NO102/4

Waitakere NOW Home® Performance Monitoring: Year Two Report

Final

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About This Report

Title

Waitakere NOW Home® Performance Monitoring: Year Two Report

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Reference

Pollard A, French L, Heinrich M, Jaques R and Zhao J. April 2008). Waitakere NOW Home® Performance Monitoring: Year Two Report. NO102/4 for Beacon Pathway Limited.

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1 Executive Summary

Overall the second year of occupation the Waitakere NOW Home® has seen a 15% increase in reticulated energy consumption, while the overall water use has decreased by 8%. The indoor temperatures and humidities have improved and the CO_2 concentrations have decreased. The post-occupancy evaluations (POEs) for the second year were producing similar responses for the first year so were discontinued in favour of a one-off Household Energy End-Use Project (HEEP) survey. The following sections highlight the Waitakere NOW Home®'s performance in the four areas of energy use, water use, indoor environment and occupant evaluations

1.1 Energy

The second year reticulated energy consumption of the Waitakere NOW Home® occupants was 15% less than the average reticulated energy use of houses constructed in Auckland since 1997 (taken from the HEEP database). However it was 15% higher than the energy consumption in Year 1. During its second year of occupation the Waitakere NOW Home® reticulated energy consumption increased from the Year 1 figure of 7400 kWh to 8500 kWh.

The electricity bill for the second year was $1640, reflecting a 24% increase in cost from the $1325 the occupants paid in the first year, in part due to higher energy costs (see Table 4).

The highest end-use of electricity is the solar water heater which has seen a large increase in energy use from the first and second years of operation, using 2340 kWh (28%) in the second year.

Initial analysis of the appliance electricity meters shows the home office computer is one of the appliances that uses a large amount of electricity, consuming 10% of the household's electricity, and is the second highest for the home.

The solar water heater converted 1880 kWh of heat from the sun into water heating in the second year of operation, contributing 45% of the energy used for water heating over the year. This reflects a cost saving of $300 per year. This is slightly below expectations with the winter-time performance of the solar water heater providing only approximately 10% of the water heating needs. It is recommended that a timer be installed on the electric supplementary heating element to prevent heating of water from the electric element in the mornings.
The Waitakere NOW Home® base load is not directly comparable to HEEP due to the varying appliance usage in the Waitakere NOW Home® requiring a different calculation method. A characteristic value for the minimal power use (the 1% percentile) for the Waitakere NOW Home® is 240 W and this high level suggests many appliances are left on continuously or in standby mode.

The Waitakere NOW Home® met Beacon's HSS High Standard of Sustainability® (HSS®) for reticulated energy use in Year 1, but not in Year 2 (see Table 1).

1.2 Water

The Waitakere NOW Home® used 82 litres per person per day (L/p/d) of reticulated water due to utilisation of a rain tank. This represents a 50% reduction in reticulated water use compared with other households in Waitakere, which easily meets the HSS® of 40% reduction, providing the baseline for the HSS® is the average for the Waitakere area.

There was an 8% decrease in the total water use for the Waitakere NOW Home® from Year 1 reducing use to 690 litres per day (L/d). However the water use during the Year 2 summer period (796 L/d) was 17% higher than the water use during the Year 2 winter period (681 L/d). For the second year, 48% of this water was supplied by the street mains and 52% from the 13 500 L rain tank. It is estimated that the Waitakere NOW Home® collected 216,000 L of rainwater (which is equivalent to 86% of the total water demands) over its second year of operation. However only 128,000 L of this water was used. Control systems, such as automatic valve switches, to maximise the amount of rain water used have the potential to greatly improve the overall effectiveness of the system.

The highest proportion of water use within the Waitakere NOW Home® goes into the shower with an overall proportion in the second year of monitoring of 42%.

The laundry was the next highest usage with 19%, followed by the toilets 15% and the outside taps 12%. The use of the outside taps was very seasonal, with 28% of summer-time usage going into taps, but with almost zero winter-time usage.

On average 202 L of water per day are used to heat water. A large proportion of this heated water (around 80%) is used in the shower.

1.3 Indoor Environment

The Waitakere NOW Home met the 2006 HSS® (Easton 2006) with average temperatures in the living space remaining at or above 18°C, and bedroom temperatures remaining above 16°C throughout summer and winter in both years. The summer-time temperatures were slightly lower in the second year of monitoring than in the first.

A fault with the temperature sensors meant that the comparison of the winter-time data covered August and September. The outdoor winter-time temperature was slightly warmer for the second year and most indoor temperatures were slightly warmer. The temperature in the bathroom was slightly cooler which could be due to the addition of a ventilation fan before the second winter. The change of the office into a bedroom, with the office being relocated into the living room, resulted in a 2°C temperature increase in the living room (now with the office computer) while bedroom 2 was 2°C cooler.

The summer-time humidity showed no remarkable change between the years. However the winter-time humidity was quite different. Overall the humidity levels in the second year were lower despite an increase in outdoor humidity, and again the change of room usage and the increase of ventilation in the bathrooms produced specific changes in the humidity levels. There was a greater variation of humidity throughout the house in the second year and further analysis, perhaps considering the absolute humidity, may be of value.

The CO_2 levels have seen a large decrease in values between the first and second years, presumably due to the increase in ventilation within the house in the second year.

1.4 Occupancy Evaluations

The POEs used in the first year highlighted that the Waitakere NOW Home® occupants were extremely pleased with the house, giving it a perfect rating of '10'.

- The Waitakere NOW Home® occupants liked:
- The layout of the rooms and good use of space
- The thermal performance of the house, in terms of stability and (almost) negating the necessity for winter-time space heating
- The concrete floor, in terms of its ability to keep clean.

However they thought the following features could have been improved:

- Tracking the small pathway stones into the house
- The 'breakfast bar' being too high
- The lack of privacy from neighbours
- Condensation on the master bedroom window in the winter-time
- The amount of decomposable recycled.

For the second year of occupancy, as the quarterly POE surveys were producing similar responses and as there was interest in obtaining more behavioural information, these surveys were suspended and the HEEP occupant survey used for this year.

2 Introduction

This report summarises learnings from the second year of monitoring and analysis of the Waitakere NOW Home®, which is located in Olympic Place, Waitakere City. This project is unique in that it conducts the most intensive and comprehensive physical monitoring of any New Zealand residence. Physical monitoring applied to the NOW Home® used a combination of electronic data loggers recording at intervals of one minute, recording some 1000 data points every day. Four thematic areas were examined in some detail as part of the physical monitoring: energy use, water use, indoor environment and social issues. Where possible, results are compared to the previous years' findings and/or other similar studies. In addition to the physical monitoring, social monitoring using periodic face-to-face post-occupancy questionnaire surveys was conducted. Further information on the monitoring challenges faced in this project is available in Andrew Pollard's paper *Practical Challenges in High Intensive Domestic Monitoring*, given to the SB07 Sustainable Building conference in 2007[2].

This report brings together information and knowledge which can feed into future NOW Home® projects, providing a real insight into the way the home interacts with the family, their lives, and the immediate surroundings, with learning opportunities and benefits in each of the physical and social areas examined. Other useful learnings include those surrounding the intensive and practical collection of data in a 'real' environment over time.

It should be noted that the monitoring environment was dynamic. That is, there were several significant changes made to the physical environment, just like any other house, over the two-year period. These changes and their timings are:

a) The installation of a Centameter (which provides a dynamic reading of the electricity usage in a prominent area) – installed 18 July 2007
b) Tank level indicator for the 13,500 L rainwater tank – installed 26 July 2007
c) Ventilation extractor fans in the bathroom and ensuite – installed 13 June 2007
d) Solar-powered stack fan in the kitchen which has no override off-switch – installed 13 June 2007
e) Changes to use of the bedroom 2 / study and living room – date changed is undetermined.

Where possible, the implications of these physical changes (and resulting social impacts) have been explored in this report.

[2] ***It is available from the Beacon website:***
http://www.beaconpathway.co.nz/images/uploads/SB07_Waitakere_NOW_Home_monitoring_Pollard.pdf

The assumption is made that the reader is familiar with the NOW Home® project. This report should be read alongside Report NO102/3, *Waitakere NOW Home® Performance Monitoring: Year One Report* (French et al 2007) which summarises the monitoring of the NOW Home® over its first year of operation. Pollard (2007) provides some insights into the practical challenges encountered with the monitoring methodology.

3 Energy Use

3.1 Overall Use

The Waitakere NOW Home® uses two sources of energy: electricity and solar. The solar contribution provides energy into the space heating and water heating needs of the household.

Beacon has identified (Easton 2006) the need to reduce the demand on reticulated energy services (electricity and gas). For the Waitakere NOW Home®, the reticulated energy use is equal to the electricity use of the household.

Non-reticulated energy is frequently used for space heating and all households will have some non-reticulated energy use as every house will have a solar contribution to its space heating requirements. During its second year of occupation the Waitakere NOW Home® has had a 15% increase in reticulated energy consumption from that used in the first year of occupancy increasing from 7400 kWh to 8500 kWh.

Table 1 gives Beacon's HSS High Standard of Sustainability® benchmarks (Easton 2006), the original NOW Home goal and typical performance for current construction meeting New Zealand Building Code requirements (Easton 2006) alongside the measured values for the Waitakere NOW Home® for the first and second years of occupation.

Target	**Annual reticulated energy use (kWh)**
NOW Home®	6000
High Standard of Sustainability	7600
Current Building Code	10000
Measured NOW Home® (1st year)	7400
Measured NOW Home® (2nd year)	8500

Table 1: HSS benchmarks compared to Building Code requirements and NOW Home goals and performance

Benchmarks from the draft Beacon HSS for reticulated energy use for new construction in climate zone 1 (Easton 2006) alongside original NOW Home® goal and typical performance for current construction meeting the New Zealand Building Code requirements

The first year report (French et al 2007) made comparisons of the Waitakere NOW Home® reticulated energy use alongside a number of matched sample groups of households taken from the HEEP database. These groups were defined as having similar characteristics to the Waitakere NOW Home® and the description and sample size of these groups appears in Table 2.

Group	Description	Size
Group 1	houses constructed after 1996	29
Group 2	houses constructed after 1996 with a household of four occupants with pre-school age children	2
Group 3	houses with a household of four occupants with pre-school age children	23
Group 4	houses constructed after 1996 located in Auckland	8
Group 5	houses constructed after 1996 located in a wider Auckland area (include the Awhitu, Orewa and Parawai HEEP clusters)	13

Table 2: HEEP subset group definitions

Figure 1 gives the comparison of the reticulated energy use of the Waitakere NOW Home® with the reticulated energy use of the households comprising of the five HEEP groups. The reticulated energy use for the Waitakere NOW Home® is now similar to the mean reticulated energy consumption for Group 1 (houses constructed after 1996) and Group 3 (household with four occupants, pre-school children). However it is 15% lower than the Group 4 mean (houses constructed after 1996 located in Auckland) and 16% lower than the Group 2 mean (houses constructed after 1996 with a household of four occupants with pre-school age children).

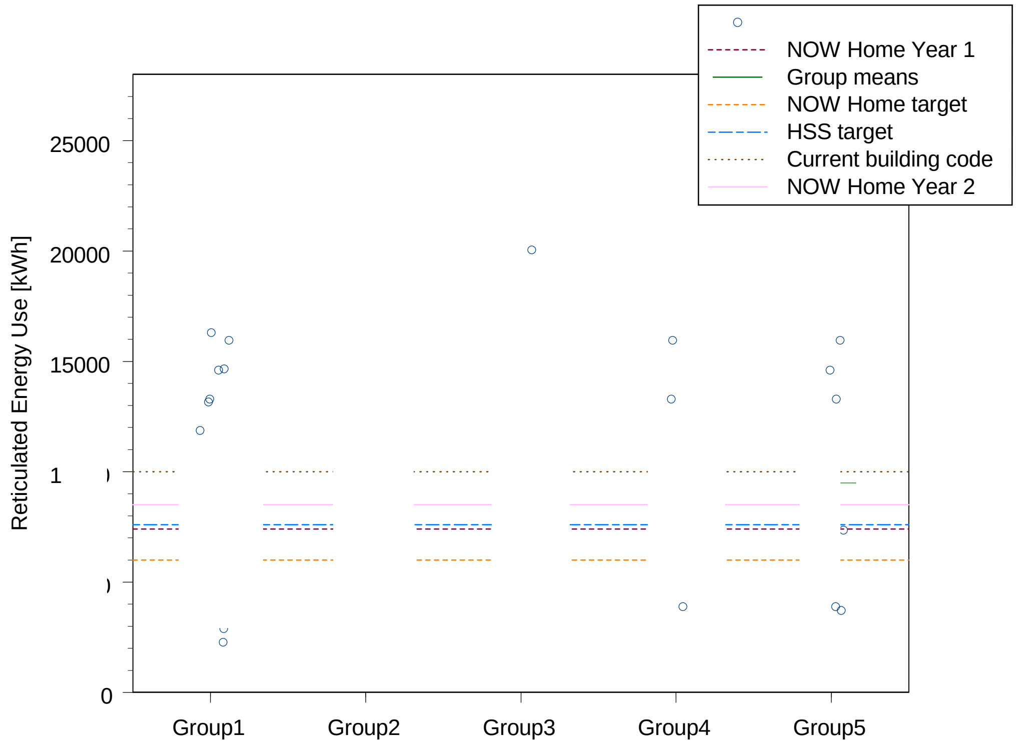

Figure 1: Comparison of the reticulated energy use of the Waitakere NOW Home® with a number of groups of HEEP houses

Figure 2 gives the daily energy use of the Waitakere NOW Home® since monitoring began. The energy use is given in units of kWh per day. The total energy use of 7400 kWh in the first year was equivalent to a daily consumption of 20.3 kWh per day, whereas the second year total energy consumption of 8500 kWh was equivalent to a daily consumption of 23.3 kWh per day.

The daily energy use of the Waitakere NOW Home® shows a strong seasonal variation on top of a steady increasing trend with the smoothed curve through the data being symmetrical about the linear regression line. The linear regression line has a slope of 0.01 kWh per day which is equivalent to an increase of energy use per year of 1400 kWh.

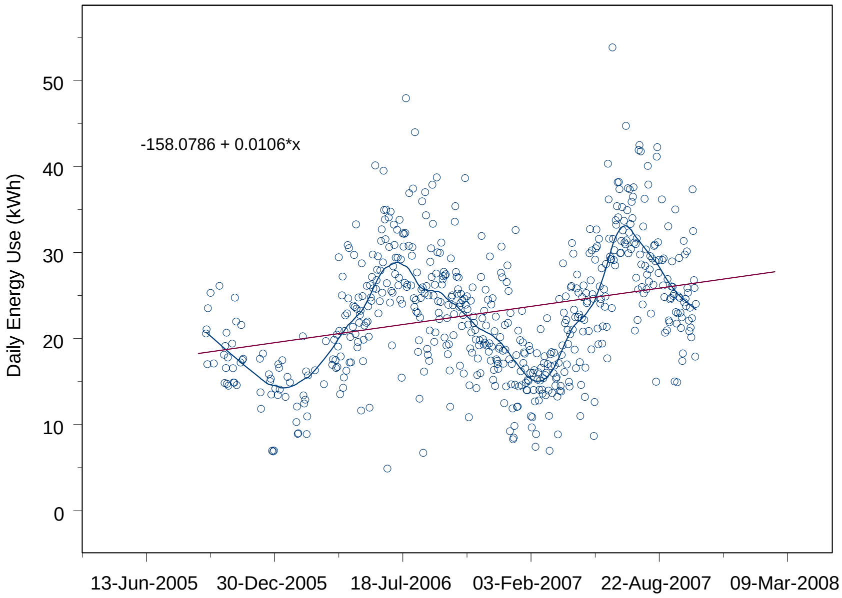

Figure 2: Daily energy use for the Waitakere NOW Home®

3.2 Energy End-use

The Year 1 report (French et al 2007) end-use breakdown of the electricity in the Waitakere NOW Home® (Figure 3) determined that the largest known share of the electricity was going into the SWH (22% including the pump energy requirements), and that all the other end-uses were each smaller than 7%. Despite having measured a range of services for the house (water heating, range, lights, refrigeration, dishwasher, water pump), there remained a large share (53%) which was unknown.

In order to improve the understanding of the total energy use, additional appliance monitoring is underway with the idea of periodically monitoring an appliance to get an estimation of its contribution to the annual electricity use of the Waitakere NOW Home®.

Figure 4 gives the estimated end-use breakdowns for the Waitakere NOW Home® for the second year of occupation

Figure 5 provides this end-use comparison in absolute terms which better allows the comparison and changes at the end-use level between Year 1 and Year 2. The statistical significance of the changes in energy end-uses over time will be examined in the third and final report.

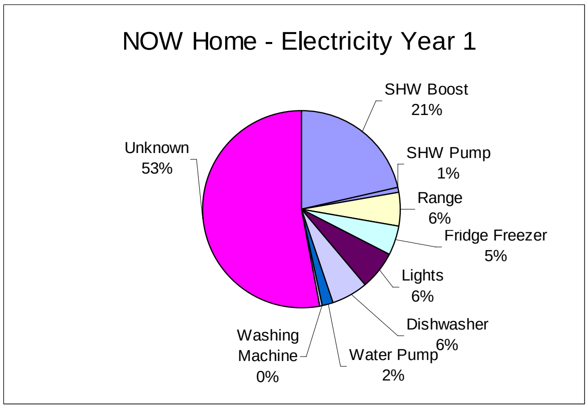

Figure 3: End-use breakdown for Year 1

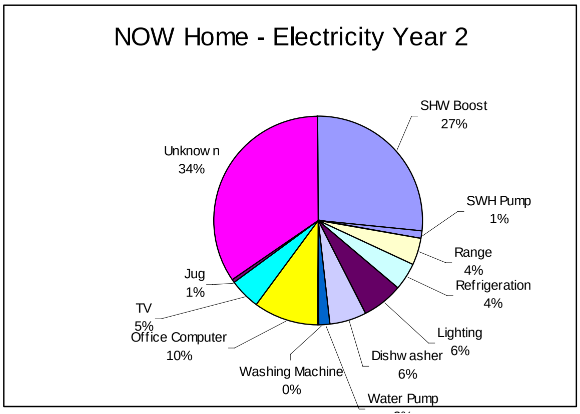

Figure 4: Estimated end-use breakdown for Year 2

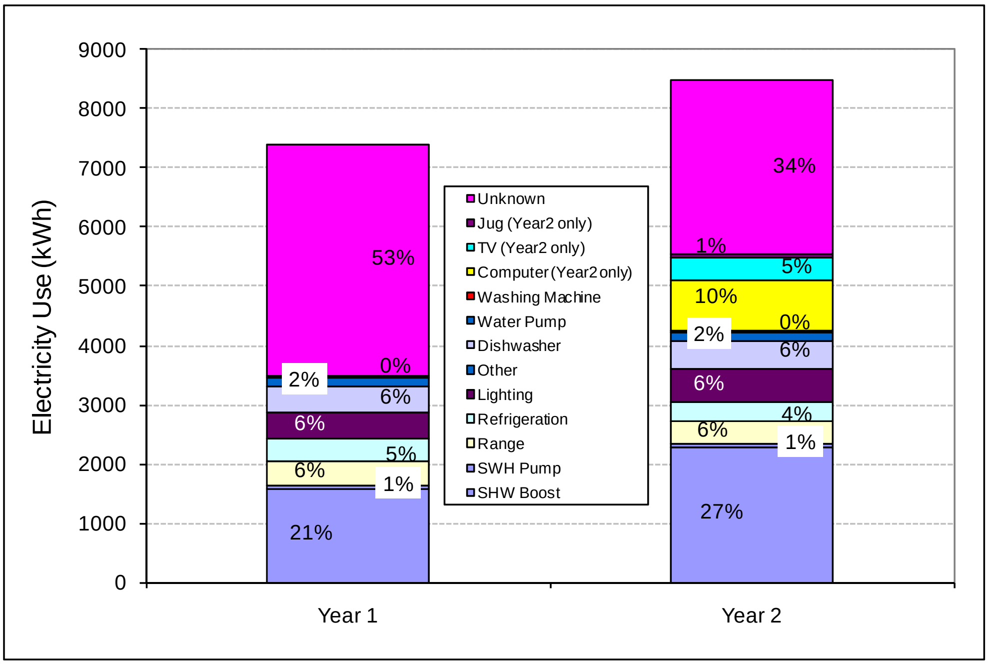

Figure 5: Comparison of end-uses for Year 1 and Year 2

For the first period between 25 August and 19 October, three additional appliance monitoring units were available to put on the office computer, the main big screen television and the electric jug.

On 19 October the TV transponder was moved to the stereo and the transponder on the jug was moved to the microwave. Future rotations of transponders may include the coffee machine, the stereo in the office and the media computer.

In order to provide an annualised estimate of these new appliance end-uses, the seasonal variation of the appliance being monitored must be small. For example there is limited value in placing a transponder on the electric blanket during summer given its winter-time usage. Likewise an estimate for the yearly use of the electric blanket based on only two weeks of monitored data in winter would be problematic as questions such as when they started using it and for how many months would remain unanswered. The clothes dryer is another appliance that may have similar seasonal use.

The extrapolation used for each of the monitored appliances was to simply calculate daily electricity consumption and assume that this is constant throughout the year.

End-use	Method	Year 1	Year 2	Change
SHW boost	Circuit	1580†	2270	44%
SWH pump	Circuit	60	73	22%
Heating‡	Appliance	0	0	0%
Range	Circuit	414	375	-10%
Refrigeration	Circuit	360	336	-7%
Lighting	Circuit	466	540	16%
Dishwasher	Circuit	426	484	13%
Water pump	Circuit	139	135	-3%
Washing machine	Appliance	30	30	0%
Home office computer	Appliance	na	847†	na
TV	Appliance	na	391†	na
Jug	Appliance	na	56†	na

Table 3: Electricity (kWh) into each end-use for Year 1 and Year 2

† Energy use data is not available for the full year for these measurements. The number shown is an annualised estimate from the available data.
‡ The heating end-use comprised the heater identified as the most likely to be used which was a fan heater stored in the living room cupboard.

From this data it is clear that the **home office computer** was an important use of electricity within the Waitakere NOW Home®, using 10% of the electricity, and was second only to the SWH in terms of the single largest end-use. The computer was higher than other, typically more intensive, end-uses such as heating, range, lighting and refrigeration. From our understanding this usage was not typical and it seemed they kept their computer running for extended periods of time. This is where level of service is an important issue, with this household having a high desire for computer use (e.g. the children have laptops).

The amount of electricity going into **solar water heating** (SWH) appears to have increased considerably between the first and second years. There are two possible reasons for this. The first is the SWH boost for the first year was only estimated and there is some uncertainty over this figure. Secondly, there has been a considerable increase in hot water use between the two years and it will be seen later in the section on water (4.1.6) that there is an increase in the winter-time hot water use from 212 L of hot water per day for the first year to 268 L of hot water per day for the second year. The performance of the solar water heater for the second year of occupation is discussed in section 3.3. It seems over time there has been a greater demand of service from the house. This may be either the occupants going back to 'old habits' or it could be they recognised the ability for this house to provide more.

Another new appliance being monitored is the **large screen TV** in the living room. This is estimated to use 391 kWh per year or 5% of the household electricity use. This is a fifth highest end-use following the SWH, the office computer, lighting and the dishwasher, and is therefore another important end-use.

The other new appliance is the **jug,** which only used 56 kWh per year. Jugs are typically one of the higher kitchen end-uses. In the Waitakere NOW Home®, however, the occupants used a coffee maker which may explain why this energy use was lower than expected.

The **lighting** load increased 16% from Year 1 to Year 2. The installation of the extractor fans in the bathrooms in June were wired into the lighting circuits so some of this increased use is likely to be due in part to the operation of the these fans.

The **dishwasher** was the only other end-use seen to have an increase in electricity use (a 13% increase), with the other end-uses remaining the same (washing machine) or showing a slight decrease (range, refrigeration and water pump) in electricity use.

The average daily profile for the fixed end-uses for the second year of the Waitakere NOW Home® is shown in Figure 6 indicating the typical timing of the end-uses.

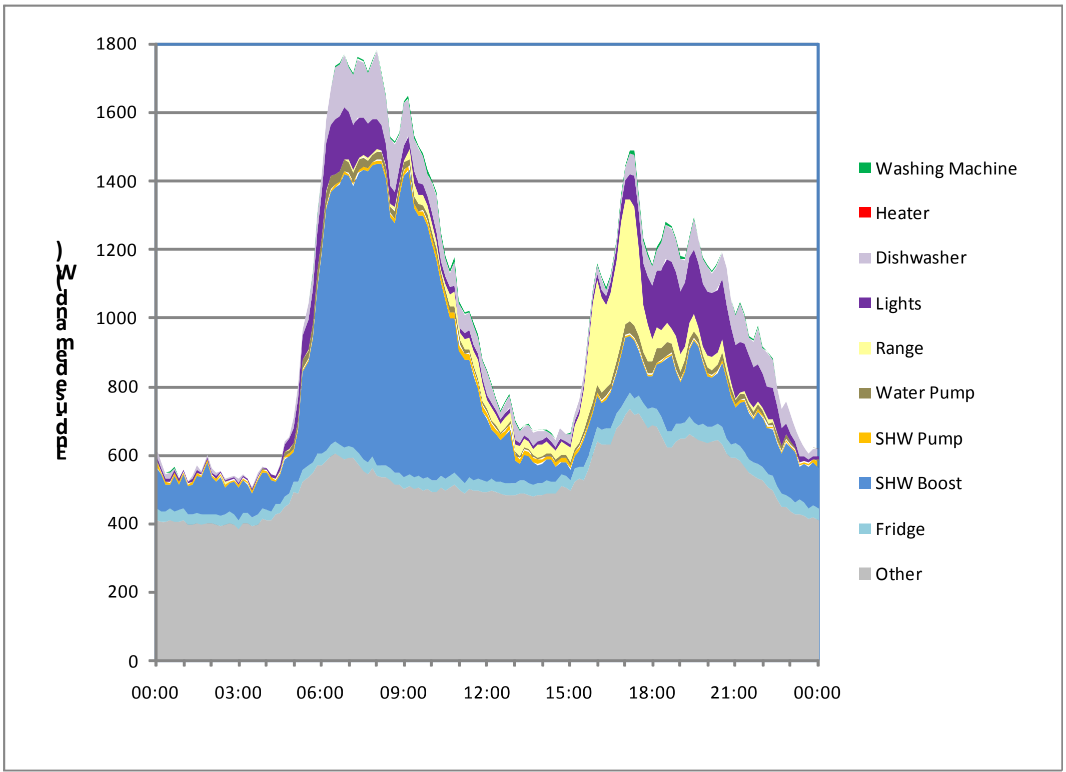

Figure 6: Average daily profile for the second year

3.3 Power Company Records

The occupants of the Waitakere NOW Home® were supplied with electricity by Mercury Energy, as they had been at their previous address. Vector was the electricity network provider in Auckland. Figure 7 provides a graph of the daily electricity use (the energy use for the monitoring equipment has been removed from this graph) for both the Waitakere NOW Home® (data on the right) and the occupants' previous home (data on the left). Figure 8 shows the same data super-imposed by time of year so that the seasonal differences can be better seen. The first year data for the first four months shows lower usage than the corresponding period the following year.

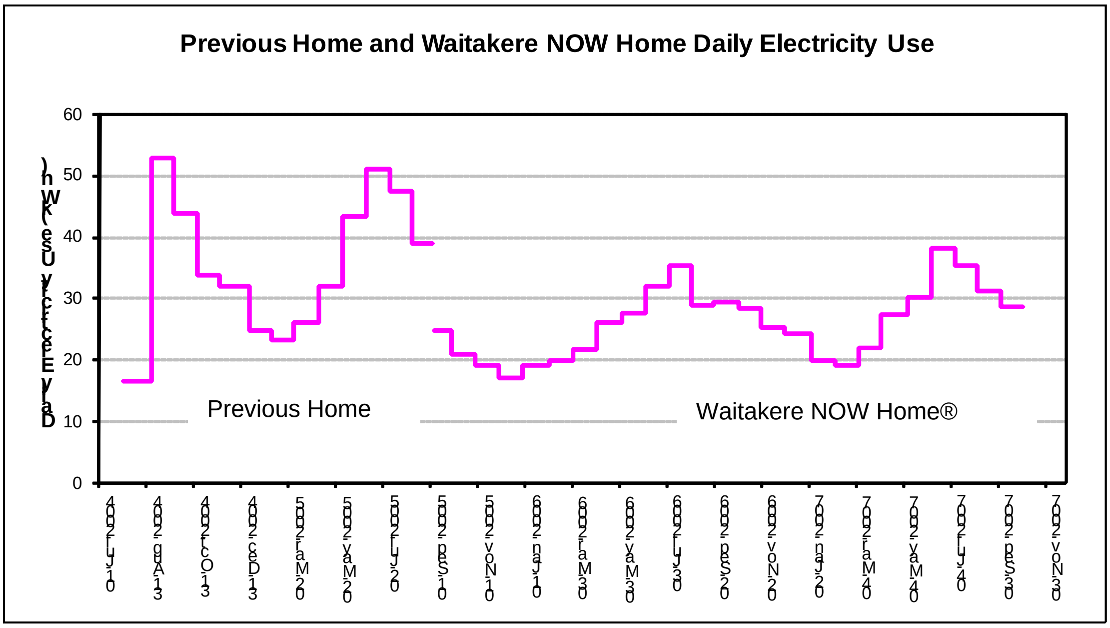

Figure 7: Electricity consumption from monthly meter readings from the Waitakere NOW Home® and the previous property rented by the NOW Home occupants

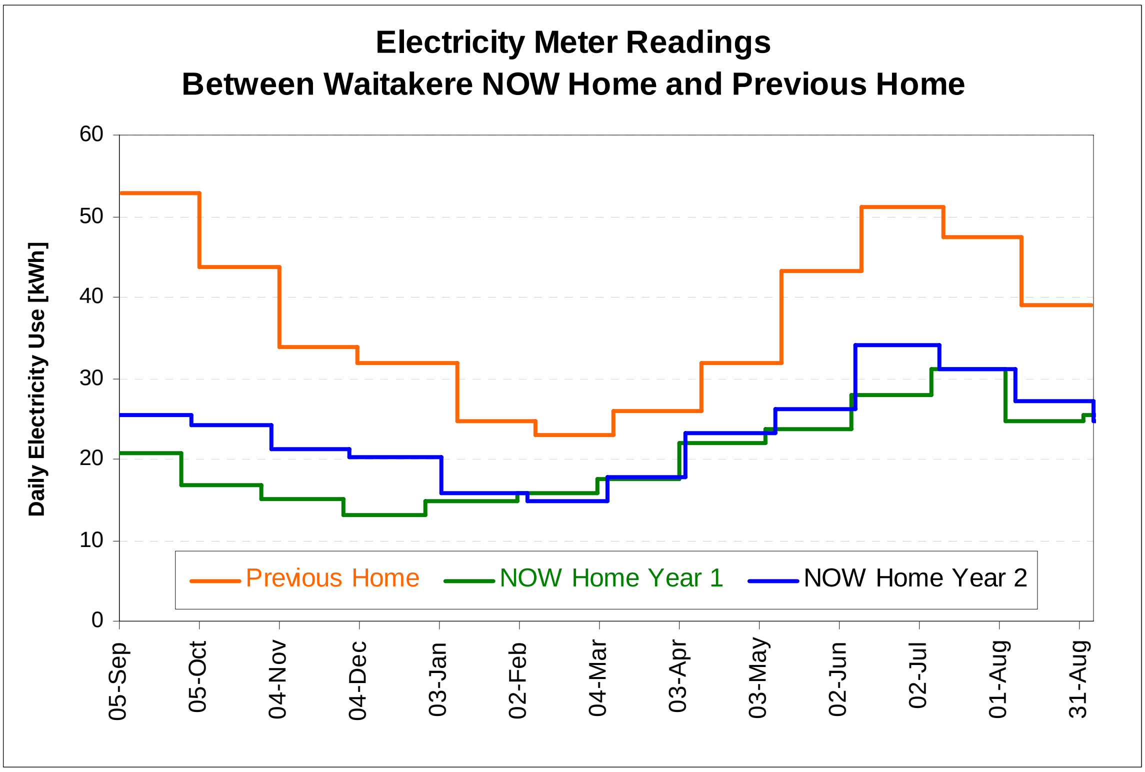

Figure 8: Seasonal electricity consumption from the monthly meter readings from the Waitakere NOW Home® and the preceding year at the previous property rented by the NOW Home occupants

The changes to the electricity charges for the Waitakere NOW Home® are summarised in Table 4. As with many electricity providers, Mercury Energy offered a 10% prompt payment discount and the costs presented here were after this discount had been applied and included GST.

Date	Variable Charge (cents/kWh)	Fixed Charge (cents/day)	Reason
Sep 2005 – Mar 2006	15.70	33.75	
Mar 2006 – Apr 2006	16.50	32.38	Mercury Energy price change
Apr 2006 – Jan 2007	17.21	33.75	Vector price change
Jan 2007 – Apr 2007	15.12	79.91	Change to standard user tariff
Apr 2007 – Oct 2007	15.93	81.87	Vector price change

Table 4: Change in electricity charges for the Waitakere NOW Home®

The cost of running the monitoring equipment was calculated by multiplying the energy used by the corresponding variable tariff. This monitoring equipment cost has been deduced from the total electricity cost to give the electricity costs incurred by the Waitakere NOW Home® occupants.

The first year of the Waitakere NOW Home®, the occupants paid $1325. For the second year the electricity bill was $1640 reflecting a 24% increase in cost. This increase is 8% over and above the increase in energy consumption between the first two years of occupancy of the Waitakere NOW Home®.

3.4 Solar Water Heating

An important energy saving feature in the Waitakere NOW Home® is the inclusion of a SWH system.

A common perception around at the time of the construction the Waitakere NOW Home® was that solar water heaters required big tanks to be installed on the roof making them looked ugly. The choice of system for the Waitakere NOW Home® was to provide a counter example and a low profile flat-plate collector (Solahart Streamline system) was installed. This included a 270 L cylinder within the house.

SWH is one of the easiest means of incorporating renewable energy into buildings. It feeds the energy from the solar radiation directly into the water within the water heating system, displacing the need to heat the water by other means such as electricity or gas.

3.4.1 Determining the solar contribution

One approach to determining the amount of additional water heating energy that would otherwise be required if the solar was not present, is to consider the amount of solar energy intercepted by the collector, the efficiency of the collector, and the various heat losses throughout the system.

This approach is difficult to achieve as many measurements on separate components of the system need to be made and undertaking these measurements while the system is being used may not be practical.

An alternate method to determine the solar contribution to the water heating is to use an 'energy balancing' method such as applied to systems tests of solar water heaters (for example see ISO 9459-3. 1997) and this was the method used for the Waitakere NOW Home® solar water heating system analysis.

Figure 9 gives a simplified schematic diagram of the Waitakere NOW Home® solar water heater set-up. Energy is supplied to the hot water cylinder by the solar collector and by the supplementary electric element. Energy is lost from the cylinder from the water drawn-off from the cylinder ('used energy') as well as the heat conduction losses (the standing losses) through the pipes and sides of the cylinder.

The energy balance is then determined according to Equation 1 and the energy supplied from the solar collector calculated by adding the used energy to the standing losses and then subtracting the supplementary electric heating.

Solar radiation via collector (solar energy)	**+**	**Supplementary electric heating (boost energy)**	**=**	**Hot water used by occupants (used energy)**	**+**	**Standing losses of cylinder (standing losses)**
Energy Sourced			=	Energy Applied		

Equation 1: Energy balance of the hot water cylinder

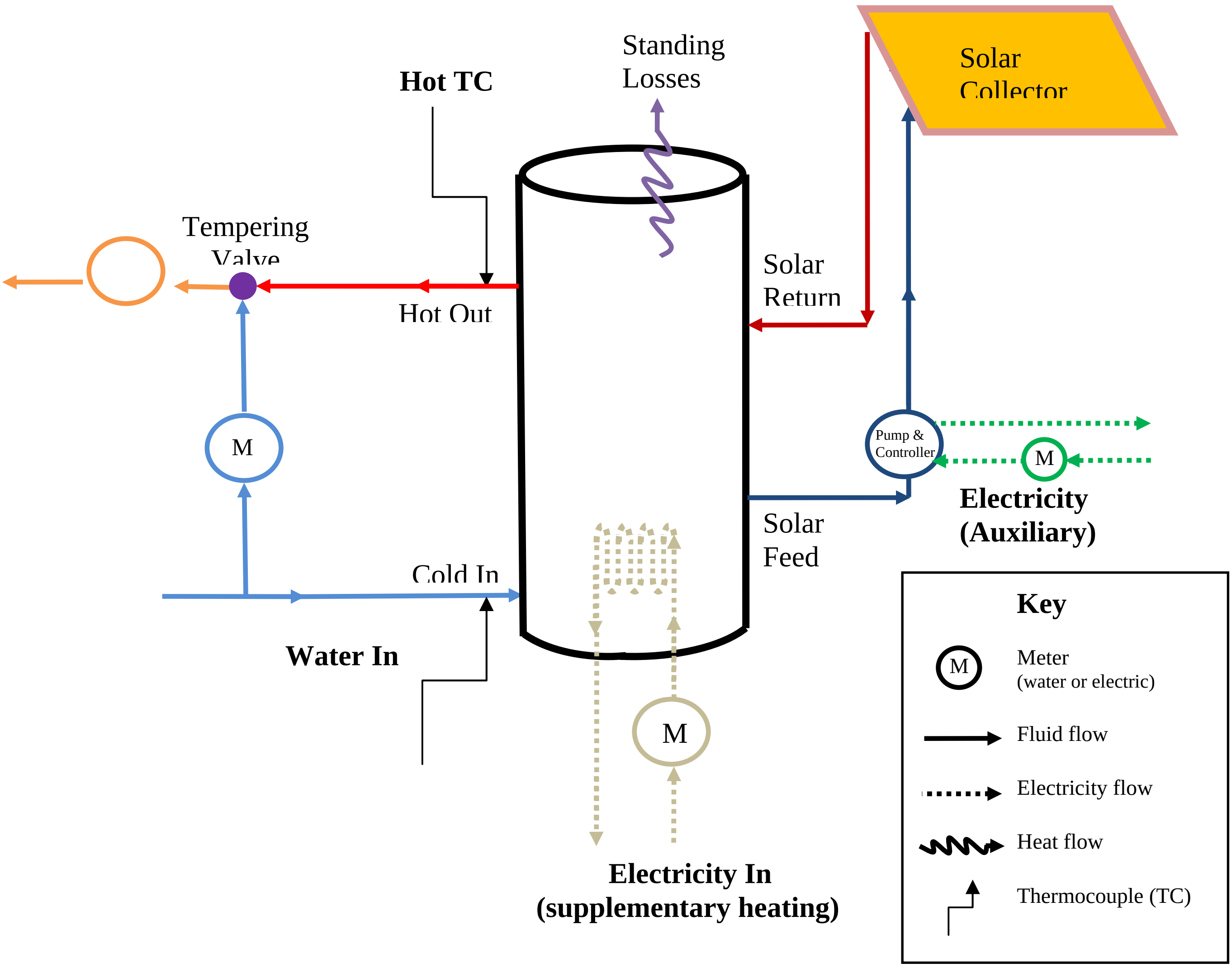

Figure 9: Schematic diagram of the Waitakere NOW Home® SWH system

In analysing the performance of the solar water heater it is also necessary to account for any auxiliary energy used by the system such as pumping water up to the collector or operating the control system. From this, a complete systems assessment can be made.
The analysis of the SWH data that follows makes use of the data from the second year of occupancy of the Waitakere NOW Home®.

3.4.2 Solar contribution

Using the energy balancing calculation in Equation 1, it can be determined that the solar energy collected by the Waitakere NOW Home® in the second year of operation is 1880 kWh, with an electricity cost of 15.93 cents per kWh. This represents a saving of $300.

The various energy figures making up the complete SWH system are given in Table 5. Based on the monitoring and the calculations, the solar contribution, that is the savings achieved from having a solar hot water system, is 45% of the total water heating energy input.

Solar (kWh)	**Supp. Electricity (kWh)**	**Used (kWh)**	**Standing Losses (kWh)**	**Total (inc. pump) (kWh)**
1880	2270	3330	820	4220

Table 5: Annual energy balances for the SWH system

The Waitakere NOW Home® performance is compared alongside the Consumer and EECA (2007) guidelines in Table 6.

Measure	**Consumer and EECA (2007)**	**Waitakere NOW Home®**
Proportion of water heating needs met by solar energy	50% – 75%	45%
Annual energy from solar	2200 kWh	1880 kWh
Annual cost savings	$350 – $400	$300

Table 6: Comparison of Waitakere NOW Home® performance with Consumer and EECA (2007) guidelines

3.4.3 Standing losses

The standing losses of the cylinder are due to the heat loss from the cylinder to the surrounding ambient environment. The Waitakere NOW Home® 270 L cylinder is an ‘A’ grade cylinder. When tested according the standards for measuring standing losses (AS/NZS 4692.1:2005) it should produce a figure of less than 2.0 kWh per day. The actual standing loss values may vary as the ambient temperatures in-use are dynamic as opposed to the static temperatures used for the standard test conditions.

Figure 10 gives the daily profile over the second year of monitoring for the Waitakere NOW Home® of the supplementary electric heating for the solar water heater and the hot water draw-off from the system. There is no regular hot water use in the early hours of the morning (12 am to 5am) with the water usage tapering off from a peak at around 6 pm the previous night. Providing that the cylinder has recovered from the draw-offs from the previous night, the early morning electricity usage (say 2 am to 4 am) would be the energy required to maintain the cylinder and would account for the standing losses of the system. The electrical energy averages out to 93 W over this time, which is equivalent to a daily standing loss of 2.2 kWh or an annual figure of 820 kWh.

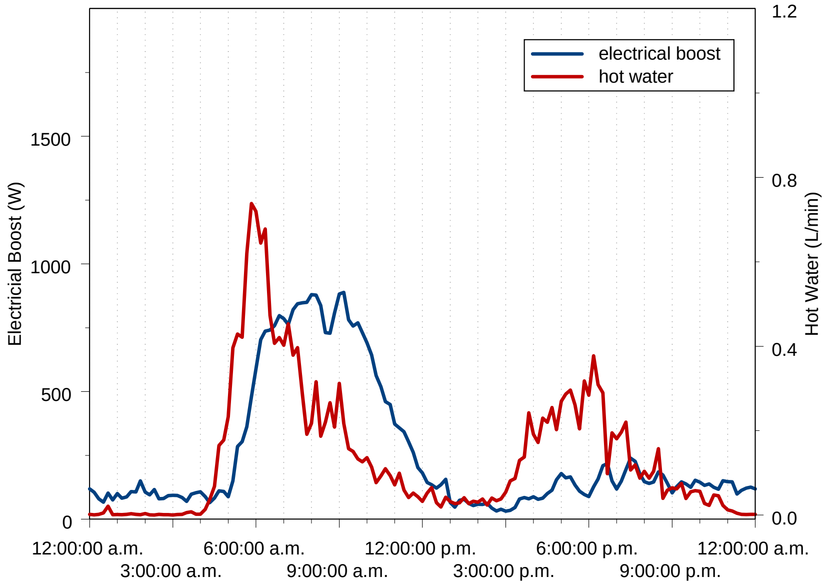

Figure 10: Average daily profile of the supplementary water heating and the hot water draw-off from the SWH system over the second year of monitoring

3.4.4 Used energy

The used energy is calculated from the hot water drawn-off from the cylinder. Water meters are sensitive to temperatures and the meters used were 'cold' (up to about 55°C) meters. The intended arrangement to measure the quantity of water drawn-off the cylinder was to place a meter directly in front of the cold inlet to the cylinder. By placing other water meters within the house, both the flow out of the tempering valve (at about 55°C) and the cold flow into the tempering valve were recorded. The drawn-off volumes were then the difference between the meter on the tempering outlet and the cold feed to the tempering valve.

The temperatures of the water entering and leaving the cylinder were recorded using thermocouples. A thermocouple was also used to record the cylinder temperature as measured at the electrical thermostat position. However, the temperatures recorded by the thermocouple on the cold inlet to the hot water cylinder recorded elevated temperatures due to heating of the water in the cold pipe from the water in the cylinder. Therefore, in place of this measurement for the cold water inlet temperature, a measurement taken from a thermocouple measuring the wall cavity temperature was used.

The used energy drawn off from the cylinder as used by the occupants was calculated for the second year to be 3330 kWh.

3.4.5 SWH performance

This section looks to further explore the performance of the Waitakere NOW Home® SWH system.

Figure 11 gives a histogram of the daily water heating needs over the second year centred around the mean of 11.4 kWh per day. It can be seen that the distribution of this value appears approximately normal.

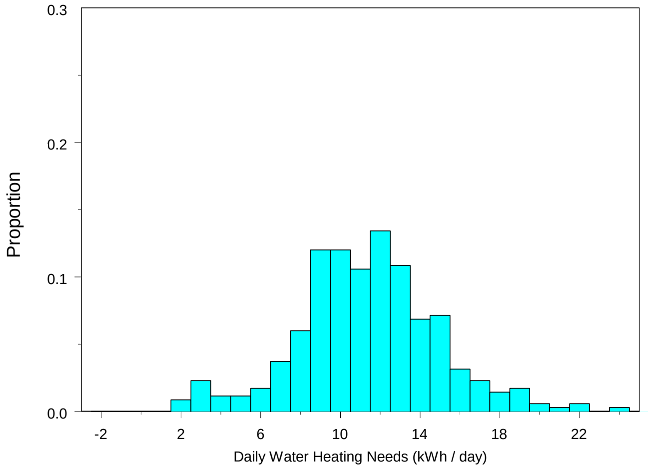

Figure 11: Histogram of the daily water heating needs

The histogram of the daily supplementary electrical heating needs is given in Figure 12. For 98 days of the year (~27% of the time) no daily supplementary heating was required, with all the energy required for the SWH system being provided by solar.

Proportion

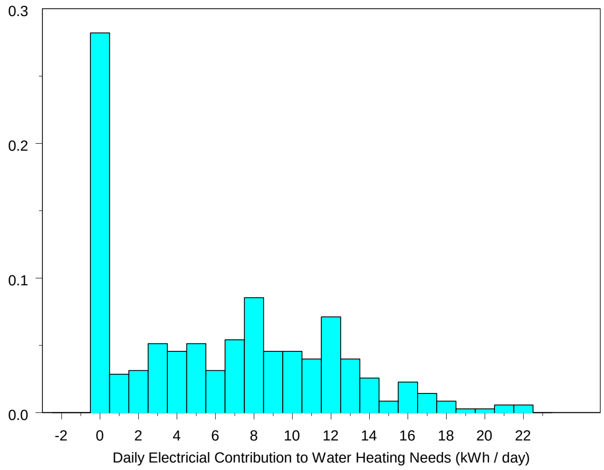

Figure 12: Histogram of the daily supplementary electric heating needs

The daily water heating needs are shown in Figure 13 with a smoothed curve shown. The total water heating needs are seen to increase in the winter (smoothed line around 15 kWh per day) and decrease in the summer (smoothed line around 9 kWh per day). The variation of the data about the smoothed line appears to be large.

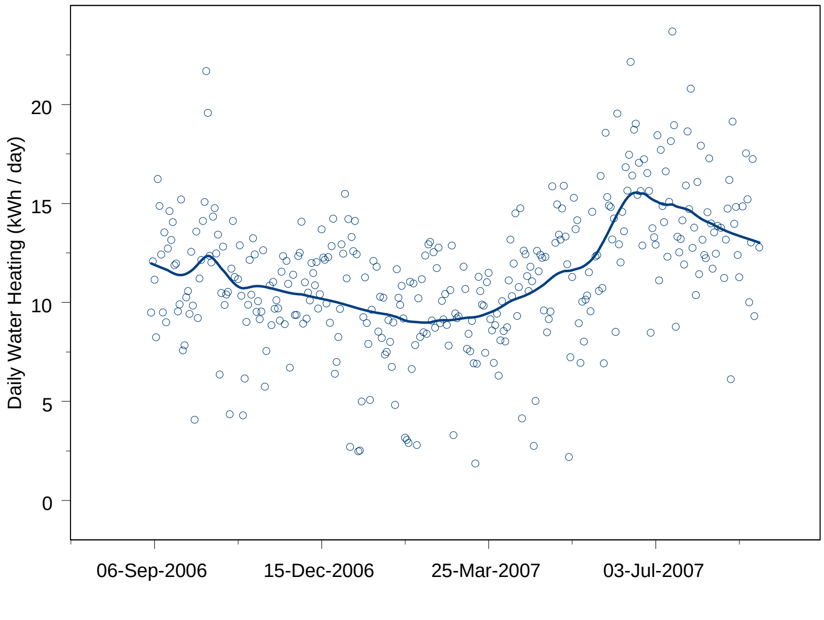

Figure 13: Daily total water heating needs

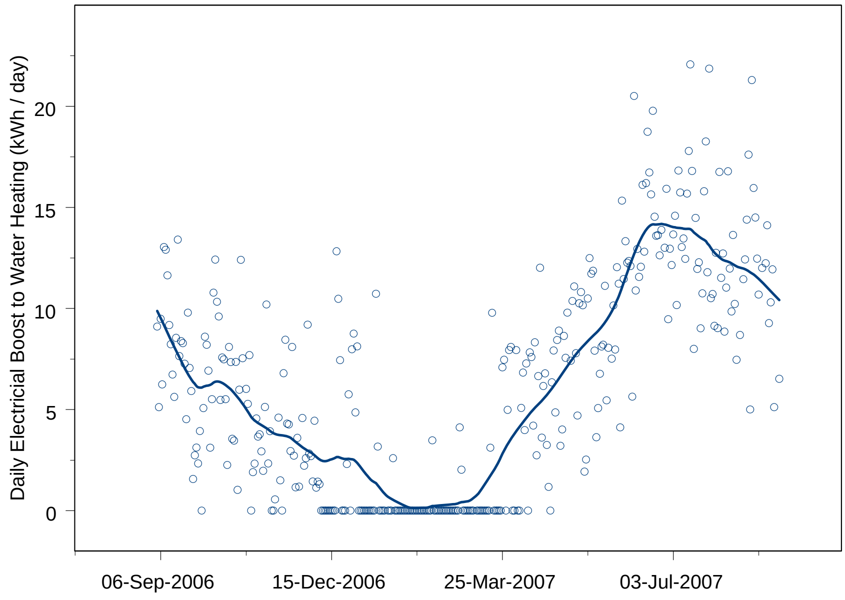

Figure 14: Daily electrical supplementary heating

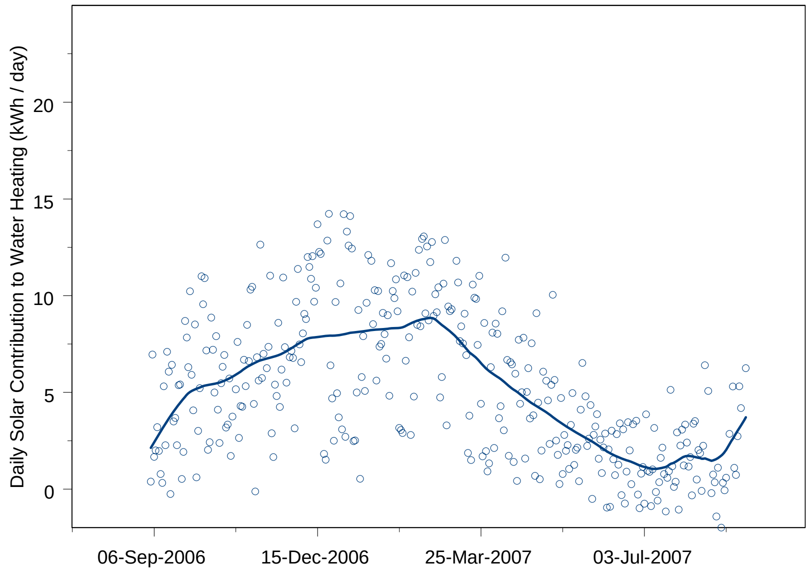

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Figure 15: Daily solar contribution to the water heating

Figure 14 gives the daily electrical supplementary heating and Figure 15 the daily solar contribution from the SWH system over the second year. From the start of December until the end of March, there are frequent zero requirements for the electrical supplementary heating.

The daily solar contribution varies with smoothed values of about 8 kWh per day in summer to a low of around 1.5 kWh per day in winter. The effectiveness of the solar water heater in winter is quite marginal, only providing approximately 10% of the water heating needs, and this is when the needs of the occupants increase. In an earlier (but still current) EECA fact sheet (EECA 2004), solar is said to be able to provide around 75% of a household's water heating in summer and between 25-45% in winter.

The daily profiles of the electrical supplementary heating and the hot water use for summer and winter are shown in Figure 16 and Figure 17 respectively. The winter-time profile of the supplementary water heating shows a pattern of operation previously identified (Pollard et al 2005) as not ideal; the supplementary water heating is operating in the morning (from about 6 am to 12 pm) once the occupants have used water (the majority of use is between 5 am and 10 am), but before the sun has had an opportunity to heat the water. There is not a large usage of hot water in the middle of the day (10 am to 4pm), so there is an opportunity for energy savings by placing a timer on the supplementary heating to exclude the electric reheating of the cylinder in the morning, allowing the sun an opportunity to heat the water.

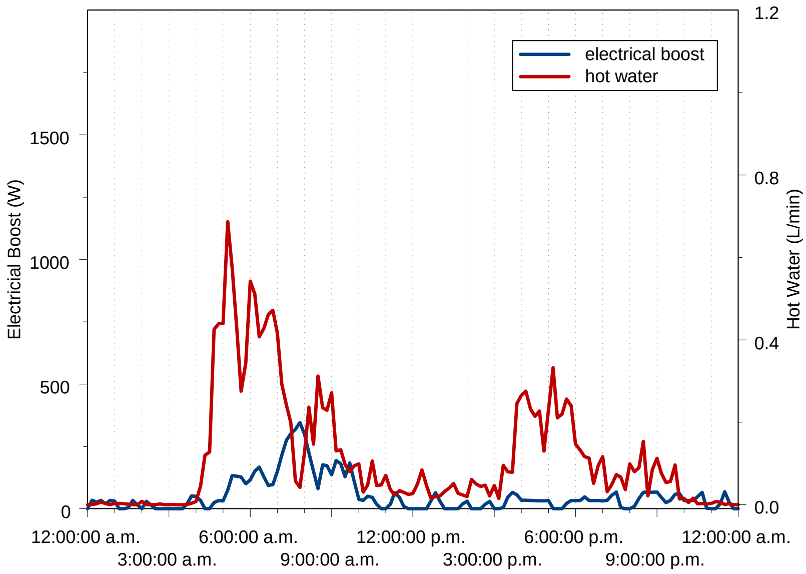

Figure 16: Summer-time daily profiles of the electrical supplementary heating and the hot water usage

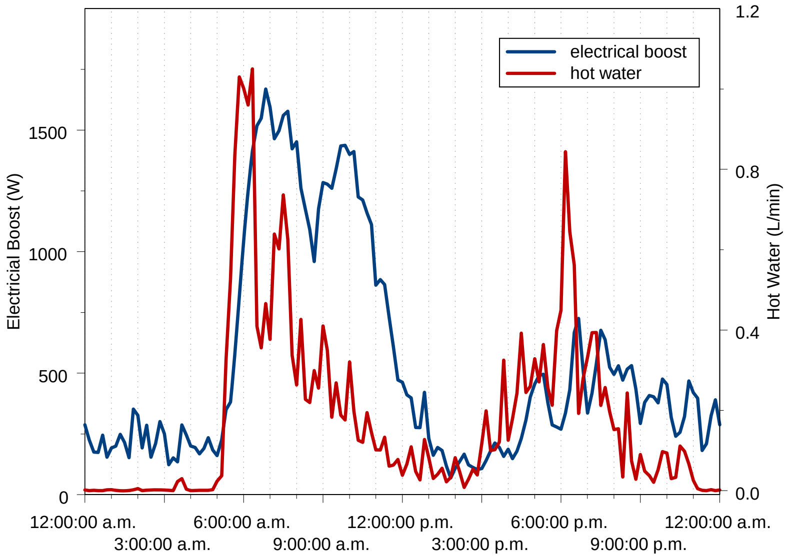

Figure 17: Winter-time daily profiles of the electrical supplementary heating and the hot water usage

With increased water heating demands in winter there is a case to be made to install solar collectors at much steeper elevations (say at 45°) than that currently taking place. The Waitakere NOW Home® solar collector was installed in line with the roof (at 20°) which shifts it performance to operating significantly better in summer-time than in winter-time.

3.5 Baseload Energy

The baseload is the typical minimal energy demand from the household when there is no occupant demand. This would include appliances that are continuously on (e.g. heated towel rails, plug-in air fresheners, cupboard heaters, computer modems, decoders etc) as well as those left in standby mode (computers, TVs, stereos, electronics, battery chargers etc). The periodic heating of the hot water cylinder is on a longer time-scale and is not included in baseload calculations.

Figure 18 gives a histogram of the 10 minute power demand for the second year of the Waitakere NOW Home®. While the peak can be seen at around 400-500 W there is an extended tail to the distribution with data out to about 9000 W.

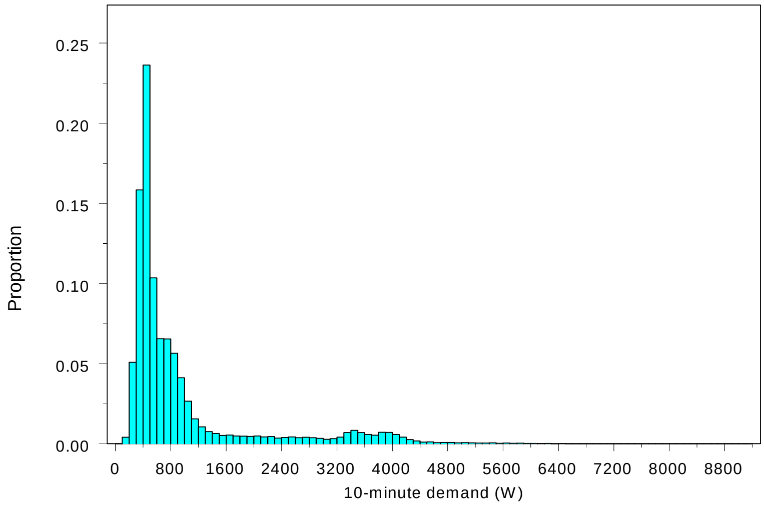

Figure 18: Histogram of the 10 minute power demands for the Waitakere NOW Home®

The standard method used in HEEP (Stoecklein et al 2001) to calculate the baseload is to take the most common value of the daily minimums which is usually the smallest value on the histogram of the daily minimums. The histogram of daily minimum power demand for the second year of monitoring for the Waitakere NOW Home® is shown in Figure 19. The daily minimums are quite varied and there is no strong single value for the variable; therefore an alternate means of representing the minimum value is required.

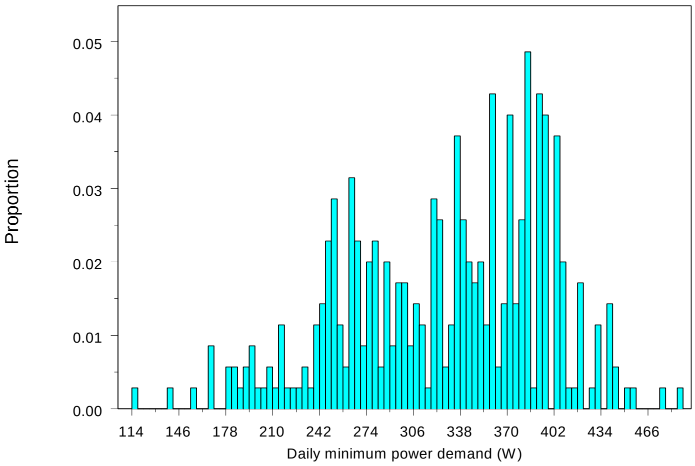

Figure 19: Histogram of the daily minimum power demand

Figure 20 provides a graph of the cumulative 10 minute power demands and Figure 21 provides an enlarged view of the lower values of this distribution. With the increase in values tapering off around the 1% level (the 1% percentile), at about 240 W one can assume this is a reasonable number to represent the minimal power demands seen for the Waitakere NOW Home®.

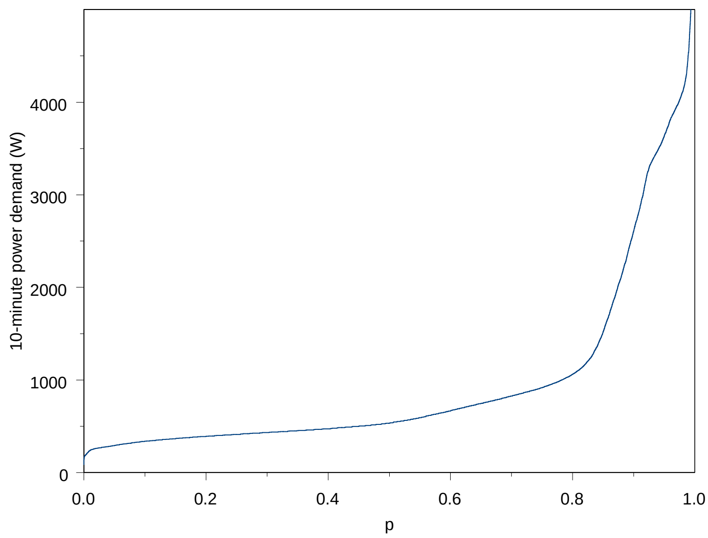

Figure 20: Cumulative function of the 10 minute power demand

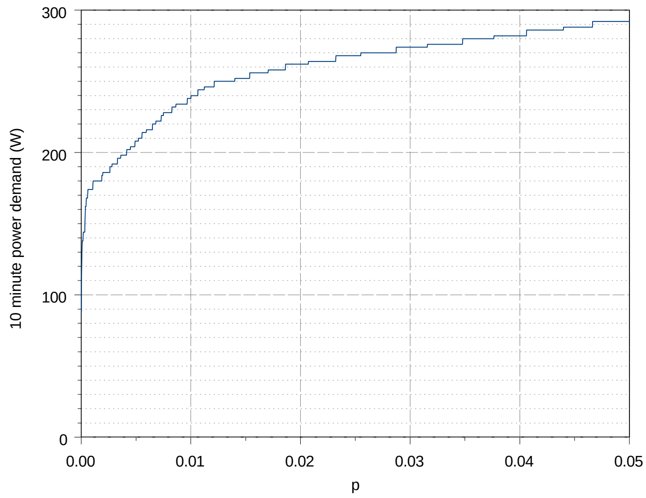

Figure 21: Low values of the cumulative function of the 10 minute power demand

The average baseload measured in HEEP was 112 W (Isaacs et al 2006), which is lower than the lowest measured 10 minute demand for the Waitakere NOW Home®, with a characteristic minimal power use of the order of 240 W. This suggests that the Waitakere NOW Home® has more appliances that are either left on continuously or in standby mode.

The Waitakere NOW Home® appears to be well serviced by computers with a number of these in use within the house. One of these was seen to be left on for extended periods of time and would be a major contributor to the baseload of the house.

A major household service that has many appliances contributing to baseload is entertainment. The Waitakere NOW Home® features many entertainment appliances such as large screen TVs, media computers, game consoles and stereos, and appears to be well serviced with a corresponding energy and baseload requirement.

4 Water Use

Very little data on residential water consumption (especially end-uses) existed in New Zealand at the time of the project, and consequently the Waitakere NOW Home® water data is a valuable source of information.

Each water end-use is directly metered (see the arrangement of water meters). This meant a total of 24 separate meters are being monitored, which was the best solution at the time the house was built. Since the construction of the Waitakere NOW Home®, BRANZ has carried out a pilot study, The Water End-Use and Efficiency Project (WEEP) (Heinrich 2006). This project used high accuracy water meters and disaggregation software to measure the water end-uses from a single water meter per house. WEEP finished in 2007, so it provides a valuable source for comparison.

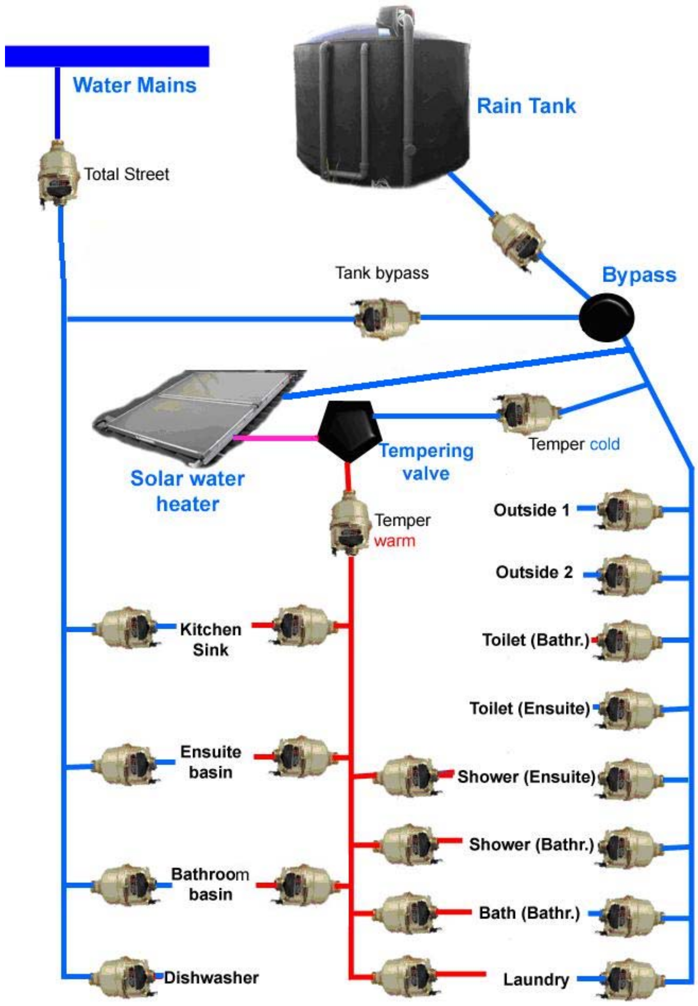

Figure 22: Water meter arrangement for the Waitakere NOW Home®

The expense and difficulty of instrumenting water end-uses with direct measurement means that future water end-use studies should concentrate on this disaggregation approach. However it is critical that some New Zealand-based direct measured water end-use information is available to provide confidence that such disaggregation techniques produce reliable results.

4.1.1 Beacon's HSS High Standard of Sustainability® (HSS®)

Beacon's HSS® specifies a 40% reduction in reticulated water use in both new and existing homes. With the rainwater tank providing a large volume of water for use in the household, the Waitakere NOW Home® reticulated water use of 82 L/p/d represents a 50% reduction in water use compared with other households in Waitakere. If the baseline for Beacon's HSS® is the average for the Waitakere area, the Waitakere NOW Home® monitoring shows it easily meets the HSS®. In fact if this result was typical for homes with rainwater tanks the HSS® benchmark could be reduced making the target level more stringent. However, the size of rain tank has a large impact on this and the Waitakere NOW Home® rain tank is larger than normally installed, particularly in suburban areas where space restrictions are more of an issue.

4.1.2 Total water use

Total water use in Year 2 has decreased by 8% from Year 1 levels, which is equivalent to 70 L/d. Throughout Year 2, the total daily water consumption was around 690 L/d, which represents a daily usage of around 172 L/p/d. Around 48% of this water was supplied by the street mains (potable), and 52% from the 13 500 L rain tank. During the summer a higher proportion of water was taken from the mains (76%) than during the winter seasons. In winter 07 the mains water proportion was around 43%, whereas in winter 06, this proportion was 14.5% (Table 7). A reason for this could be due to the use of the bypass valve, or it simply could be climatic conditions. This will be further examined in section 4.1.5

Period	Dates		Proportion (%)		Volumes (L/p/day)			Volumes (L/house/day)		
	Start	End	Street	Tank	Street	Tank	Total	Street	Tank	Total
Winter 06	1-Jun-06	1-Aug-06	**14.5**	**85.5**	20.4	120.8	**141.2**	81.7	483.2	**565.0**
Summer 06/07	1-Dec-06	28-Feb-07	**75.7**	**24.3**	150.5	48.4	**198.9**	602.0	193.7	**795.6**
Winter 07	1-Jun-07	1-Aug-07	**43.4**	**56.6**	73.9	96.2	**170.2**	295.8	384.9	**680.7**
Year 1	4-Sep-05	4-Sep-06	**53.1**	**46.9**	100.9	89.1	**189.9**	403.5	356.3	**759.8**
Year 2	4-Sep-06	4-Sep-07	**47.7**	**52.3**	82.3	90.1	**172.4**	329.2	360.6	**689.7**

Table 7: Tank and street proportions, daily per person use and daily household usage

During the summer period, slightly higher water usage has been observed (796 L/d equal to 199 L/p/d) compared to both winter periods. A comparison of both winters shows that during winter 06 the water usage was 565 L/d (141 L/p/d) which increased to 681 L/d (170 L/p/d) during winter 07. This is an increase of around 20%. This is consistent with the overall increases in service expectations of the household as shown in the energy section of this report.

Typical recorded and measured daily per capita water uses are summarised in Table 8 below for comparison purposes. These have been ordered by source and provide varying levels of accuracy where some may have been simply the total volume divided by the number of homes while others provide measured data. The average yearly water consumption of the Waitakere NOW Home® is around 252 000 L (63 000 L per person or 172 L/p/d), which is comparable with figures measured in both the WEEP Kapiti project (Heinrich 2007) and the Auckland region. For the Waitakere district (supplied by EcoWater), 165 L/p/d of water were used on average, which is comparable to the total water consumption of the Waitakere NOW Home® (see Heinrich 2006).

Area	Average Consumption	Source	Residential metering
	(L/p/d)		
Hutt City	381	Wellington City Council – Annual Report 2005	NO
Porirua City	327	Wellington City Council – Annual Report 2005	NO
Upper Hutt City	408	Wellington City Council – Annual Report 2005	NO
Wellington City	451	Wellington City Council – Annual Report 2005	NO
Paekakariki*	603	Kapiti Coast District Council	NO
Paraparaumu/Raumati*	621	Kapiti Coast District Council	NO
Waikanae*	808	Kapiti Coast District Council	NO
Otaki*	1070	Kapiti Coast District Council	NO
Kapiti average	1300	Dominion Post 3/12/2005 (see References)	NO
Auckland	185	Auckland Water Management Plan 2004	YES
Wellington	240	Auckland Water Management Plan 2004	NO
Invercargill	245	Auckland Water Management Plan 2004	NO
Hamilton	260	Auckland Water Management Plan 2004	NO
Palmerston North	265	Auckland Water Management Plan 2004	NO
Christchurch	280	Auckland Water Management Plan 2004	YES
Kapiti (winter)	168	BRANZ SR 159 - WEEP (Heinrich)	YES
Kapiti (summer)	204	BRANZ SR 159 - WEEP (Heinrich)	YES
Kapiti (average)	184	BRANZ SR 159 - WEEP (Heinrich)	YES
Auckland City (Metrowater)	184	WaterCare Services Ltd. Asset Management Plan (2006)	YES
Manukau (Manukau water)	189	WaterCare Services Ltd. Asset Management Plan (2006)	YES
North Shore	199	WaterCare Services Ltd. Asset Management Plan (2006)	YES
Waitakere (EcoWater)	165	WaterCare Services Ltd. Asset Management Plan (2006)	YES
Papakura (United Water)	190	WaterCare Services Ltd. Asset Management Plan (2006)	YES
Rodney (District Council)	179	WaterCare Services Ltd. Asset Management Plan (2006)	YES

Waitakere NOW Home® Period	Average Consumption	Source
	(L/p/d)	
Winter 06	141	This report
Winter 07	170	This report
Summer 06/07	199	This report
Year 1	190	This report
Year 2	172	This report
*Peak consumption summer 2001		

Table 8: Reported daily per capita uses reported in New Zealand. **(Source BRANZ – SR 149 Heinrich, updated)**

The following graph (Figure 23) shows the distribution for daily water use over the whole monitoring period for the Waitakere NOW Home®. This shows that there is a wide distribution in the amount of water used. The majority of daily uses are between 500 and 700 L/d. When the daily water use equals zero, the occupants are away from the premises. A small proportion of uses are 1500 L/d and above, which is mainly due to outside uses, such as irrigation. The readings of the water meters on the outside taps confirm this claim. The maximum use was found on 11 December 2005 and was around 4800 L/d. A possible reason for this abnormally high amount is outdoor hoses being left on for a long period to either water grass or the garden. It is interesting to note this was during the first summer when planting was still being established.

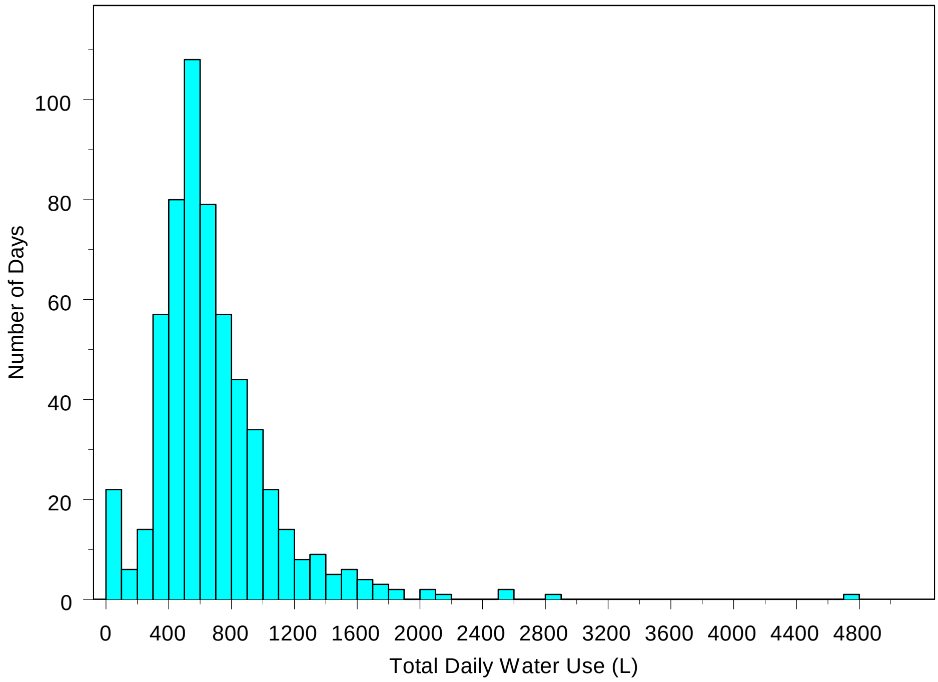

Figure 23: Histogram of the daily water use for the Waitakere NOW Home®

4.1.3 Proportion of end-use

This section examines the proportion of water end-uses. The end-use water data analysis was to use pulsed output data from water meters placed in line with each water end-use within the house. Owing to plumbing requirements, many of these water meters needed to be placed in difficult to access locations within the roof space. It was not intended to read these meters and to instead rely on the pulse data from each meter.

As there were interruptions to the pulse data collection, it was necessary to take meter readings of all of the water meters in the Waitakere NOW Home®, including those in the roof space, to determine the total usage for each water end-use.

In undertaking these water meter readings in winter 2007, some unexpected inconsistencies between the meter readings and the pulse data for the ensuite toilet and cold laundry tap were discovered. These inconsistencies have meant the information used in the Year 1 report (French et al 2007) on the end-use proportions under-reported both of these end-uses.

The method to re-establish these end-uses involved taking the total meter readings and subtracting the other known uses from them leaving a total for the cold laundry and ensuite toilet end-uses. Electrical information was available as to when the washing machine was used so this information was used to proportion usage to the laundry with usage at other times being assigned to the ensuite toilet.

Figure 24 shows the distribution of the end-uses for the summer period. The highest use was found to be the shower, representing 34% of the total usage. Outdoor uses are the second highest use with 28%, the laundry using 17% followed by the toilet with 11%. Overall tap uses represents 7% of the total water used (3% bathroom and 4% kitchen), which suggests that tap usage can be evenly split between the two separate sources. The dishwasher and the bathtub are the smallest uses, representing 2% and 1% of the total uses respectively. Unlike the WEEP methodology, where leaks are represented as a separate category, any leaks within the Waitakere NOW Home® system will be recorded within the corresponding end-use category. As there were data interruption problems with the summer monitoring of Year 1, the end-uses over the two years can only be compared for the winter period.

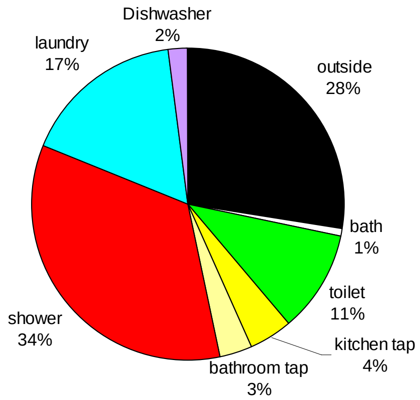

Figure 24: Summer 2006 – 2007 (1 December 2006 to 28 February 2007) – end-uses

The winter uses are shown in Figure 25. The largest end-use during the winter was again found to be the shower, with just under half of the total uses (49%). The laundry used 19% and the toilet 18%. Overall tap use accounts for 9% of the total uses (5% kitchen and 4% bathroom). This confirms the findings from the summer that tap use is almost equal in both the kitchen and the bathroom, with a slightly higher proportion being used in the kitchen. The dishwasher uses around 3% and the bath around 2% of the total water. During the winter period outdoor use was almost zero.

Figure 25:. Winter 2007 (1 June 2007 – 31 August 2007) – end-uses

The two previous graphs have shown the summer and winter water uses, whereas the following graph (Figure 26) shows a summary of uses throughout the second year monitoring. The shower used around 42% of all the water throughout the year, the laundry around 19% and the toilet 15%. Outdoor uses average at around 12% throughout the whole year and indoor tap usage is at around 9%.

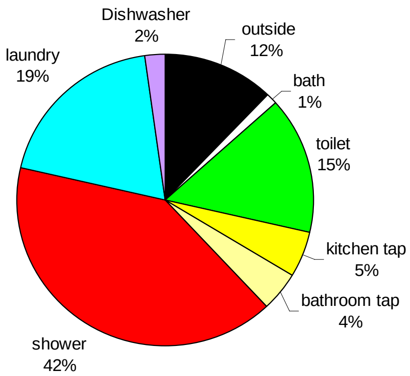

Figure 26: Year 2 (4 September 2006 – 4 September 2007) – end-uses

Figure 27 and Figure 28 look at the daily volumes per person, to compare between the volumes used in the Waitakere NOW Home® and in WEEP. During the winter (Figure 27) the volumes used for each of the end-uses tend to be similar for most end-uses, except the water used in the shower and outside show variations. For the summer period (Figure 28) the main variation is the water used in the shower and for the toilet.

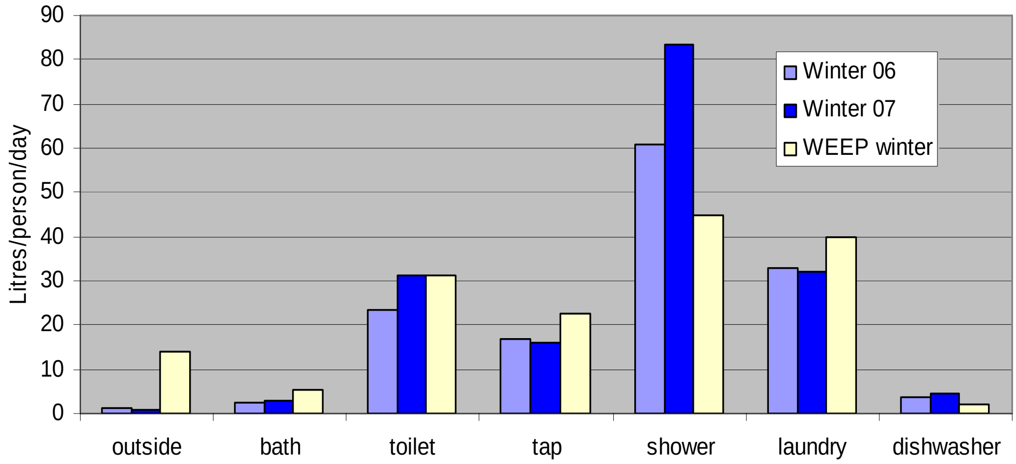

Figure 27: Indoor end-use comparison on a volume basis – winter period

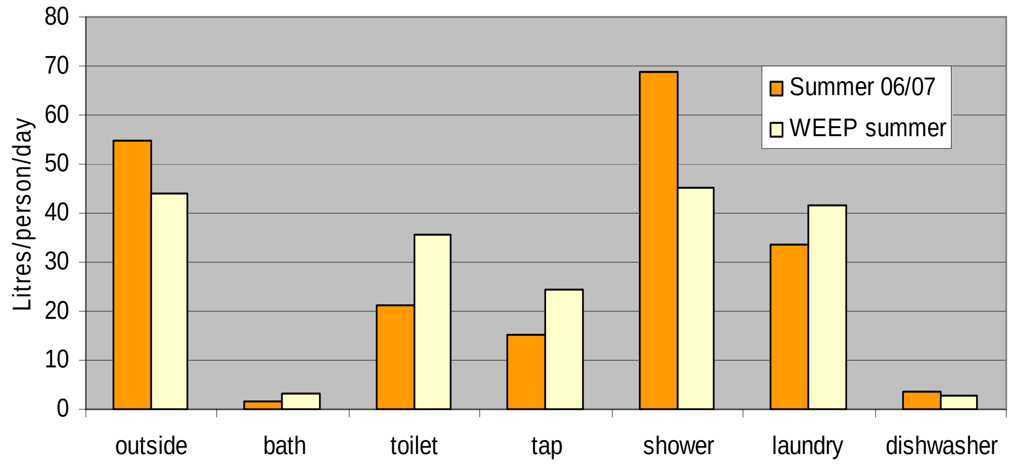

Figure 28: Indoor end-use comparison on a volume basis – summer period

By comparing the indoor uses measured in the Waitakere NOW Home® with data measured in WEEP (Heinrich 2007), similarities can be seen (Table 9), even though the percentage share of end-uses is different for the larger uses. The shower was found to be the highest use, followed by the laundry, the toilet and the overall tap usage in both the Waitakere NOW Home® and WEEP. The bathtub and dishwasher showed similar trends as well. As the shower uses nearly half the water in the Waitakere NOW Home®, the percentages of the other uses are skewed. It is better to examine the daily volumes as in Figure 27 and Figure 28.

Indoor End Use	Summer 06/07 (%)	WEEP summer (%)	Winter 07 (%)	WEEP winter (%)
Bath	1.0	2.0	1.7	3.8
Toilet	14.8	22.9	18.3	21.3
Tap (overall)	10.6	15.6	9.4	15.5
Shower	47.6	29.8	49.1	30.5
Laundry	23.4	27.4	18.9	27.1
Dishwasher	2.5	1.8	2.6	1.4

Table 9: Comparison of the Waitakere NOW Home's indoor uses and WEEP

The following graph (Figure 29) shows a comparison between the water used in the Waitakere NOW Home® during winter 06, winter 07, summer 06/07 and the over the whole of Year 2. This information is also represented in Table 10 below.

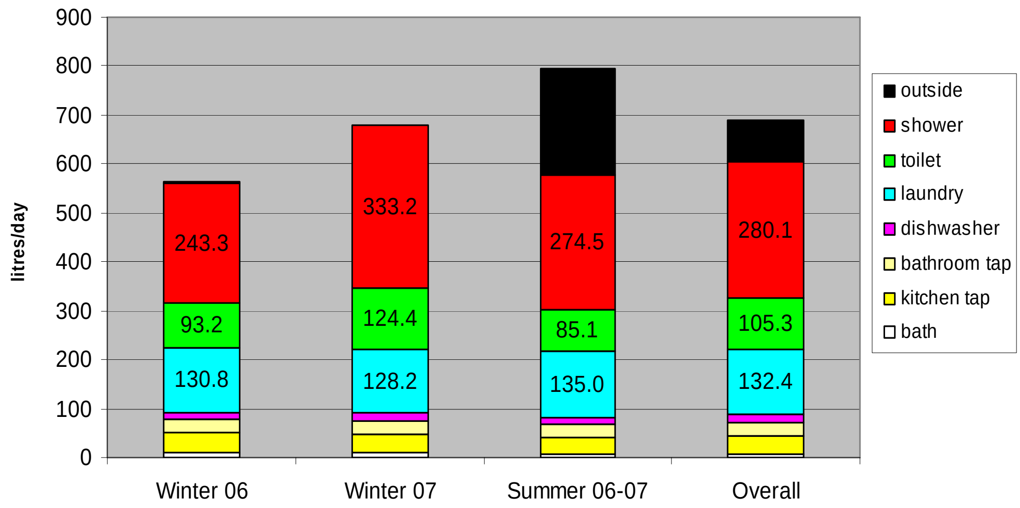

Figure 29: Waitakere NOW Home® water consumption – end-use breakdown and seasonal variations

Water use has increased from winter 2006 to winter 2007 by 116 L/d, an increase of around 20%. The main reason for this difference was increased usage in the shower and the toilet. During the summer, the main difference to the winter was an increased use for outdoor purposes. The water used in the shower gradually increased throughout Year 2. The following Table 10 shows a seasonal comparison of end-use proportions and the corresponding daily volumes in litres. The increase in water used for showering could be due to an increase in shower frequency or shower duration. This will be further examined in the final report.

End-Use	Winter 06		Winter 07		Summer 06-07		Overall	
	(%)	L/day	(%)	L/day	(%)	L/day	(%)	L/day
	1.0	5.5	0.4	2.6	27.6	219.4	12.2	84.3
Bath	1.7	9.8	1.7	11.3	0.8	6.0	1.2	8.1
Toilet	16.5	93.2	18.3	124.4	10.7	85.1	15.3	105.3
Kitchen tap	7.4	42.0	5.4	36.6	4.2	33.7	5.1	34.9
Bathroom tap	4.6	25.8	4.0	27.1	3.5	27.5	4.2	29.2
Shower	43.1	243.3	48.9	333.2	34.5	274.5	40.6	280.1
Laundry	23.1	130.8	18.8	128.2	17.0	135.0	19.2	132.4
Dishwasher	2.6	14.7	2.6	17.4	1.8	14.5	2.3	15.6
Total	100.0	565.1	100.0	680.8	100.0	795.7	100.0	689.7

Table 10: End-use distribution and seasonal variations

4.1.4 Rainwater

This section examines the amount of captured rainwater using weather data (source: www.wounderground.com) for the area. The amount of rainwater harvested depends on the roof area and the annual rainfall. This is approximated by Equation 2.

Amount of Rainwater Captured (m^3)	**=**	**85% Efficiency**	**×**	**Roof Area (m^2)**	**×**	**Annual Rainfall (m)**

Equation 2: Rainwater harvesting formula

The total rainfall for Year 2 from 04 September 2006 until 04 September 2007 was 1211 mm over the whole year, which is slightly lower than the yearly average of around 1300 mm. The roof area, which equals the plan area of the roof of which rainwater is captured (including overhangs), equals 194 m^2. Table 11 shows the amount of rainfall and the amount of rainwater collected during each of the months. In total around 216 000 L were collected during Year 2, which represents 86% of the total annual household usage. However, as only 128 000 L of tank water was used, 88 000 L of rainwater had to be "disposed" of, which is more than an average person would use over a one-year period. Opportunities to maximise the rainwater use of the Waitakere NOW Home® would include more careful control of the bypass valve which is discussed in the next section (4.1.5).

		Rainwater Captured (L)	Water Consumed (L)			
Month	**Rainfall (mm)**	**Total**	**Street**	**Tank**	**Total**	**Tank Bypass**
Sep-06	45	7,372	7,304	8,900	16,204	7,285
Oct-06	146	24,042	1,323	17,110	18,434	5
Nov-06	49	8,000	1,469	17,431	18,899	0
Dec-06	51	8,419	12,487	7,555	20,042	11,238
Jan-07	69	11,309	9,551	9,879	19,430	8,113
Feb-07	12	1,969	32,140	0	32,140	31,243
Mar-07	235	38,701	13,899	10,845	24,744	12,525
Apr-07	76	12,565	3,393	14,050	17,443	2,181
May-07	36	5,864	10,688	8,400	19,088	9,750
Jun-07	118	19,518	11,789	9,405	21,194	10,639
Jul-07	242	39,874	14,052	7,770	21,822	12,842
Aug-07	134	22,031	983	16,824	17,807	0
Monthly Average	**101**	**16,639**	**9,923**	**10,681**	**20,604**	**8,818**
Total	**1,312**	**216,303**	**119,075**	**128,170**	**247,244**	**105,820**

Table 11: Quantity of rainwater captured and water consumed

Figure 30 shows: the monthly amount of total water used; the amount of tank water; the amount of water going through the bypass; and the amount of rainwater collected in each of the months during the Year 2 monitoring period. During February the largest amount of water was used, and a very small proportion of rainwater was captured, due to dry conditions. Thus in this month the occupants made use of the bypass valve.

During March and July, just under 40 000 L of rainwater was collected during each of the two months, being nearly double the amount of water used in total and nearly four times as much as the water drawn from the tank. Still the bypass was being used during this period; even though the tank water would have sufficiently covered the demand. It is situations like these that cause inefficient use of the tank system. The use of the bypass valve is further discussed in section 4.1.5.

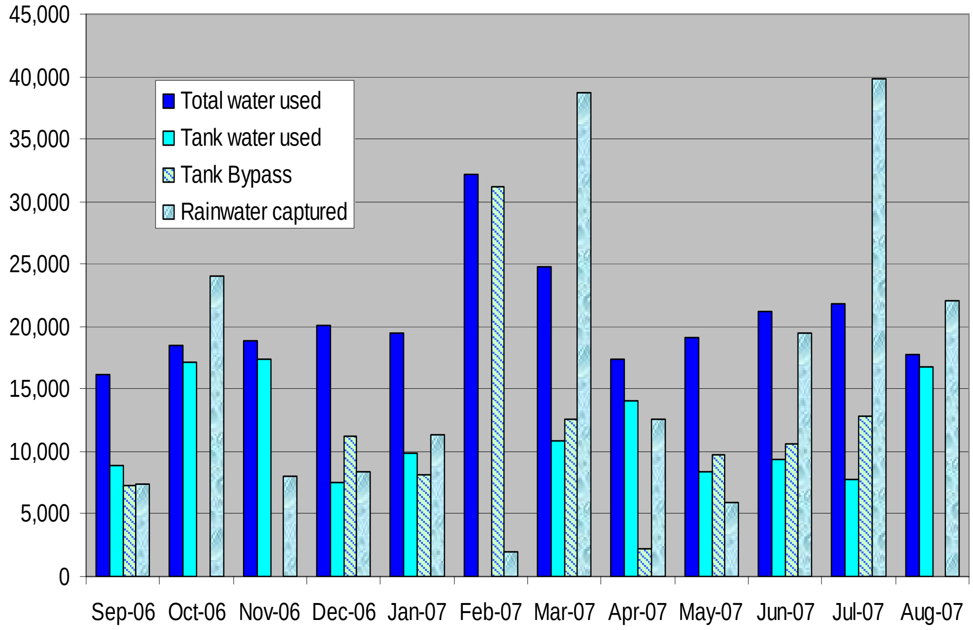

Figure 30: Rainwater system feasibility and bypass usage

4.1.5 Bypass usage

When there is not sufficient water in the rain tank the occupants can switch a bypass valve to use mains water instead of the rainwater from the tank. This has to be done manually. This section examines how the bypass valve has been used during the monitoring period. Figure 31 shows a histogram of daily bypass uses and the associated volumes. For the majority of the time, the bypass valve is not used and the volume is therefore zero. However when the tank is empty the bypass valve is used for extended periods of time, hence the majority of uses are in the region of 700 to 800 L, which represents the daily average use. Larger uses, above 1500 L/d and more, are not uncommon and tend to drain the tank. These larger daily uses are mainly due to outdoor uses.

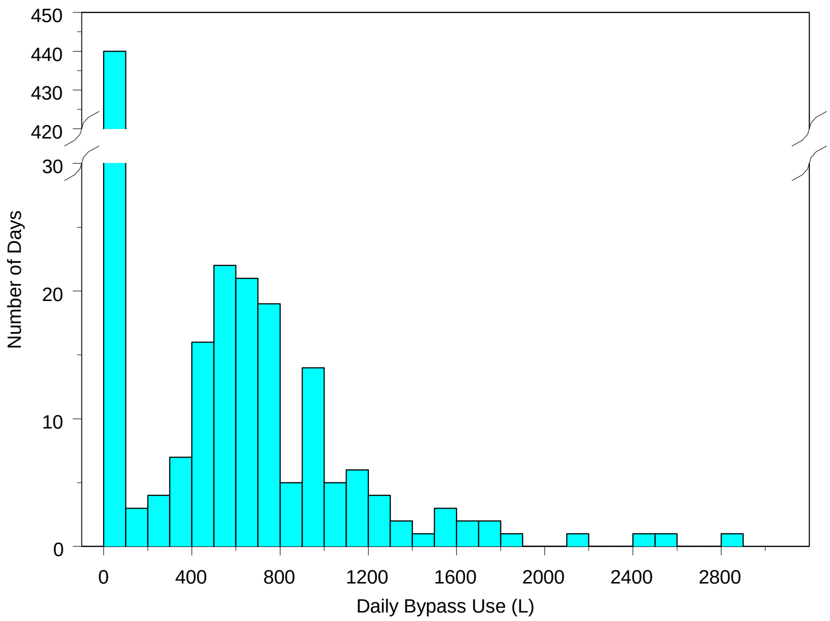

Figure 31: Histogram of the daily bypass usage

During the Year 2 monitoring the bypass has been used on 131 days, which is 36% of the time, with a daily volume of 808 L on each of these days. Hence mains water was used to supplement the tank's supply, not the other way around. The longest period the bypass has been used for consecutive days is 44. Other periods, with up to 30 days of bypass use, are not uncommon. As switching the bypass is a manual process, switching back to tank water is often forgotten, even if there is sufficient water in the tank and tank water has to be disposed off. This is one of the main reasons why the proportion of rainwater and mains water varies by such a large degree throughout the year. One of the improvements to the Waitakere NOW Home® has been the installation of a tank level gauge at the end of July 2007. There has not been sufficient comparable data after this change to gauge if this has been effective.

To optimise the use of rainwater **an automated switch should be installed**. This would allow rainwater to be used when it is available rather than relying on the occupants to switch back to the tank supply. A possible arrangement for this would be to directly link this to the water level in the tank, to ensure the tank water is used more efficiently.

The following table shows the water use proportions from the tank and the mains supply during periods where the bypass was **not** used. During the 121 day period (30 March 2006 until 28 July 2006), only 5.7% of the total water consumed came from the mains supply; the remainder was supplied by the tank. This similarity is shown in other periods during which the bypass was not used. An option for avoiding the use of the bypass could include the installation of a larger volume tank, to ensure longer duration dry periods can be bridged, or automating the bypass system so it is not dependent on the user. Despite easily meeting the HSS®, the potential water savings could be much greater with better use of controls and operation of the bypass system.

Period			**Proportions (%)**	
Start	Finish	# of days	Street	Tank
30-Mar-06	28-Jul-06	121	5.7	94.3
18-Sep-06	14-Dec-06	88	7.4	92.6
12-Mar-07	26-Apr-07	46	8.9	91.1
21-Jul-07	25-Sep-07	67	5.6	94.2
		Average	6.9	93.05

Table 12: Consecutive periods of non-bypass usage

4.1.6 Hot water proportions

The focus of this section is to look at the proportion of hot water used. On average around 202 L/d of hot water are used, which is around 21% of the total uses during the summer period and just under 40% of the total uses during the winter period. A larger amount of hot water is used during the winter than during the summer period. To achieve consistent shower water temperatures a greater volume of heated water needs to be mixed with the cold water which is at a lower temperature over winter. On average around 80% of the total amount of hot water is used in the shower. The remainder of the hot water is being used by the kitchen and bathroom taps, and a small proportion in the laundry.

	Units	**Winter 06**	**Winter 07**	**Summer 06-07**	**Overall**
Total Use	L/d	565.1	680.8	795.7	689.7
Total Use	L/p/d	141.3	170.2	198.9	172.4
Total hot water	L/d	**212.3**	**268.4**	**168.4**	**202.4**
Total hot water	L/p/d	**53.1**	**67.1**	**42.1**	**50.6**
Proportion of hot water	%	37.6	39.4	21.2	29.3
Hot water used in shower	%	**75.8**	**78.1**	**81.7**	**79.7**

Table 13: Hot water usage

4.1.7 Time of day profiles

The sizing of water utilities networks is dependent on the household peak loads. At an individual level, time of day profiles showing water use are really only of behavioural interest, but at the utility level they provide useful information. This project provided the first measured breakdown information on household water end-uses by time of day in New Zealand. Throughout the day water use does not remain constant. Uses occur at certain times of the day, with peak uses observed in the morning and in the late afternoon. This trend can be observed in the Waitakere NOW Home®. This section shows a detailed analysis of how water is used throughout the day. The following graph (Figure 32) shows the daily profile of the total water usage across both the summer and winter period. Water use peaks at 0600 and just after 1800 for both summer and winter. These peak usages are further broken down in Figure 34 and Figure 35 which examines the daily profiles of the end-uses.

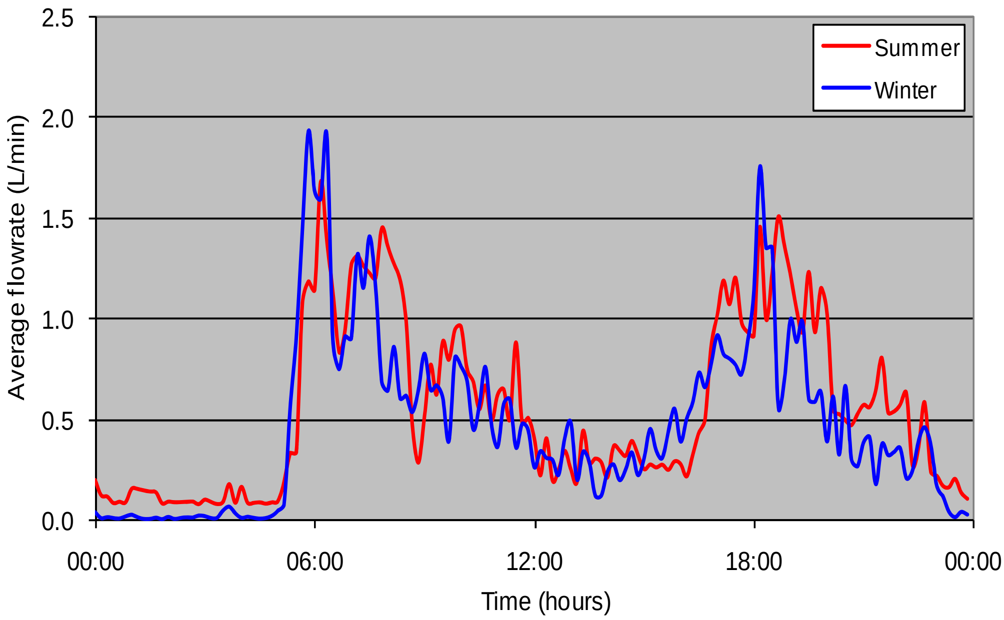

Figure 32: Daily profile of total water usage

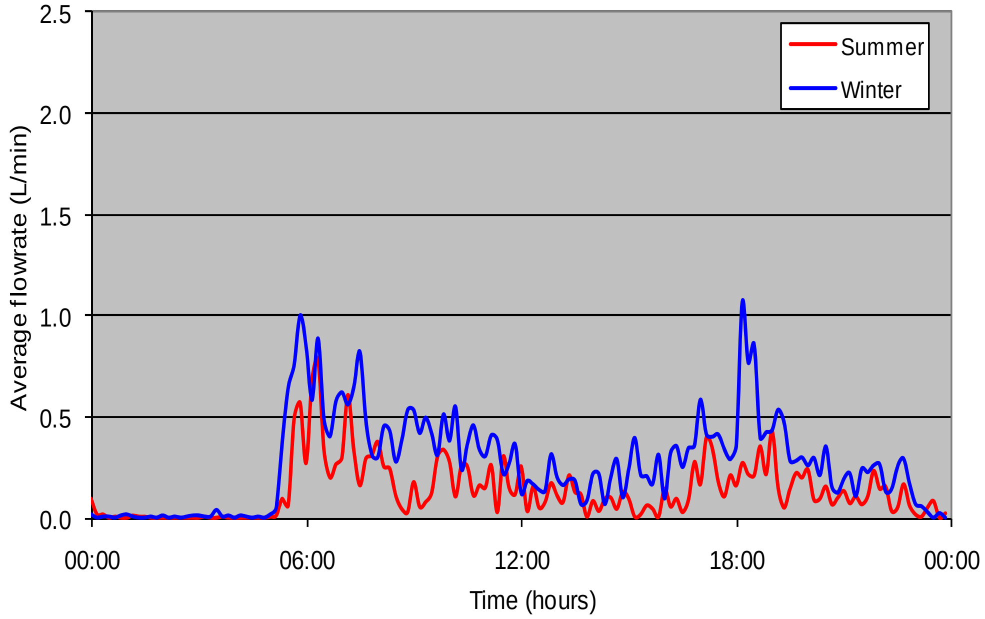

Figure 33: Daily profile of rain tank usage

Figure 34 shows the daily profiles of end-uses for the summer period of Year 2 (01 December 2006 until 28 February 2007). The main use, which is the shower, starts to peak from 0500 until 0800 hrs and from around 1700 hrs. This morning period is also where the highest flow throughout the day is observed. Outside uses tend to peak in the afternoon, from around 1700 hrs until around 2200 hrs. Laundry use does not have as clearly defined peaks, and the data suggests that this use is spread throughout the day. However, the main use of the laundry tends to occur from 0800 hrs until 1400 hrs. Toilet use, which is shown in green, tends to peak during the morning after the occupants get up, and from around 1700 hrs, when the occupants presumably return from work. This coincides with the peaks for the bathroom tap. Bathtub usage, although a very small proportion of total use, tends to peak in the afternoon from around 1600 hrs. The other uses tend to be constant throughout the day.

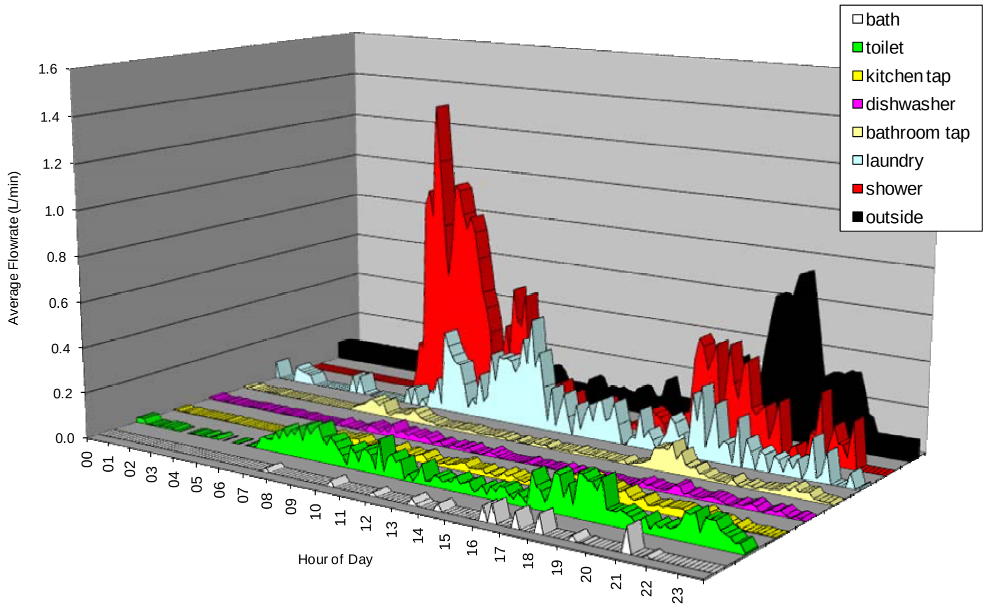

Figure 34: Daily end-use distribution summer 2006 / 2007

The winter daily flows are shown in Figure 35. The peaks show similar tendencies as for the uses observed during the summer period. The shower produces a greater peak demand during the winter period both during the morning and the afternoon. Laundry use is more evenly spread out during the day in the winter than during the summer. Bathtub uses tend to be concentrated from 1500 hrs until 1700 hrs only.

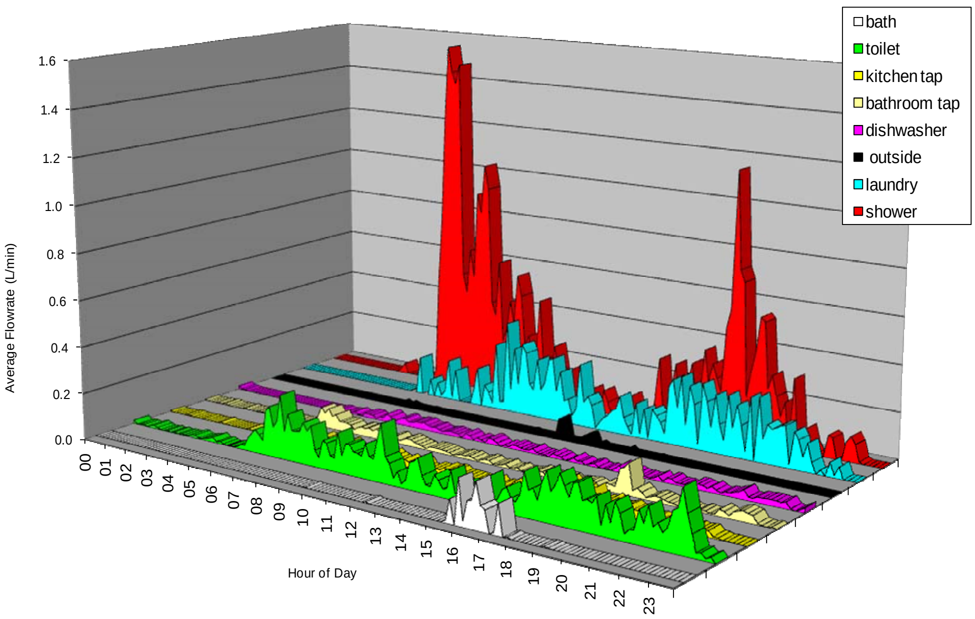

Figure 35: Daily end-use distribution winter 2007

5 Indoor Environment

Temperatures and relative humidity (RH) have been measured in the bedrooms, family room, living room and bathroom as well as outside. Two sensors have been used in the family room: the 'A' sensor which is placed mid-height and the 'B' sensor which is placed high on top of cupboards. In addition to the internal measurements of temperature and RH, the outside temperature and RH were measured using sensors housed in a weather screen placed on the top of the rain tank on the south side of the house.

The single location CO_2 measurement was situated central to the house in the family room.

Between the Year 1 and Year 2 report, and based on the Year 1 report findings, three major changes have occurred in the Waitakere NOW Home® which affected the indoor environment during the second year of operation:

- The installation of extractor fans in the bathroom and ensuite in June 2007
- The installation of a solar-powered stack fan in the kitchen in June 2007
- The study (bedroom 2) was converted to a bedroom to allow single occupancy for the two children's bedrooms. The office computer has been relocated to the computer nook in the living room.

5.1 Temperatures

The Waitakere NOW Home® temperatures met the HSS® temperature benchmarks of 18°C for living rooms and 16°C for bedrooms in both 2006 and 2007.

5.2 Summer temperatures

The Waitakere NOW Home® met Beacon's HSS® under Indoor Environment Quality for indoor temperatures through summer in the bedrooms (16°C minimum average temperature) and living space (18°C minimum average temperature).

The summer temperature profiles for the first and second years of the Waitakere NOW Home® from a broad sense look similar. These are shown in Figure 36 and Figure 37 respectively. The peak in bedroom 3 in the mornings is due to the early sun hitting the logger directly and should be ignored; likewise the peak in the evenings for the bathroom is also due to the sun hitting the logger.

Table 14 provides a tabulation of the mean temperatures for each of the rooms (the family room sensors have been averaged together) at various times of day. For all rooms except the bedroom 2 / study, the temperature is slightly lower over the 2006-2007 summer than the previous summer. However the temperature difference is not as large as the external temperature reduction. The increase in the bedroom 2 / study could possibly be explained by the change of use of this room. The mean temperatures are still very warm, especially during the night (up 0.4°C from 2006), given the large temperature drop outside (decrease of 1.6°C). As the stack fan was not installed until after the 2007 summer it will be interesting to examine the summer 2007-2008 data to see what impact this will make to the high internal temperatures experienced over summer in the final report.

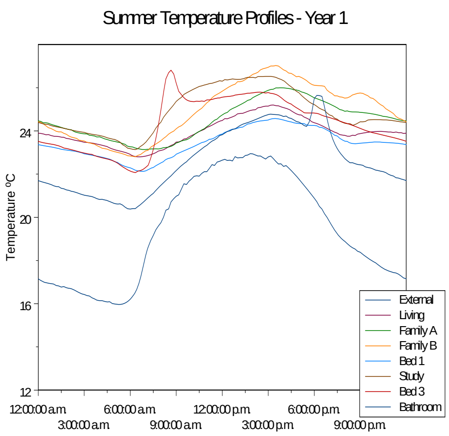

Figure 36: Summer temperature profile – Year 1

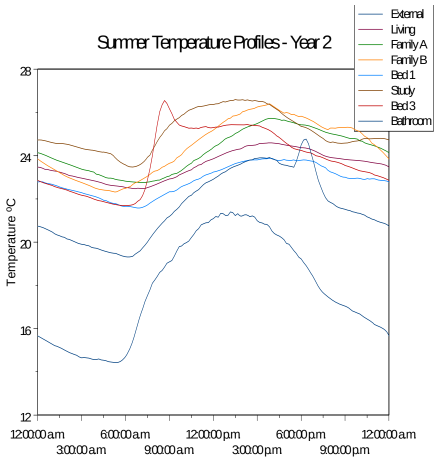

Figure 37: Summer temperature profile – Year 2

	Temperature (°C)				Temperature (°C)		
Living room	**2006**	**2007**	**Difference**	**Family room**	**2006**	**2007**	**Difference**
24 hr	23.94	23.56	-0.38	24 hr	24.71	24.31	-0.40
Morning	23.08	22.64	-0.44	Morning	23.37	23.03	-0.34
Day	24.56	23.99	-0.57	Day	25.48	25.02	-0.46
Evening	24.06	24.01	-0.05	Evening	25.39	25.19	-0.20
Night	23.39	22.92	-0.47	Night	23.63	23.09	-0.54
Bedroom 1				**Bedroom 3**			
24 hr	23.44	22.86	-0.58	24 hr	24.32	23.84	-0.48
Morning	22.49	21.91	-0.58	Morning	24.65	24.35	-0.30
Day	23.98	23.33	-0.65	Day	25.56	25.31	-0.25
Evening	23.74	23.32	-0.42	Evening	24.34	23.77	-0.57
Night	22.82	22.18	-0.64	Night	22.85	22.15	-0.70
Bedroom2/Study				**Bathroom**			
24 hr	24.91	25.12	+0.21	24 hr	22.62	21.67	-0.95
Morning	24.35	24.38	+0.03	Morning	21.42	20.38	-1.04
Day	26.21	26.26	+0.05	Day	23.92	23.04	-0.88
Evening	24.7	24.92	+0.22	Evening	23.28	22.4	-0.88
Night	23.81	24.21	+0.40	Night	20.98	19.9	-1.08
External							
24 hr	19.45	17.86	-1.59				
Morning	19.66	18.00	-1.66				
Day	22.34	20.66	-1.68				
Evening	19.16	17.7	-1.46				
Night	16.52	14.93	-1.59				

Table 14: Summer mean temperatures by time of day and room

5.2.2 Winter temperatures

The Waitakere NOW Home® mean winter temperatures in the living space and bedrooms met the Beacon HSS for average temperature under Indoor Environment Quality. Living space temperatures remained at or above the 18°C benchmark throughout winter, as did the bedrooms which remained above the 16°C benchmark.

When looking at this section, it is worth noting that the data of the first and second winters cannot be directly compared due to challenges with the logging equipment (see Pollard 2007). The analysis of the first and second winters makes use of data collected in the latter part of the winter from 11 August to 31 September, and is therefore not directly comparable to the winter temperatures seen in the Waitakere NOW Home® Year 1 report (French et al 2007).

The winter temperature profiles are shown in Figure 38 and Figure 39 with the data tabulated by room and time of day in Table 15. The outside temperatures for the second year are between 0.3°C and 1.3°C warmer, depending on the time of day. However, only three out of the six rooms monitored have an increase in temperature (family room, living room and bedroom 1). Small temperature decreases can be seen in bedroom 3 (0.2°C to 0.7°C thought to be due to fewer occupants in this room) and the bathroom (0.8°C to 1.1°C thought to be due to an extractor fan being been installed). There is however a large increase in temperatures in the living room (2.1°C to 2.2°C) and a corresponding decrease in temperatures in bedroom 2 / study (2.1°C to 2.6°C). For the first year bedroom 2 / study was used as a home office and had much office equipment running regularly including a computer which was left running all of the time. This electrical equipment would be producing a measurable amount of heat into this room. In the second winter the office was relocated into the living room.

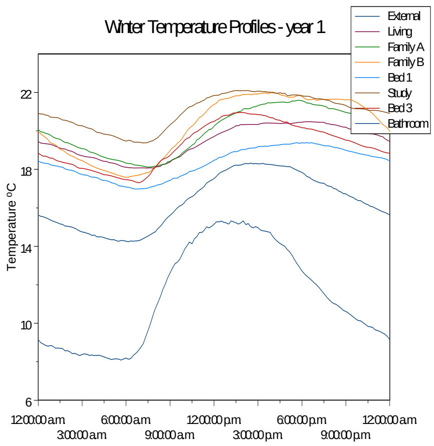

Figure 38: Winter temperature profile – Year 1

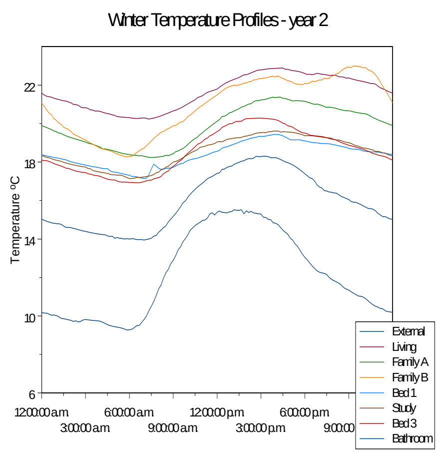

Figure 39: Winter temperature profile – Year 2

	Temperature (°C)				Temperature (°C)		
Living room	**2006**	**2007**	**Difference**	**Family room**	**2006**	**2007**	**Difference**
24 hr	19.44	21.63	+2.19	24 hr	20.1	20.4	+0.30
Morning	18.14	20.38	+2.24	Morning	18.18	18.81	+0.63
Day	19.8	22.06	+2.26	Day	20.81	20.95	+0.14
Evening	20.25	22.42	+2.17	Evening	21.33	21.65	+0.32
Night	18.69	20.78	+2.09	Night	18.73	19.09	+0.36
Bedroom 1				**Bedroom 3**			
24 hr	18.34	18.39	+0.05	24 hr	19.27	18.58	-0.69
Morning	17.15	17.58	+0.43	Morning	18.02	17.25	-0.77
Day	18.61	18.78	+0.17	Day	20.36	19.58	-0.78
Evening	19.11	18.85	-0.26	Evening	19.73	19.09	-0.64
Night	17.67	17.78	+0.11	Night	18.01	17.4	-0.61
Bedroom 2 / Study				**Bathroom**			
24 hr	20.99	18.51	-2.48	24 hr	16.32	15.96	-0.36
Morning	19.64	17.5	-2.14	Morning	14.82	14.36	-0.46
Day	21.7	19.08	-2.62	Day	17.56	17.43	-0.13
Evening	21.48	19.11	-2.37	Evening	17.04	16.46	-0.58
Night	20.14	17.65	-2.49	Night	14.76	14.38	-0.38
External							
24 hr	11.47	12.16	+0.69				
Morning	10.53	11.23	+0.70				
Day	14.59	14.87	+0.28				
Evening	11.32	11.9	+0.58				
Night	8.45	9.71	+1.26				

Table 15: Winter mean temperatures by time of day and room

5.3 Relative Humidity (RH)

Beacon's HSS® (2006) for RH was for bedrooms and living spaces to be between 20% and 70% RH at all times. This section shows how the Waitakere NOW Home® performed using mean humidity levels, thereby excluding outliers from analysis.

5.3.1 Summer relative humidity

Based on mean RH figures (see Table 16), the Waitakere NOW Home® met Beacon's 2006 HSS for RH of between 20% and 70% RH in the bedrooms and living spaces during summer.

Overall the summer-time humidities between the first and second year of operation are slightly lower most of the time in all rooms. The summer-time relative humidity daily profiles for the first and second year of the Waitakere NOW Home® are shown in Figure 40 and Figure 41, with Table 16 providing the numerical results with time of day information.

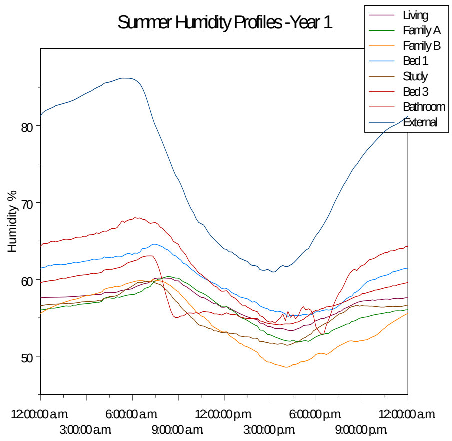

Figure 40: Summer humidity profile – Year 1

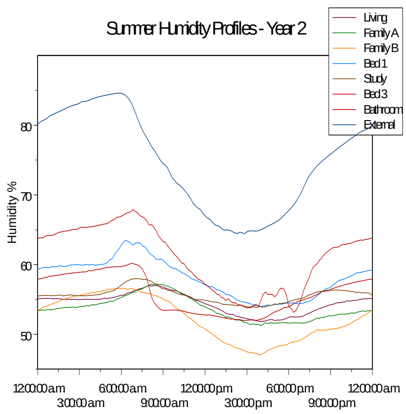

Figure 41: Summer humidity profile – Year 2

	Relative Humidity (%)				Relative Humidity (%)		
Living room	**2006**	**2007**	**Difference**	**Family room**	**2006**	**2007**	**Difference**
24 hr	57.0	54.4	-2.5	24 hr	55.2	53.0	-2.3
Evening	56.1	53.5	-2.6	Evening	52.9	51.2	-1.6
Morning	60.0	56.8	-3.2	Morning	59.7	56.3	-3.4
Day	55.8	53.8	-2.0	Day	53.8	51.8	-2.0
Night	58.2	55.2	-3.0	Night	57.6	54.9	-2.7
Bedroom 1				**Bedroom 3**			
24 hr	60.0	58.1	-1.9	24 hr	57.9	55.8	-2.0
Evening	57.8	56.0	-1.8	Evening	57.3	55.7	-1.6
Morning	64.0	61.9	-2.1	Morning	59.6	57.0	-2.6
Day	58.1	56.5	-1.6	Day	55.0	52.7	-2.3
Night	62.6	60.5	-2.1	Night	61.0	59.0	-1.9
Bedroom2/Study				**Bathroom**			
24 hr	55.6	55.6	+0.1	24 hr	61.5	61.0	-0.5
Evening	55.3	55.6	+0.3	Evening	59.2	59.3	+0.1
Morning	58.9	57.6	-1.3	Morning	66.5	65.9	-0.5
Day	53.0	54.8	+1.7	Day	57.8	57.0	-0.8
Night	57.6	56.0	-1.6	Night	66.1	65.5	-0.7
External							
24 hr	73.9	74.7	+0.8				
Evening	78.1	78.0	-0.1				
Morning	64.3	67.3	+3.1				
Day	72.5	73.3	+0.8				
Night	84.3	83.0	-1.3				

Table 16: Summer RH means by time of day and room

5.3.2 *Winter relative humidity*

Based on mean RH figures (see Table 17), the Waitakere NOW Home® met the 2006 HSS® for RH of between 20% and 70% RH in the bedrooms and living spaces during winter, aside from in bedroom 2 / study in 2007.

Despite meeting the HSS® for RH in 2006, bedroom 2 / study exceeded the HSS® by 0.6% mean RH overnight during the winter period in 2007 with a figure of 70.6%. Bedroom 1 morning mean RH levels exceeded the HSS® with 74.8% RH in 2006, but met the HSS® in 2007.

Overall there appears to be a reduction in the RH levels despite an increase in outside humidity. There also appears to be an increase in the spread of values.

As the humidity data was collected alongside the temperature data, the winter period in this section is based on the monitoring period from 11 August to 31 September (also see section 5.1.2).

The winter profile data is seen in Figure 42 for the first year and in Figure 43 for the second year with Table 17 providing the numerical results and time of day information.

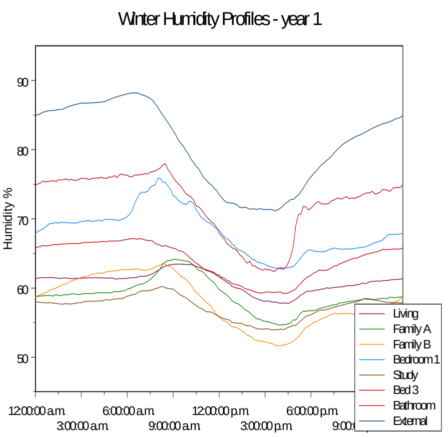

Figure 42: Winter humidity profile – Year 1

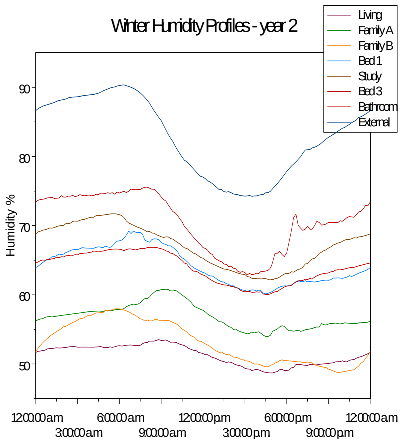

Figure 43: Winter humidity profile – Year 2

The change of usage for the living room and bedroom 2 / study is again clearly seen with a drop in the RH in the living room (9% to 10%) and a corresponding increase in RH in bedroom 2 / study (8% to 12%). The balanced nature of these changes tend to indicate that the common element (the shifting of the office computer) is the cause of the changes and that the observed changes in RH are a result of the change in room temperature which is in turn a result of the heat produced from the electronic equipment.

	Relative Humidity (%)				Relative Humidity (%)		
Living room	**2006**	**2007**	**Difference**	**Family room**	**2006**	**2007**	**Difference**
24 hrs	60.9	51.3	-9.6	24 hrs	58.5	55.0	-3.5
Morning	62.5	53.1	-9.4	Morning	62.7	58.0	-4.6
Day	60.5	50.9	-9.5	Day	57.1	54.7	-2.4
Evening	60.2	49.9	-10.3	Evening	56.8	52.6	-4.2
Night	61.4	52.4	-9.1	Night	60.3	56.7	-3.6
Bedroom 1				**Bedroom 3**			
24 hrs	68.2	64.2	-4.0	24 hrs	64.0	63.9	-0.1
Morning	74.8	68.4	-6.4	Morning	66.5	66.7	+0.3
Day	66.9	62.9	-4.1	Day	61.4	62.5	+1.1
Evening	65.8	62.0	-3.8	Evening	63.5	62.5	-1.0
Night	69.8	66.5	-3.3	Night	66.6	65.9	-0.7
Bedroom2/Study				**Bathroom**			
24 hrs	57.3	67.1	+9.9	24 hrs	72.2	70.5	-1.7
Morning	59.9	69.3	+9.4	Morning	77.0	75.2	-1.7
Day	55.7	64.7	+9.0	Day	67.3	66.6	-0.7
Evening	57.3	65.4	+8.1	Evening	72.8	69.6	-3.2
Night	58.2	70.6	+12.4	Night	75.8	74.4	-1.4
External							
24 hrs	80.6	82.7	+2.1				
Morning	86.1	88.1	+2.0				
Day	74.2	77.1	+2.9				
Evening	80.0	81.2	+1.3				
Night	86.7	88.8	+2.1				

Table 17: Winter mean RH by time of day and room

Despite a reduction in occupancy, bedroom 3 has had little change in RH between Year 1 and Year 2.

The family room and bedroom 1 have both had a reduction in RH between Years 1 and 2. Both of these rooms now have adjoining rooms which have mechanical ventilation. A smaller reduction in RH levels between Year 1 and Year 2 in the bathroom occurred despite this room having direct mechanical ventilation. It should be noted however that the reduction in absolute humidity in the bathroom is greater than is apparent by the reduction in RH because there was a temperature decrease between Years 1 and 2 for the bathroom.

Relative humidity (RH) is an awkward parameter to examine given that warmer air can hold a greater content of moisture and that the comparison to the corresponding changes in temperature is required. While RH does provide a measure of condensation risk, knowing the total moisture level (absolute humidity) within the house (which can be calculated from the measured RH and temperature) can assist with understanding the moisture loadings within the NOW Home®.

5.4 Carbon Dioxide (CO_2) Levels

The CO_2 concentrations in the Waitakere NOW Home® were measured in the family room. As there are no combustion processes taking place within the Waitakere NOW Home® (e.g. no gas appliances, smokers etc), the CO_2 within the home reflects the ambient conditions it is exposed to as well as the CO_2 exhaled by the occupants. Over a longer period of time the number of people within the Waitakere NOW Home® is consistent so that variations in CO_2 levels are likely due to changes in ventilation.

A time-series plot of the 10 minute data (Figure 44) shows higher values in CO_2 during the winter 2006, with Table 18 providing monthly mean values showing a similar trend. Extractor fans were added to both bathrooms and a solar-powered stack fan to the kitchen (adjacent to the family room) in mid-June 2007. It seems plausible that the increased ventilation due to these fans would have reduced the CO_2 levels for winter 2007 to what they would have otherwise been.

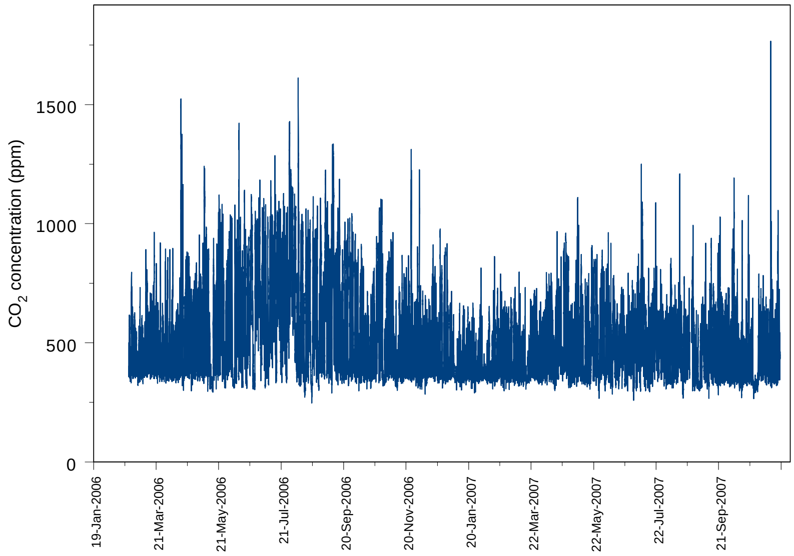

Figure 44: CO_2 concentrations in the family room of the Waitakere NOW Home®

The average daily profiles of the CO_2 levels for both winters are shown in Figure 45. The overall reduction in CO_2 between Year 1 and Year 2 can be clearly seen in both. Both the absolute values and the differences between the winters begin to increase from ambient levels (around 400 ppm) until about midnight when the CO_2 levels slowly decrease. In the morning there is an increase in levels, but after that a rapid decrease and a narrowing of the differences until reaching ambient levels at late afternoon.

Monthly	CO_2 (ppm)	
Average	2006	2007
Jan		410
Feb		424
Mar	459	435
Apr	523	499
May	568	497
Jun	652	487
Jul	730	510
Aug	633	478
Sep	651	470
Oct	522	439
Nov	496	
Dec	481	

Table 18: Monthly CO2 levels

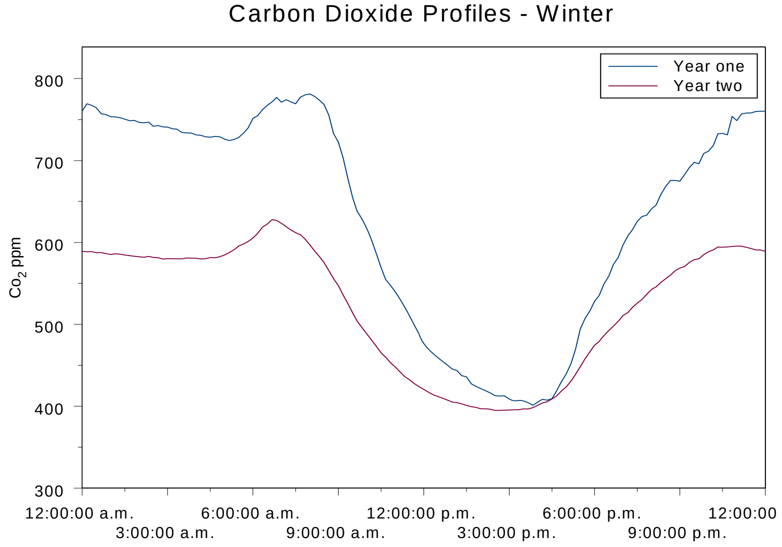

Figure 45: CO2 winter profile – comparing two years

6 Social Analysis

This section of the report provides an overview of the post occupancy evaluation undertaken and recommendations for further research, as a result of the information collected in the second year.. A very different occupancy-related survey was trialled in Year 2, but which still investigated the more difficult to quantify social issues to complement the intense physical (quantitative) monitoring of the building.

6.1 Overview

The quarterly POEs that were carried out for the Waitakere NOW Home® as part of the first[3] of the two-year longitudinal (monitoring) social investigation were replaced in the second year by a one-off evaluation. The change in survey was due to the limitations (mainly the fact that very similar answers were being given for all the longitudinal questions) with the Year 1 survey.

For the Year 2 approach, a HEEP survey (version 19) was chosen to replace the NOW Home® questionnaire as a one-off information collection exercise. The HEEP survey is considered robust, having undergone rigorous trialling and fine-tuning over the decade it was in active operation. In addition, given the more comprehensive way in which (both physical and behavioural) data is captured within the HEEP survey, it provides more possibilities in terms of querying information and the ability to cross-check and compare social with physical aspects. Essentially, even though the HEEP survey takes considerably longer to conduct, given that it is a one-off measure, it seemed a logical way to progress the NOW Home® research.

As part of the 10 year long HEEP study, the survey questionnaire was typically carried out during the installation of the monitoring equipment, usually by interviewing one of the adults (e.g. the decision-maker). In all, some 80 questions are asked to give a very comprehensive overview of the house, its features, its occupants and how they interact within it as part of their day-to-day living. The HEEP NOW Home® survey was undertaken on 23 May 2007, with both the adult occupants present over a period of one-and-a-quarter hours. All questions were asked apart from those for which BRANZ had already established the information (i.e. house physical characteristics and the energy billing amounts) or issues which were deemed unnecessary (i.e. the disclosure agreement).

[3] ***Details of the first year's approach can be found in the Year One report (French L et al, 2007).***

7 Conclusions

7.1 Energy

During its second year of occupation the Waitakere NOW Home® has had a 15% increase in reticulated energy consumption from that used in the first year of occupancy, increasing from 7400 kWh to 8500 kWh. This figure was still 15% less than the average reticulated energy use of houses constructed in Auckland since 1997 taken from the HEEP database.

The electricity bill for the second year was $1640, reflecting a 24% increase from the $1325 the occupants paid in the first year.

The largest end-use of electricity is the solar water heater, which has seen a large increase in energy use from the first and second years of operation, using 2340 kWh (28%) in the second year.

Initial analysis of the appliance electricity meters shows the home office computer is one of the highest electricity-using appliances, the second highest for the home, consuming 10% of the household's electricity.

The solar water heater converted 1880 kWh of heat from the sun into water heating in the second year of operation, contributing 45% of the energy used for water heating over the year. This reflects a cost saving of $300 per year. This is slightly below expectations, with the winter-time performance of the solar water heater providing only approximately 10% of the water heating needs. It is recommended that a timer be installed on the supplementary heating element to prevent heating of water from the electric element in the mornings.

The Waitakere NOW Home® baseload is not directly comparable to HEEP due to the varying appliance usage in the Waitakere NOW Home® requiring a different calculation method. A characteristic value for the minimal power use (the 1% percentile) for the Waitakere NOW Home® is 240 W, and this high level suggests many appliances are left on continuously or in standby mode.

7.2 Water

There was an 8% decrease in the total water use for the Waitakere NOW Home® from Year 1 reducing use to 690 L per day. However the water use during the Year 2 summer period (796 L/d) was 17% higher than the water use during the Year 2 winter period (681 L/d).
For the second year, 48% of this water was supplied by the street mains and 52% from the 13 500 L rain tank. It is estimated that the Waitakere NOW Home® collected 216,000 L of rainwater (which is equivalent to 86% of the total water demands) over its second year of operation. However only 128,000 L of this water was used. Control systems, such as automatic

valve switches, to maximise the amount of rainwater used have the potential to greatly improve the overall effectiveness of the system.
The highest proportion of water use within the Waitakere NOW Home® goes into the shower with an overall proportion in the second year of monitoring of 42%. An examination of the showering behaviour will be undertaken for the final report. The laundry was the next highest usage with 19%, followed by the toilets 15% and the outside taps 12%. The use of the outside taps was very seasonal, with 28% of summer-time usage going into taps but with almost zero wintertime usage.

On average 202 L/d are used to heat water. A large proportion of this heated water (around 80%) is used in the shower.

7.3 Indoor Environment

The summer-time temperatures between the first and second years in the Waitakere NOW Home® had a slight reduction in temperatures.

A fault with the temperature sensors meant that the comparison of the winter-time data covered August and September. The outdoor winter-time temperature was slightly warmer for the second year and most indoor temperatures were slightly warmer. The temperature in the bathroom was slightly cooler, which could be due to the addition of a ventilation fan before the second winter. The change of the office into a bedroom, with the office being relocated into the living room, resulted in a 2°C temperature increase in the living room (now with the office computer) while bedroom 2 was 2°C cooler.

The summer-time humidities show no remarkable change between the years. However the winter-time humidities were quite different. Overall the humidity levels in the second year were lower despite an increase in outdoor humidity, and again the change of room usage and the increase of ventilation in the bathrooms produced specific changes in the humidity levels. There was a greater variation of humidity throughout the house in the second year and further analysis, perhaps considering the absolute humidity, may be of value.

The CO_2 levels have seen a large decrease in values between the first and second years, presumably due to the increase in ventilation within the house in the second year.

7.4 Post-occupancy evaluations

For the second year of occupancy, as the quarterly post occupancy evaluation surveys were producing similar responses and as there was interest in obtaining more comprehensive behavioural information, the original survey was replaced with the one-off HEEP occupant survey.

8 References

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9 EDA Graphs

With extensive amounts of data processed in the HEEP project, exploratory data analysis (EDA) graphs were developed to allow the data to be quickly examined. A series of these EDA graphs have been generated for the Waitakere NOW Home® and are included in this appendix.
In order to understand the EDA graphs, read the following edited description of the format of the plots(taken from a HEEP homeowner report) first, and refer to the example plot provided in Figure 46.

Figures 47 to 56 are EDA graphs for different aspects of the Waitakere NOW Home:

- Figure 47. Total electricity used by the household (excludes monitoring equipment)
- Figure 48. Supplementary electrical heating for the SWH systems
- Figure 49. Range (oven and hobs)
- Figure 50. Lighting circuit (including the bathroom ventilation)
- Figure 51. Fridge freezer
- Figure 52. Pump for the solar hot water collector
- Figure 53. Dishwasher
- Figure 54. Pump for the rain tank water
- Figure 55. Fan heater (no usage recorded)
- Figure 56. Washing machine

How to read an EDA graph

The house label, appliance label and appliance description appear in the title of the graph. Underneath the title is summary information. This reports the number of days monitored, the number of days of NAs (missing values), then the percentage of valid data points with power in the ranges: equal to zero W, greater than zero and less than 20 W, and greater than 20 W, and finally the energy use (kWh) over a year (1 average day x 365). These percentage ranges correspond roughly to the proportion of the time the appliance was drawing no power, the proportion of time in 'standby' mode (if that applies to the appliance), and the proportion of time in operation. As the time resolution is only 10 minutes, this description will not be valid for appliances with switching cycles shorter than 10 minutes.

Each individual EDA graph (see Figure 46) contains three plots: a *histogram* of the power recorded every 10 minutes; a *time-series plot* of the power every 10 minutes; and time-series plots of the *7-day moving average* power consumption (solid line, left axis) and *daily profile* (dashed line, right axis).

The *histogram* shows how often the power was in a given range. The power range in W is on the horizontal axis and the counts are on the vertical axis. For appliances that have too many values in the 'zero' bin, this bin is replaced by a number, otherwise the remaining bins would be too small to see clearly.

The *time-series plot* has the date (start of month) on the horizontal axis, and the appliance power in W on the vertical axis. As there is so much data, the lines sometimes overlap slightly, causing a solid block of black. This indicates rapid switching between high and low values. If a solid block has an apparent straight edge on the top or bottom, this indicates that it is switching to a constant value. If the solid block has a ragged edge, it is switching to a changing value. Periods of missing values are indicated by a straight horizontal line near the top of the time-series plot. These may occur if there was a problem with the monitoring, a power cut, or the appliance was not monitored during a given period.

The third plot contains the ***7-day moving average plot*** and ***daily profile***. The two lines provide an average ***daily profile*** (dot-dash line) running from midnight to midnight, and a ***7-day moving average*** running from the start to the end of the data (solid line). In the example of Figure 46 the average ***daily profile*** for this total load channel shows a low overnight baseload, stepping up at 5 am to a morning peak at 7 am, stabilising for the day with a slight fall off in the early afternoon, and then rising to a peak of 1500 W at 7 pm, which falls off into the later evening. The ***7-day moving average*** removes the fluctuations over the day and shows any seasonal pattern. The winter peak (June through September) shows clearly, suggesting the use of electric space heating in this house

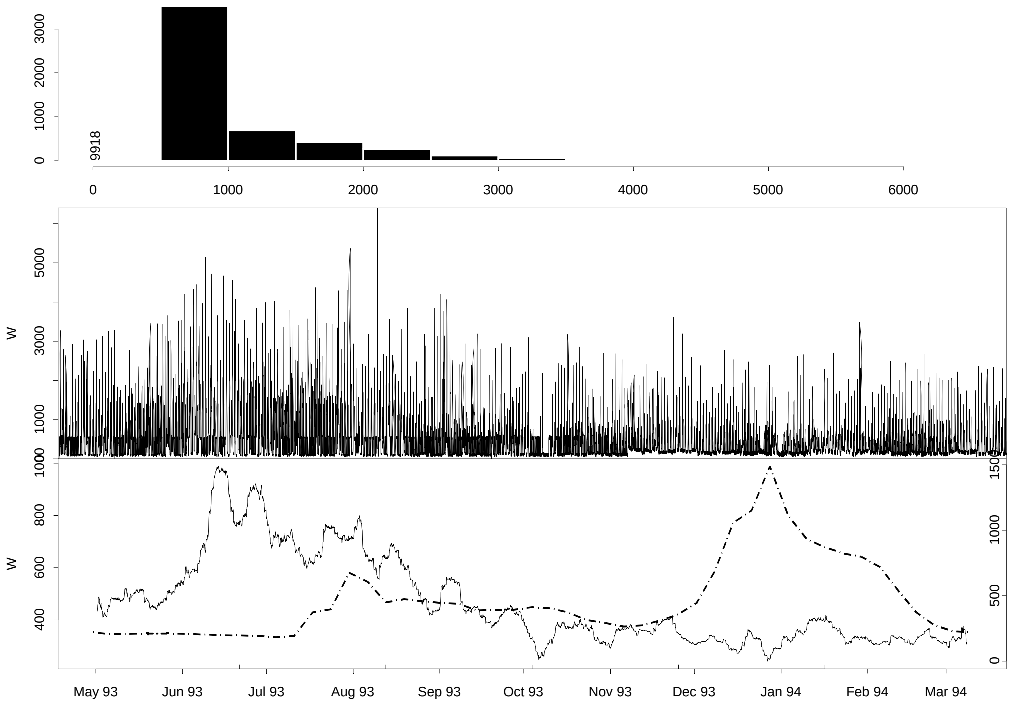

Figure 46: Example of an EDA plot for a single appliance

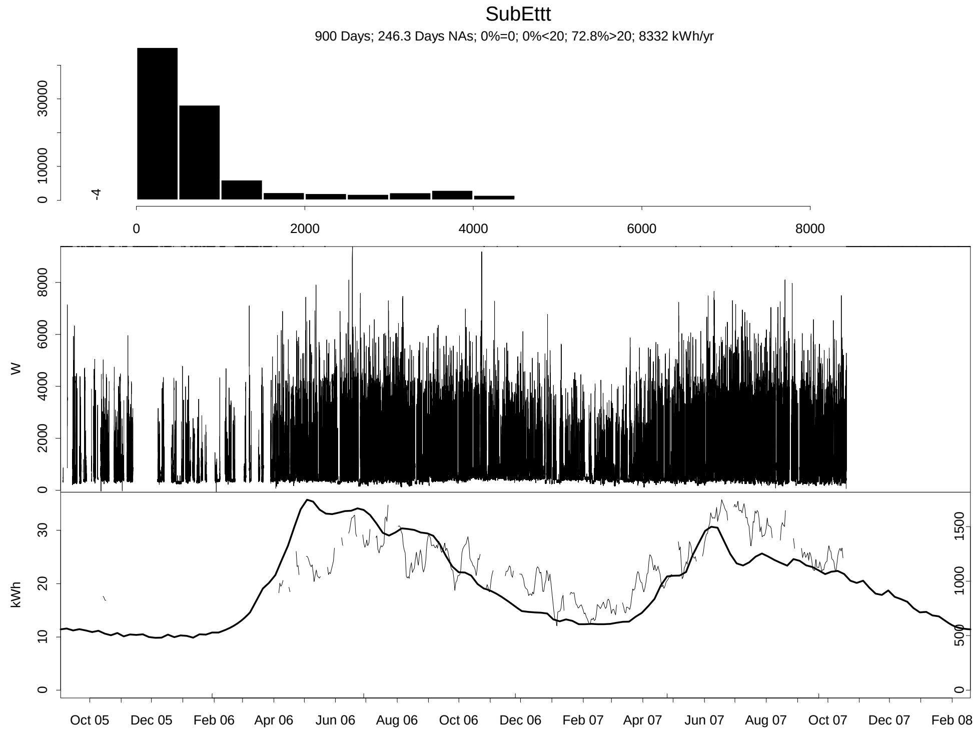

Figure 47: Total electricity used by the household (excludes monitoring equipment)

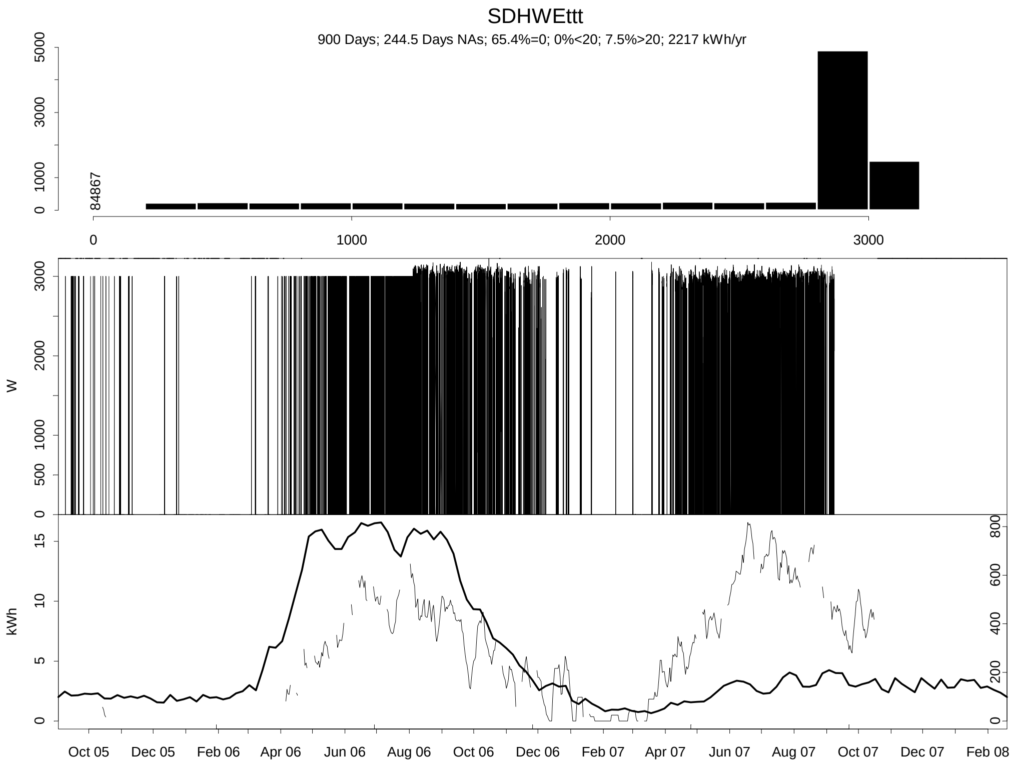

Figure 48: Supplementary electrical heating for the SWH systems

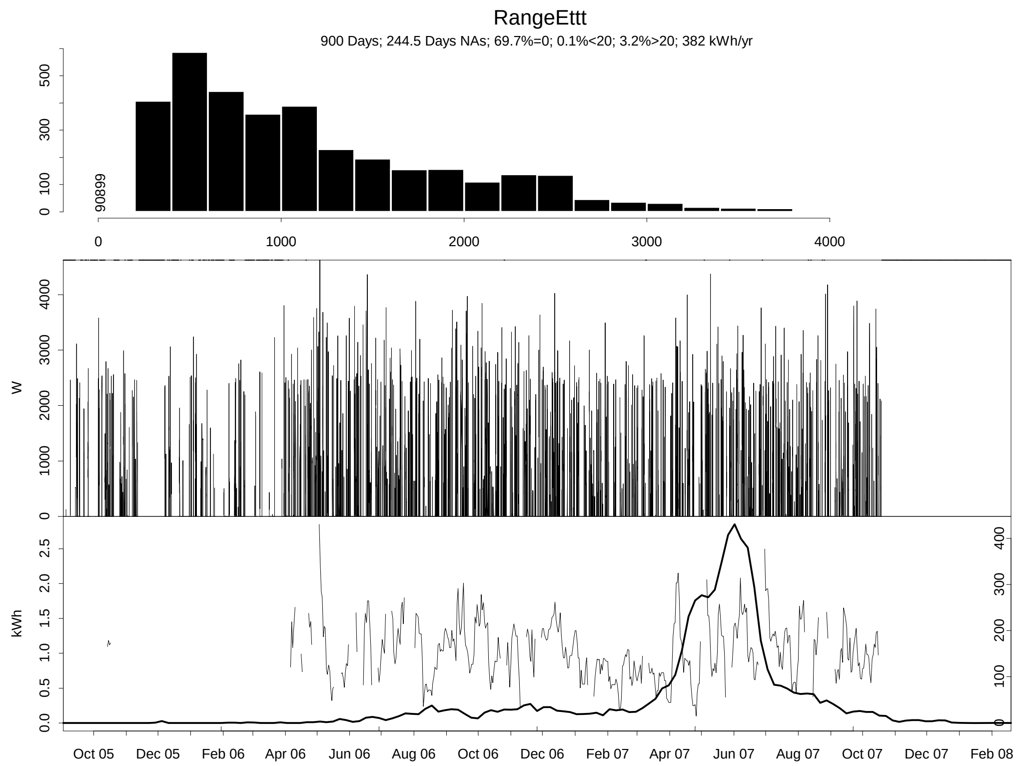

Figure 49: Range (oven and hobs)

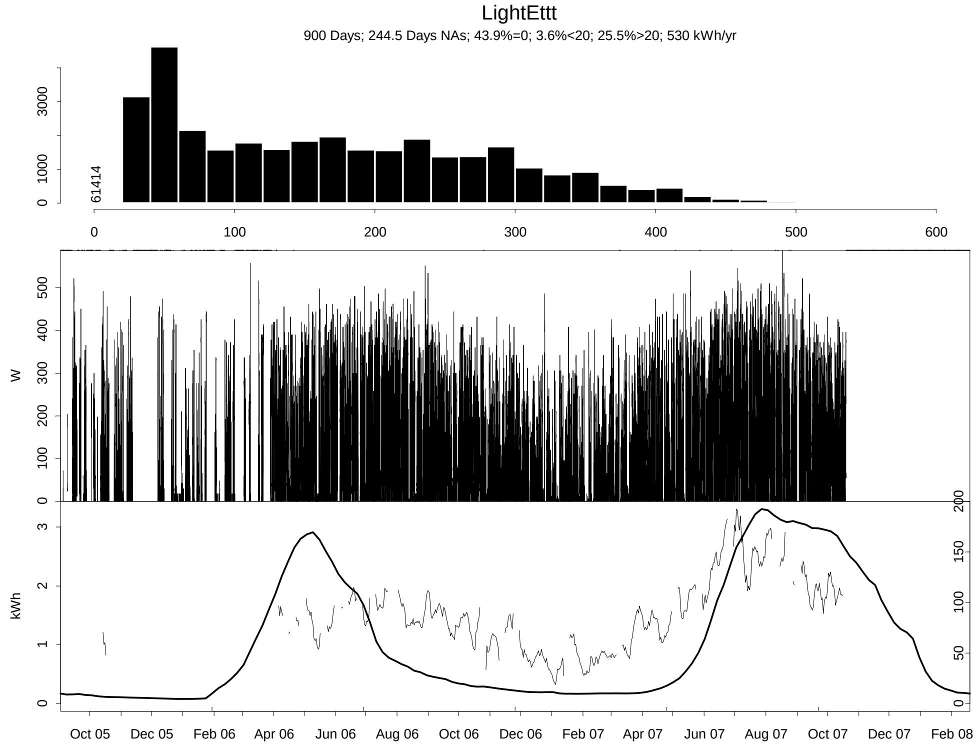

Figure 50: Lighting circuit (including the bathroom ventilation)

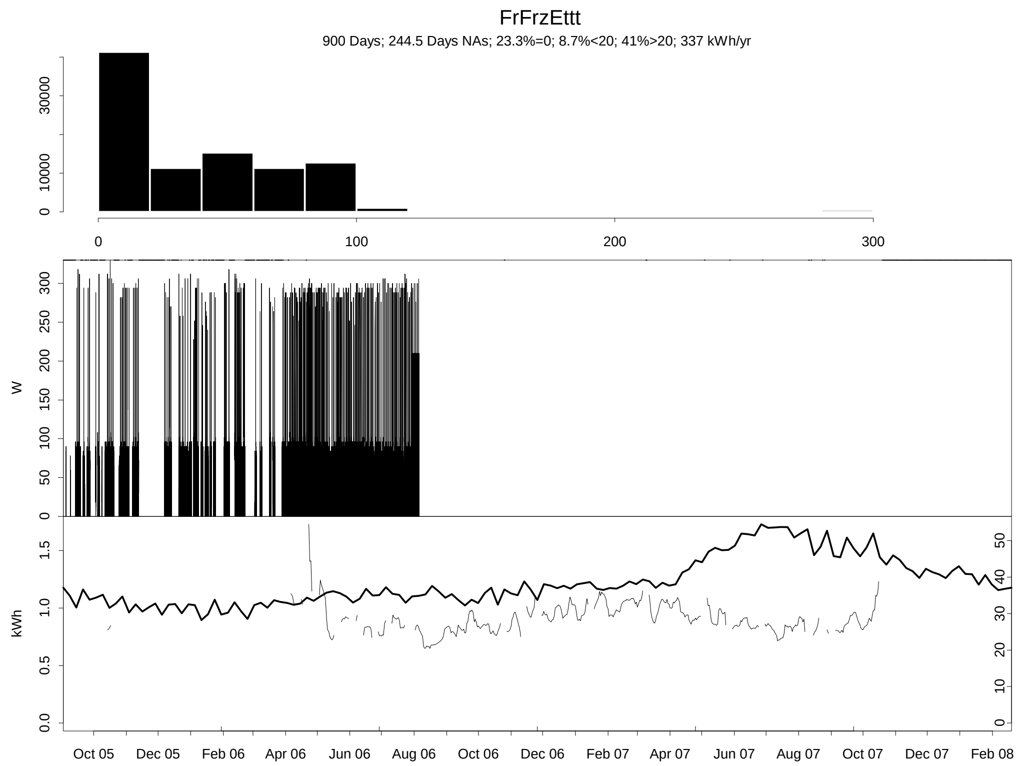

Figure 51: Fridge freezer

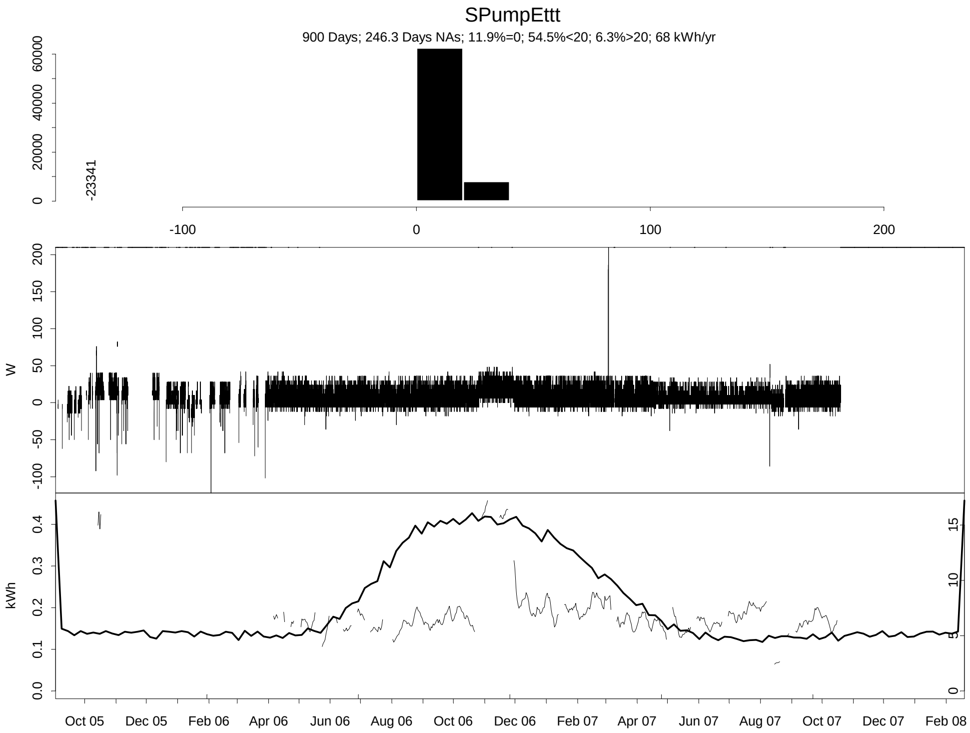

Figure 52: Pump for the solar hot water collector

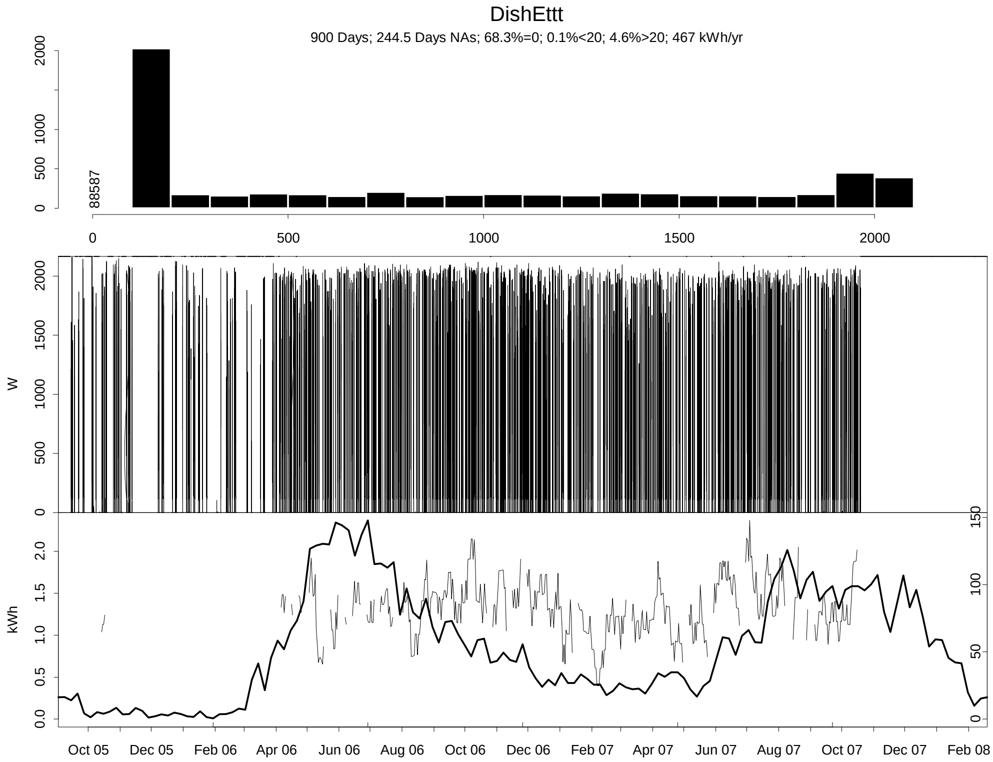

Figure 53: Dishwasher

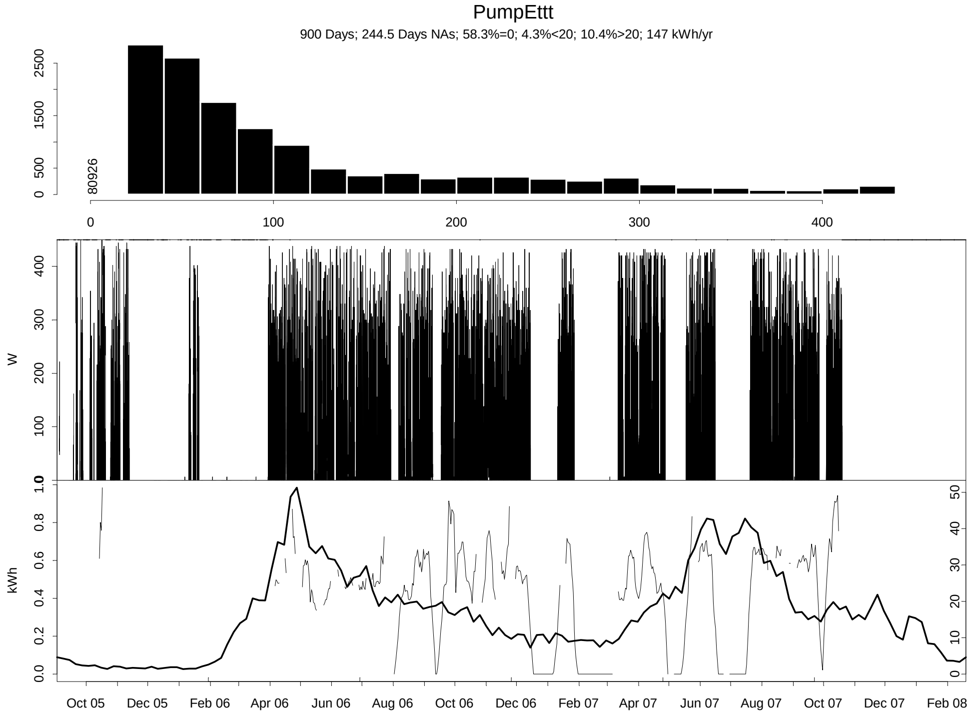

Figure 54: Pump for the rain tank water

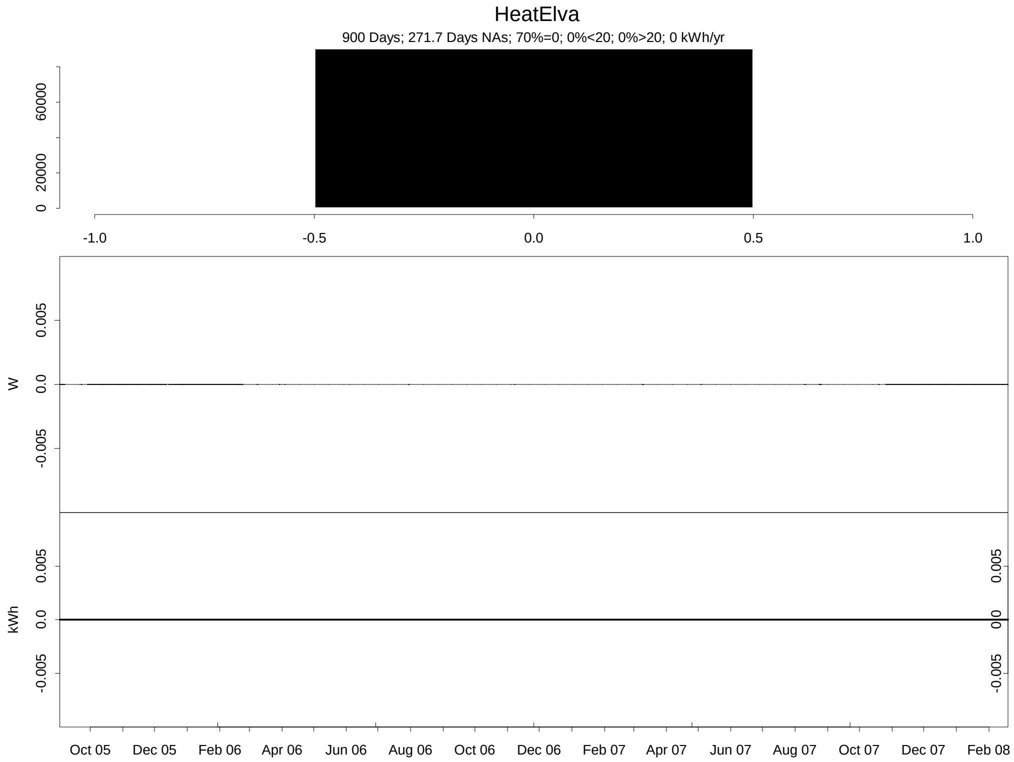

Figure 55: Fan heater (no usage recorded)

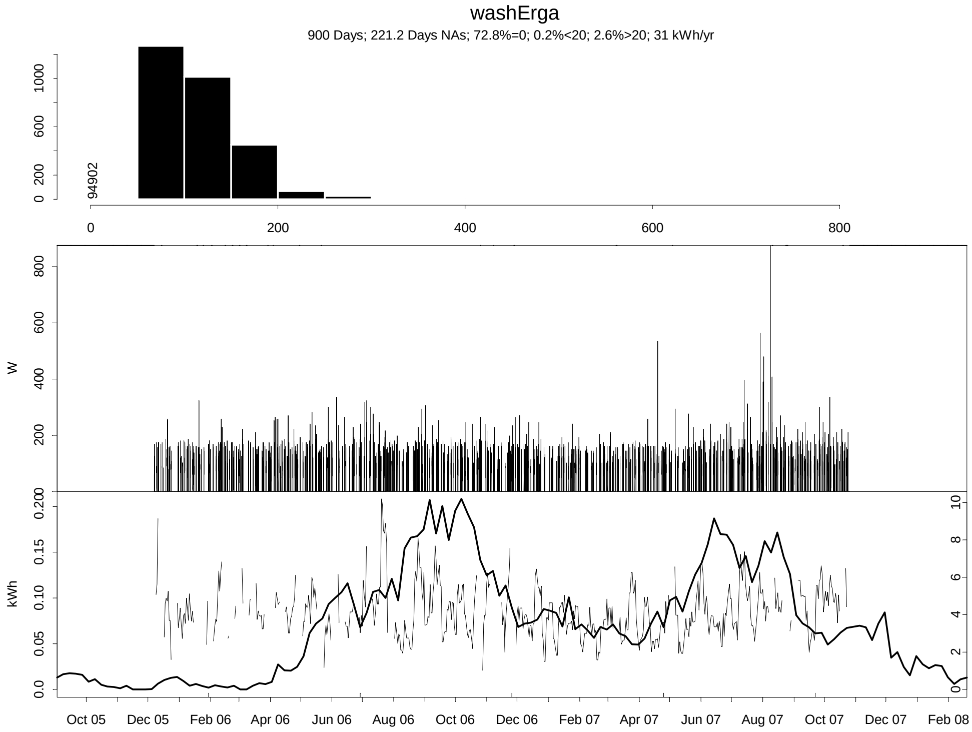

Figure 56: Washing machine