WATER EFFICIENCY INFRASTRUCTURE AND ENERGY REQUIREMENTS AT THE RESEARCH HOUSE

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Abstract

Research House is part of the Queensland Department of Housing's 'Towards Healthy and Sustainable Housing Research Project'. The aim of the venture was to construct a house with sustainable building design and test how the features worked with a rental clientele. Research House was built in Rockhampton, with the data collection undertaken by the Central Queensland University (CQU). The house is equipped with a 75-channel data logger that continuously collected water use, energy use and generation, temperature, and rainfall information. As the house was designed for the rental market, the sustainable features of the house are passive in nature requiring no or very little direct manipulation by the householder. Water efficient infrastructure, such as flow-reduced taps and a front-loading washing machine, were installed throughout the house. All wastewater-generating infrastructure and garden irrigation implements were equipped with a water meter and individually monitored. The electrical demands of the house and the electricity generation through solar panels were also observed. The water-use figures and total energy requirements of Research House have been collected and collated for more than two years. These data allow for a partial evaluation of the sustainable design of Research House.

Keywords

Householder interaction, housing design, power requirements, sustainability, water consumption

1 Introduction

Research House is part of the 'Towards Healthy and Sustainable Housing Research Project' an initiative of the Queensland State Government. The Queensland Department of Housing has a 'Smart Housing Program' that aims to develop housing designs that have social, environmental, and economic sustainability (QG 2005). A 'Smart House' is safe, livable, resource efficient, and cost-efficient over-time. Research House is intended to trial one of the 'Smart House' designs (QG 2004).

Research House has been constructed using environmentally friendly materials (such as fly ash blocks), been designed to be responsive to natural breezes, has innovative approaches to insulation and ventilation, and uses energy and water efficient infrastructure (see Figure 1) (QG 2005). As part of the social sustainability program the mechanisms Research House uses to conserve resources are passive in nature (QG 2005). Research House is a rental property and part of the Queensland Department of Housing public housing stock. The tenants who live in Research House have been taken from the normal public housing waiting list and are not selected on the basis of environmental awareness. Since Research House was built there have been several changes in tenancy (QG 2004). The technology used at Research House must be robust and have limited maintenance requirements as legislation (Residential Tenancy Authority Act) restricts the access that landlords, or people acting on their behalf, have to a rental property.

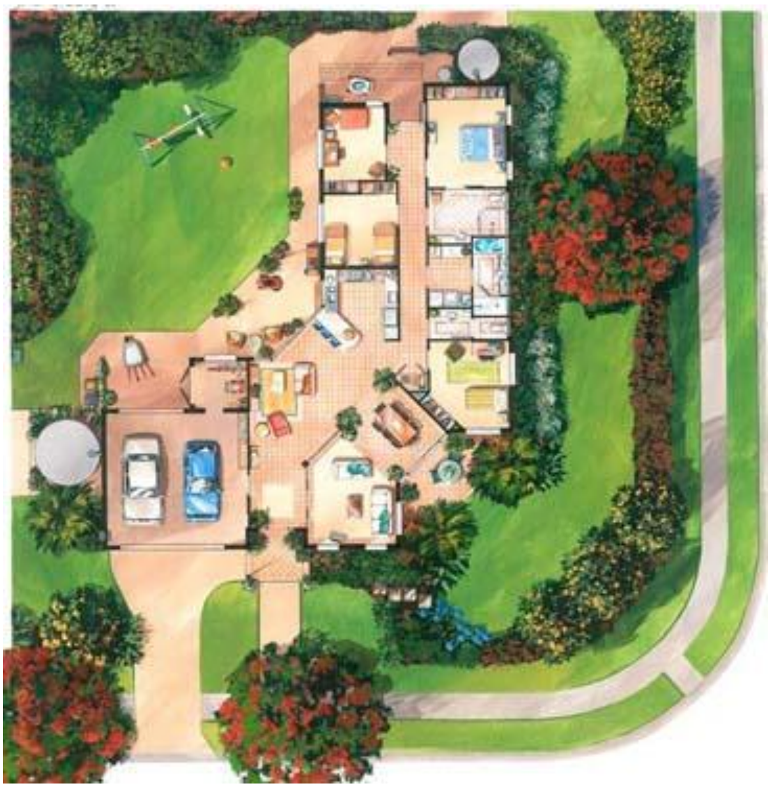

Figure 1. Artist's Impression of Research House Floor Plan

Research House is an extremely valuable tool as it provides information on how members of the general public can live in a sustainable manner. Many sustainable housing research projects take place in private dwellings using householders who are already committed to a resource-efficient lifestyle (Gardner and Millar 2003). While these studies are valuable they may overestimate the potential resource savings of a housing design due to the user patterns and behaviour of the householders. As the tenants change over time in Research House, different user patterns and behaviours will be able to be assessed. The infrastructure at Research House will also be able to be assessed on whether its efficiency performance degrades overtime. Studies at resorts/hotels have shown that drips and leaks maintenance programs are required on some infrastructure for it to maintain its efficiency (Kele *et al.* 2003).

The aim of this paper is to establish information on the water efficient infrastructure was installed at Research House, its energy requirements, and the yearly water consumption of each individual component.

2 Infrastructure and Data Collection

There were two design philosophies used for the water infrastructure at Research House; water efficiency and volume fill (QG 2004). It was understood that while most items in the house could be built using water-efficient infrastructure, some objects such as the bath, were filled by people to a desired depth regardless of the tap-flow rate. The two design philosophies were used to ensure that the basic criterion of economic sustainability was met

(QG 2004). The cost of installing flow restrictors on the bath taps was never going to be recouped through saved water if the tenants filled the bath to a predetermined volume. Economics is quite often thought of in the broad scale but ignored for smaller items (Beatty *et al.* 2005; Choe and Fraser 1998). The entire water and energy efficient household infrastructure was purchased with the intention that any excess money spent on a more expensive item (such as hot water system) or a new stand-alone item (such as a flow restrictor) would be recorded and a pay-back period in years would be calculated using the money saved from reduced water bills (QG 2004). This type of calculation is required to provide an economically sustainable determination of the house design (Icke *et al.* 1999).

All wastewater-generating infrastructure was equipped with a water meter (see Table 1). If the item used electricity an energy sensor was installed. The water and energy efficiency of each appliance was theoretically determined.

Table 1. Wastewater Generating Infrastructure, Data Collection, and Efficiency Rating

Item	Water Sensor (Y/N)	Water Efficiency Rating	Energy Sensor (Y/N)	Energy Efficiency Rating
Hot Water Unit	Y	Unrestricted Volume fill	Y	5 stars
Ensuite Toilet	Y	3/6 L dual flush	N	N/A
Ensuite Shower	Y	9 L/min	N	N/A
Ensuite Vanity	Y	6 L/min	N	N/A
Toilet	Y	3/6 L dual flush	N	N/A
Toilet Vanity	Y	Automatic Sensor Tap	N	N/A
Bath	Y	Unrestricted Volume fill	N	N/A
Kitchen Sink	Y	9-12 L/min	N	N/A
Dishwasher	Y	AAA 8 L/min	Y	4 stars
ZIP hot/cold Tap	Y	Unrestricted Volume fill	Y	Unavailable
Bathroom Vanity	Y	6 L/min	N	N/A
Bathroom Shower	Y	9 L/min	N	N/A
Washing Machine	Y	AAA 8 L/min	Y	4 stars
Laundry Tub	Y	Unrestricted Volume fill	N	N/A
Mains	Y	Unrestricted	N	N/A

At Research House a 75-channel data logger was established to collect water, energy, temperature, and weather sensor information. The data from the fifteen water-flow sensors and four relevant energy sensors will be discussed in this paper. Water volume was measured using water turbine transducers (QG 2004). As water flowed through the transducers, turbine blades rotated interrupting a laser light from a digital optical transmitter, which in turn creates a digital pulse that is recorded and converted into a water volume (QG 2004). This form of data collection allows for precise knowledge on a minute-to-minute basis as to what volume of water was used in specific locations within Research House. Problems with suspended solids in the reticulated water supply were encountered in the earlier months of the trial. An in-line filter to remove the solids was installed directly after the water-mains entry to the property and the problem was solved (QG 2004). The major electrical components were individually metered; smaller appliances could not be metered but a formula for electrical requirements was calculated (QG 2005). All the logged data were complied and presented through LabVIEW^{TM}.

3 Results and Discussion

The energy meters attached to the dishwasher and washing machine showed that actual electrical requirements were significantly different to the manufacturer's predicted energy label usage for the period between December 2002 and November 2003(see Table 2).

Table 2. Predicted Energy and Actual Energy and Water Use for Selected Whitegoods

Item	Energy Label kWh/yr	Actual Energy Use kWh/yr
Dishwasher	256	307
Washing Machine	225	205

The dishwasher (Dishlex – Electrolux Australia) used approximately 17% more electricity than envisaged and the washing machine (Front-loader Westinghouse – Electrolux Australia) 10% less. There has been much debate in the water industry about sustainable housing design and washing machines in particular, such as top-loader versus front-loader machines (see http://www.nrm.qld.gov.au/list_archives/water-recycling/index.html). Much information for this debate has been obtained from the manufacturer's energy label rather than from machines in households and field-tested data. The manufacturer's information is based on a projected daily figure achieved under ideal minimum energy performance standards conducted under a controlled laboratory environment (QP 2005). Householders through their user patterns and behaviour can use resource-efficient infrastructure inefficiently and vice-versa. This can result in theoretical resource-usage patterns based on manufacturer's data being inaccurate. In regards to Research House the dishwasher may have used more electricity because it was overloaded or the householders may have been using specific high-energy wash-cycles. The information shows that in relation to energy it may be more sustainable to have smaller more frequent washes. Educating householders on proper usage is still important even in a passive designed house with resource-efficient infrastructure. The debate between front-loading and top-loading washing machines is largely meaningless if user patterns and behaviours are not considered.

In Table 3 the yearly water and energy usage for the selected items at Research House are depicted. The yearly water usage for the hot water system could not be separately described in Table 3 as the hot water was used in a variety of items. It is known that the hot-water system used 129 L of water/day (11% of total use) over the period of this study (QG 2004). The majority of the reticulated water at Research House was used for outdoor purposes. While the majority of this is assumed to be for garden irrigation it also includes car washing and other outdoor water activities. The garden at Research House was designed to have minimal water requirements (drought-proof plants) and a water efficient irrigation mechanism (automated irrigation system) (QG 2004). However, it was observed that the tenants did water the garden themselves through sprinklers, garden hoses and soakage hoses. The householders also applied additional irrigation water to the yard from the two rainwater tanks. It was not possible to quantify the amount of irrigation water supplied from the rainwater tanks (QG 2004).

The volume of water used for outdoor activities highlights the importance of householder education in regards to user patterns and behaviours. Drought resistance plants should not have required this amount of water. It is possible that the plants were over-watered through manual irrigation techniques implemented by the tenants. As many people consider watering the garden to be therapeutic how does this practice fit into the concept of resource efficient housing design?

Table 3. Yearly Water and Energy Usage at Research House for Dec. 2002- Nov. 2003

Item	Yearly Water Use (L)	Percentage of Total Water Use	Percentage of Energy Use
Outdoor Use	214 620	51%	N/A
Showers and Bath	77 015	18%	N/A
Kitchen Sink	46 720	11%	N/A
Toilet	42 340	10%	N/A
Washing Machine	15 695	4%	2.3%
Dishwasher	10 585	3%	3.4%
Laundry Tub	9 490	2%	N/A
Zip Hot/Cold Tap	3 285	1%	6.8%
Hot Water System	-	-	13.5%

During the course of the yearly recording period (1st December 2002 to the 30th November 2003) there were 4.67 people residing at the property. Two adults and three teenage children, one of the teenage children was only present for part of the year (QG 2004). Data comparison with other reports for water and energy consumption is difficult as most articles detail information on a per household basis rather than a per capita. The number of people living inside a household is a major factor when considering water and energy usage. While the data are reported as a household figure, a per capita figure can be obtained for the presented data by dividing by 4.67.

Inside Research House the largest water consumption was from showers and baths (approximately 211 L/day). It was known that the tenants preferred showers to baths (QG 2004). The kitchen sink and the toilet had similar volumes; although it is expected that some of the kitchen water would have been used for cooking and drinking purposes and not have immediately entered the wastewater stream. Examination of the times the kitchen sink was used confirms that the majority of the water usage occurred during expected mealtimes. The washing machine only used 4% of the total water and 2.3% of the total electricity. While there is a debate about washing machine designs in the Australian water industry, the data from Research House show that washing machines are only responsible for a small amount of the total resource use for this specific dwelling. With the refrigerator using 14% and the hot water system 13.5% of the total energy usage at Research House there may be more benefit in seeking energy efficiency from the infrastructure that uses the most energy rather than focusing on small percentage energy savings from items such as the washing machine and the dishwasher. The dishwasher used more energy than the washing machine but only about 2/3 of the water; it is thought that the difference was due the heating of the water in the dishwasher. The laundry tub was used infrequently; an examination of the water use patterns showed that it was not used on a daily basis. The Zip constant hot/cold water tap used only 1% of the water but required more electricity than the washing machine and the dishwasher put together. It cost $70/year to run although the cost of this may have been offset as the refrigerator was not used to chill water and no kettle was required (QG 2005). Whether $70 worth of electricity would have been used to boil water in a kettle or to chill water in a refrigerator is unknown.

The hot water system used at Research House for the first year of the trial utilised a heat pump technology (Quantum). This entails a refrigeration principal where heat is drawn out of one space and discharged into another (QG 2004). The Quantum hot water system does not have a heating coil at the base like most other systems, but instead has a heating coil that runs the full length of structure. This equates to an even water temperature throughout the system and less water wastage from people letting water run through a tap until it is warm (QG 2004). Over time the hot water technology at Research House will be changed so that different systems can be tested. The Quantum technology will be replaced by an electric boosted solar hot water system (Solahart), which in turn will be substituted with an instantaneous gas system (Bosch). This will be done so the most sustainable form of water heating can be established. The Quantum system used approximately 60% less energy than what is reported for an average Queensland off-peak electric hot water system (QG 2005). This equates to a saving of about 777 kg of green house gases (GHG). The energy efficiency of a Quantum hot water system can be expressed as a coefficient of performance (COP). The COP is the ratio of energy transferred to the water to the electricity consumption of the compressor (QG 2005). The Quantum system at Research House had a mean COP of 3.09 which means that for each unit of electricity supplied from the mains another 3.09 was supplied free from the environment. Depending on the volume of water heated the Quantum system would take between 5-7 years before the added cost of its installation would be paid back in relation to a standard off-peak system. The long payback period isn't of great concern as the system has a tank-life warranty of fifteen years; which is considerably longer than most off-peak electric technologies. The Quantum system does produce a noise from the compressor, which is about 52dBa at a distance of 1.5 m or approximately that of a new standard domestic refrigerator. From the data collected the heat pump system appeared to be a more sustainable option than conventional boilers for the heating of domestic water.

The daily water usage per capita at Research House is of interest to sustainable housing design and integrated water management is concerned. The water supply and wastewater treatment requirements of urban developments are based on an Equivalent Person (EP) calculation. While there is a variety of different definitions for the exact volume of an EP one standard definition is that one EP equals 250 L of wastewater. The practice of the various State Governments and Local Government Authorities in Australia of having slightly different definitions of EP has caused considerable confusion. The historical and scientific basis for the calculation of EP is not well known. The data from Research House show that on a daily per capita basis the volume of indoor water use from which wastewater will be produced is only 120 L (see Table 4).

Table 4. Daily Wastewater Production Per Capita at Research House compared to EP

	Average Daily Total Water Use	Average Daily Indoor Water Use	Average Daily Indoor Per/Person Water Use	Standard Equivalent Person (EP) Water Use
Research House	1150 L	562	120 L	250 L

Resource efficient infrastructure and its widespread acceptance by Government authorities and the general public are relatively new. While some organisations have altered EP values for resource efficient developments this has been done on an *ad-hoc* basis with very little consistency. The 120 L does not take into account potable use and spillage so the actual amount of wastewater produced per capita/day would be smaller. A reassessment of the EP calculation and how it applies to resource efficient designs needs to be undertaken. This process needs to occur on a national basis and be applied consistently. Wastewater treatment systems, whether they are part of a reticulated sewage treatment plant or an on-site system are not efficient, economic and may not supply quality treatment if they are over-sized for the required task. It is important to note that basing a new EP volume on bench-top studies without evaluating the impacts of people's user patterns and behaviours would not produce a realistic alternative. A 'Smart House' needs to be part of a 'Smart Development' and designing new resource efficient houses without reassessing the parameters used to design water supply and wastewater treatment is not a sustainable practice.

4 Conclusions

Research House will be a valuable tool for the long-term assessment of resource efficient sustainable housing design. While this report focuses on the first year's data the continuing information will be important in determining whether infrastructure maintains the same level of water and energy efficiency over time, or if it degrades in performance, and if so at what rate. The multiple data collection points have reduced the need for theoretical water and energy usage calculations within the house and provide real-time infrastructure specific information. The changing tenancy patterns allow for appraisals on usage patterns and behavioural differences of the general public. The ability to make precise per capita calculations and compare them with yearly total use figures allows for some realistic field analysis of potential new EP calculations for sustainable developments. Data from dwellings such as Research House have the ability to provide relevant information for the long-term sustainable planning of Queensland's housing development.

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