor to find out exactly how much energy is being used, distribution of compact Fluorescent globes and water efficient showerhead (Queensland Government, 2008c).

Here are some additional retrofitting options:

- **Using energy efficient lighting** -By replacing a regular bulb with a compact fluorescent globe, energy used for lighting can be saved by up to 80 per cent. They are much cheaper to run and can last around ten thousand hours.

- **Switching to an energy efficient hot water system –** Queensland houses use significant amount of energy for water heating so when it is the time to replace the old hot water system, replacing it with a solar or gas hot water system should be considered.
- **Installing a rainwater tank -** Rainwater is a valuable natural resource that can be collected for use around the house. A rainwater tank can save up to 100,000 litres of water each year, in an average home in Queensland. Rainwater can be used for watering lawns, washing cars, flushing toilets, as the cold water for the washing machines, topping up swimming pools etc.
- **Switching to water efficient gadgets –** It is required by the law to replace existing non efficient water devices with water efficient three star shower roses and dual flushing toilets in residential properties in Queensland.
- **Buying high performance appliance –** In Australia, energy rating of appliances are mandatory so it is easy to choose high performance products in the market.

DISCUSSION

Energy efficient buildings are integrated outcome of climatic design principles, approriate building materials and techniques, and water and energy efficient appliances. There was a period, when energy was considered as ever lasting resources. Buildings were designed with “one design fits everywhere” attitude. Any discomfort caused due to the design or construction inefficiencies could be removed by introducing airconditioners or heaters to maintain comfort conditions. The scenario has changed as the world is facing an energy crisis. Moreover, the issue of climate change is of paramount importance in all sectors including the building sector.

Together with the enhancement and renovation of the existing buildings, efforts to increase energy efficiency in them should be the main aim of the construction sector which could influence the global sustainability significantly (Çakmanus, 2007). There have been various initiations to maintain a standard construction practice in Australia. Commonwealth Government and all the states and territories governments are working together to set a benchmark for housing standards. Nationwide House Energy Rating Scheme (NatHERS) is such an outcome which provides a framework for various computer software tools to rate the energy efficiency of the Australian homes. It works equally good for both the new constructions as well as for retrofittings in the existing stock. In new constructions, it can be used to fine tune the design ideas whereas in retrofittings, various options can be tested to identify the best energy efficient retrofitting options. In this paper, insulation upgradation, enhancement of ventilation by adding ceiling fans, introduction of thermal mass to moderate internal air temperature, upgrading windows to double glazing in living areas and installing additional shading devices on the east and west, resulted in the higher star rating for the existing house. The new rating achieved was 8 stars, better than the initial 5 stars. This is equivalent to reducing total heating and cooling energy demand by more than 40 percent from 66.4 MJ/m^2 to 27.4 MJ/m^2. Incorporation of thermal mass together with enhanced ventilation (using ceiling fans) helps to gain 2 stars which is a very good achievement. Addition of thermal mass illustrated the possibility of reducing both heating and cooling energy required to maintain thermal comfort in the house. Additional features such as energy efficient lighting, hot water systems, rainwater tanks, energy and water efficient appliances can be upgraded to reduce the operational energy demand. These upgradation can be done without disturbing the regular use of the building. Structural changes such as adding thermal mass in to the house, replacing windows are expensive changes but the performance of the house will be significantly enhanced with these changes.

The retrofitting measures can be planned for various stages so as not to make it an economic burden. Commonwealth Government of Australia has recently announced green loan package for the households interested in upgrading their houses. The Government provides economic support to install rooftop solar power panels, solar hot water systems, rainwater tanks and grey water recycling. Similarly, states and local governments also provide incentives.

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