# EC1504

# Heat pump water heater performance

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# Heat pump water heater performance

## 1. CLIENT

Parex Industries Limited
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## 2. OBJECTIVE

Parex Industries requested BRANZ to collect performance data on three Stiebel Eltron heat pump water heater (HPWH) systems located in Auckland, Wellington and Christchurch. The three HPWH systems were monitored for a year to allow the HPWH systems to experience a range of environmental conditions and to allow for characteristic annual performance to be assessed. BRANZ was also asked to provide weather data from the NIWA Cliflo database for suitable locations over the monitored period.

## 3. METHOD

Each HPWH was instrumented as indicated in Figure 1. A thermocouple logger was used to record the hot and cold water temperatures. The water use of the system was measured by a Manuflo MES-MR water meter with a pulsed output of 34 pulses per Litre and a Siemens S2AS electricity meter with a pulsed output for each Watthour of electrical energy consumption of the HPWH unit. The pulsed outputs of both the water meter and the electricity meter were recorded by BRANZ pulse loggers recording at six minute intervals.

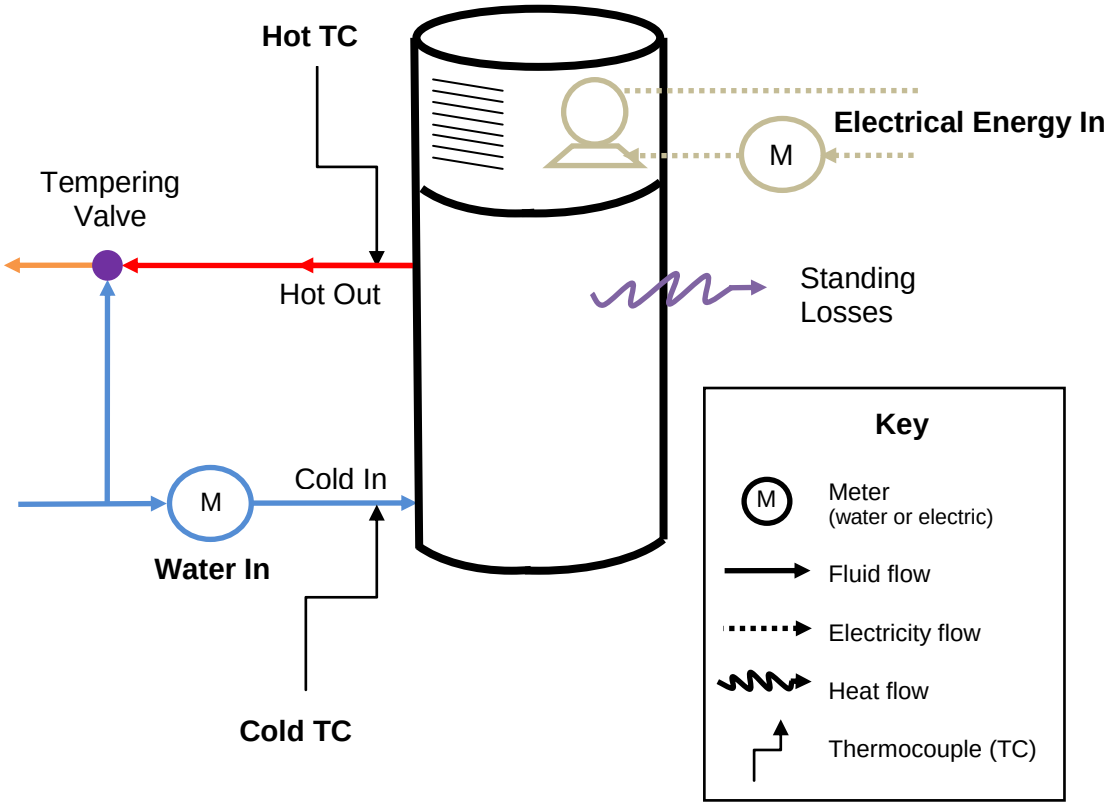


**Figure 1 Monitoring arrangement for each HPWH**

# 4. COMPILING DATA

The raw data files from each of the loggers were processed to convert the thermocouple responses to actual temperatures and the pulses to either electrical demand (in Watts) or water demand (in Litres per minute) over the corresponding six minute interval.

The collected data from each of the systems is provided in the Microsoft Excel (2007) datafiles;

**ah3.xlsx** for the Auckland system

**wh1.xlsx** for the Wellington system

**ch1.xlsx** for the Christchurch system

The data is labelled;

**dhwE** for the electrical energy demand (watts) over the logging interval,

**dhwF** for the water flow (litres per minute) over the logging interval,

**cldT** for the cold water inlet temperature at start of the logging interval,

**hotT** for the hot water outlet temperature at start of the logging interval,

**huvT** for the temperature of the logger at the start of the logging interval.

A broad overview of the data in these files in provided in the graphs given in Appendix A.

While the logger temperature (huvT) measured for each site provides an approximate indication of the temperature at each site, its measurement does not follow meteorological practices. To provide some correspondence to measured weather data, temperature and humidity data was retrieved from the NIWA Cliflo database. The sites chosen were of major climate stations close to the measurement site. The sites used were Whenuapai (NIWA Agent Number 23976) for the Auckland system, Wellington Airport (NIWA Agent Number 3445) for the Wellington system and Kyle Street (NIWA Agent Number 24120) for the Christchurch system.

Data was downloaded for the period from 1 April 2008 to 23 September 2009 to cover the analysed monitoring period of all the sites. The data is provided in the Excel 2007 file **WeatherData.xlsx.**

Figure 2 shows a timeline of the period of data collection from each of the HPWH systems and the period of weather data sourced. The period of data collection for the HPWH systems is shown in blue with the darker blue colour indicating the period of analysis undertaken in section 5. The weather data was compiled for the period shown in red and covers the period of analysis for all three of the sites.

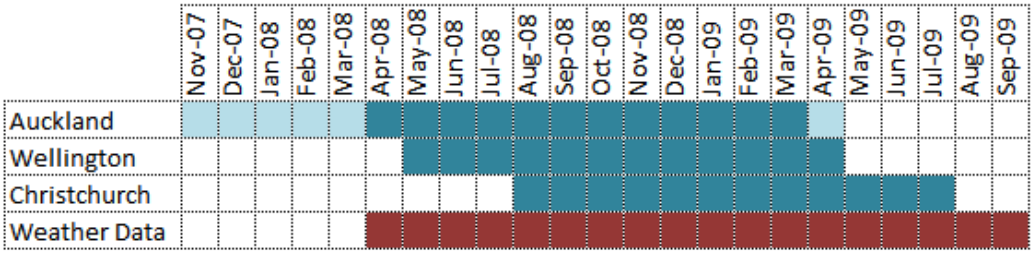


**Figure 2 Measurement collection period for the three sites (blue) with the period of weather data (red)**

# 5. RESULTS

The peak in temperature of the measurement from the outside of the water pipe is slightly delayed from when the water is drawn-off from the cylinder. Therefore, the response from the thermocouples need to be offset one measurement step when it is used in calculations.

The energy contained in the water drawn-off from the HPWH was calculated every six minutes from the product of the temperature difference of the outgoing to the incoming water, the volume of water drawn-off and the volumetric heat capacity of water.

The average of the available data of the measured volume of hot water, the measured electrical energy of the HPWH system and the calculated energy content of the drawn-off water over one year is shown in Table 1. Also shown in Table 1 is the coefficient of performance (COP) of the each of the systems which is calculated as;

$$COP = \frac{Q_{draw\ off}}{E_{ne}} \quad (5.1)$$

where $Q_{draw\ off}$ is the energy content of the drawn-off water

$E_{ne}$ is the non-environmental energy (ie the electrical input energy) to the HPWH system

In comparing COP values it is important to consider what values are achieved by reference systems. For electric storage cylinders the standing losses can be a sizable proportion of the heat loss of the system. Results from the HEEP project indicate that average standing losses are of the order of 33% of total water heating energy leading to COP for an average electric storage cylinders of 0.67. A system with a COP of 1.34 would therefore require half as much water heating energy as a standard electric storage cylinder for a given amount of hot water.

**Table 1 Performance of the HPWH systems**
**(all data to two significant figures)**

| System | Hot Water use (Litres / day) | Draw-off Energy (kWh / year) | Electrical Energy (kWh / year) | COP |
|---|---|---|---|---|
| Auckland | 100 | 1700 | 1500 | 1.2 |
| Wellington | 180 | 3400 | 1900 | 1.8 |
| Christchurch | 170 | 2700 | 1900 | 1.5 |

# 6. APPENDIX A: EDA GRAPHS

To examine the extensive amount of data present, it is convenient to use Exploratory Data Analysis (EDA) graphs to allow a broad overview of the data to be seen. EDA plots of the systems are given in Figure 3, Figure 4 and Figure 5 with the following providing an overview of the graphs.

The channel label appears in the title of the graph: The first three characters are the site location either Auckland (**ah3**), Wellington (**wh1**) or Christchurch (**ch1**). The rest of characters indicate what is displayed in the series of three panels under the title. ***dhwE*** is the non-environmental electricity usage of the HPWH system; ***dhwF*** is the cold water flow into the HPWH system; ***hotT*** is the temperature of the hot water outlet; ***cldT*** is the temperature of the cold water inlet to the HPWH system and ***huvT*** is the temperature of the logger which can be used as an approximate measure of ambient conditions close to the system.

Underneath the channel label 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 values in the ranges: equal to zero; greater than zero and less than 20; greater than 20; and finally the energy use (kWh) over a year (one average day x 365) is provided for electricity channels or the average temperature for temperature channels.

Each individual EDA graph contains three plots: a ***histogram,*** a ***time-series plot*** and a ***daily profile*** of the data recorded every six minutes.

The ***histogram*** shows how often the data was in a given range. The data range is given 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 (below the daily profile graph), and the data value 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, and 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 heavy blue straight horizontal line near the top of the time-series plot.

The third plot contains two separate plots. The plot shown in red is the average ***daily profile*** for the respective channel averaged over the complete set of data. The left of this profile is midnight and early morning, to midday in the middle and evening on the right hand side of the plot. The other plot is shown in black is a ***moving average*** of the data. This moving average plot uses the same time axis as for the second time-series plot which can be read from directly below the graph.

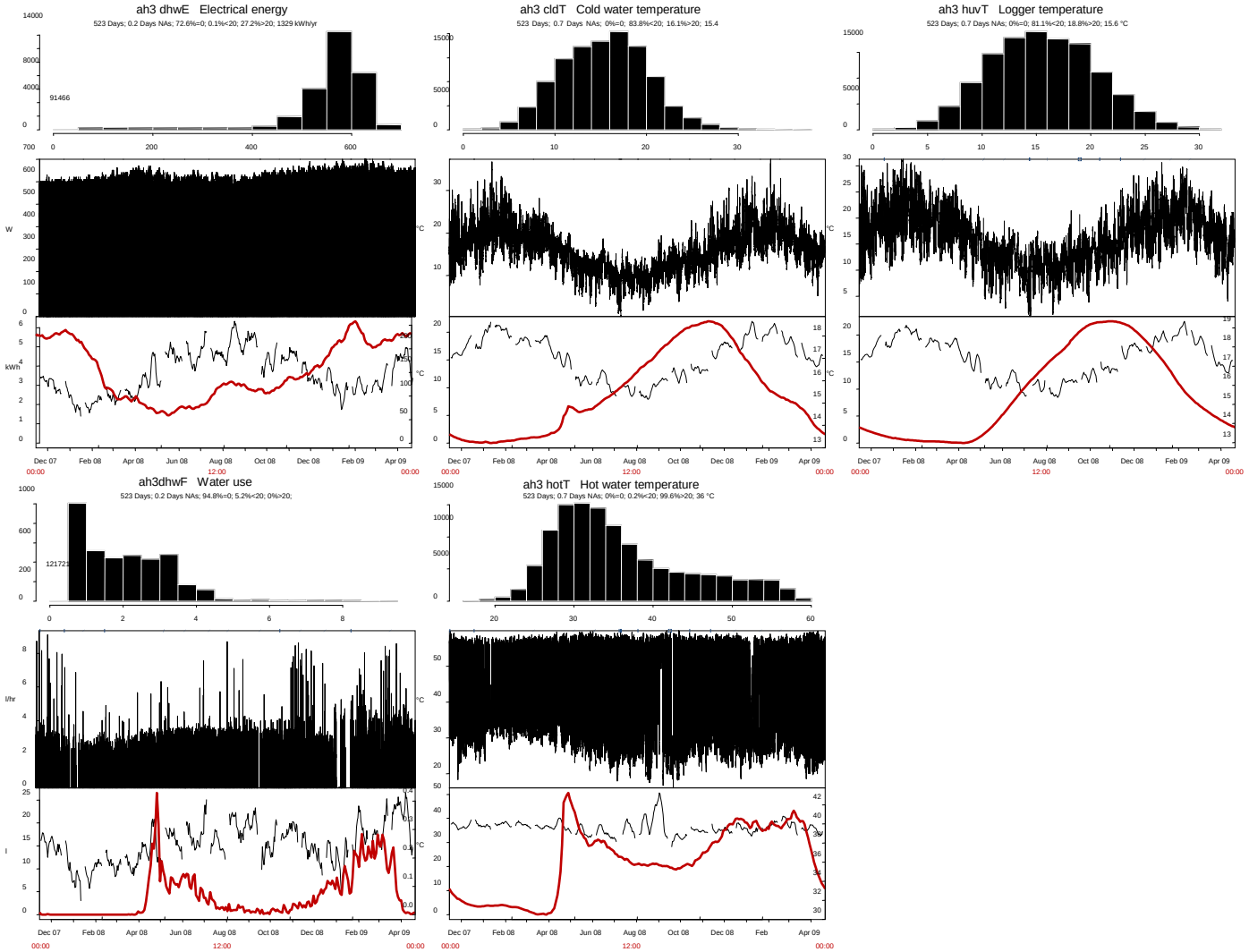


**Figure 3 EDA plots for the Auckland system**

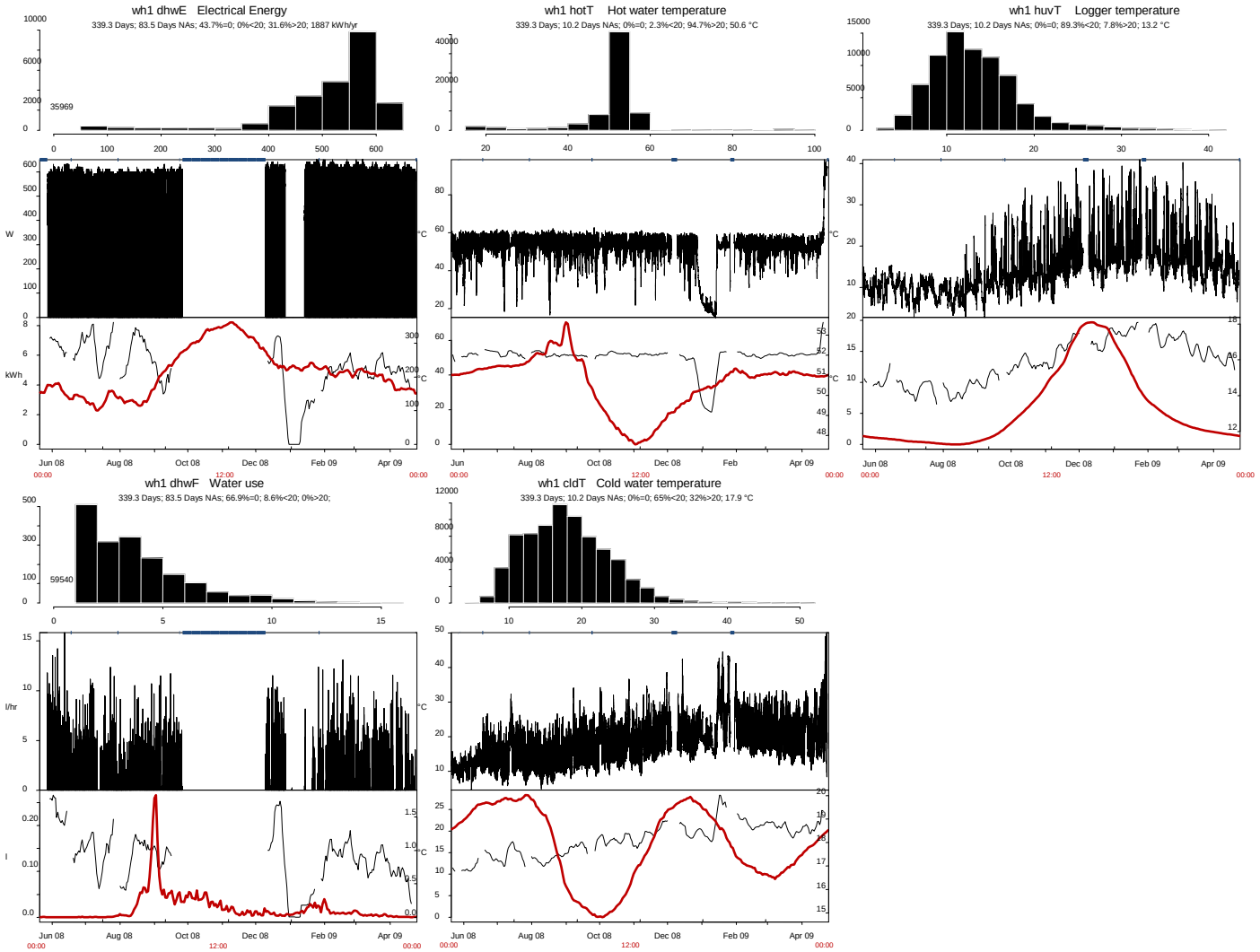


**Figure 4 EDA plots for the Wellington system**

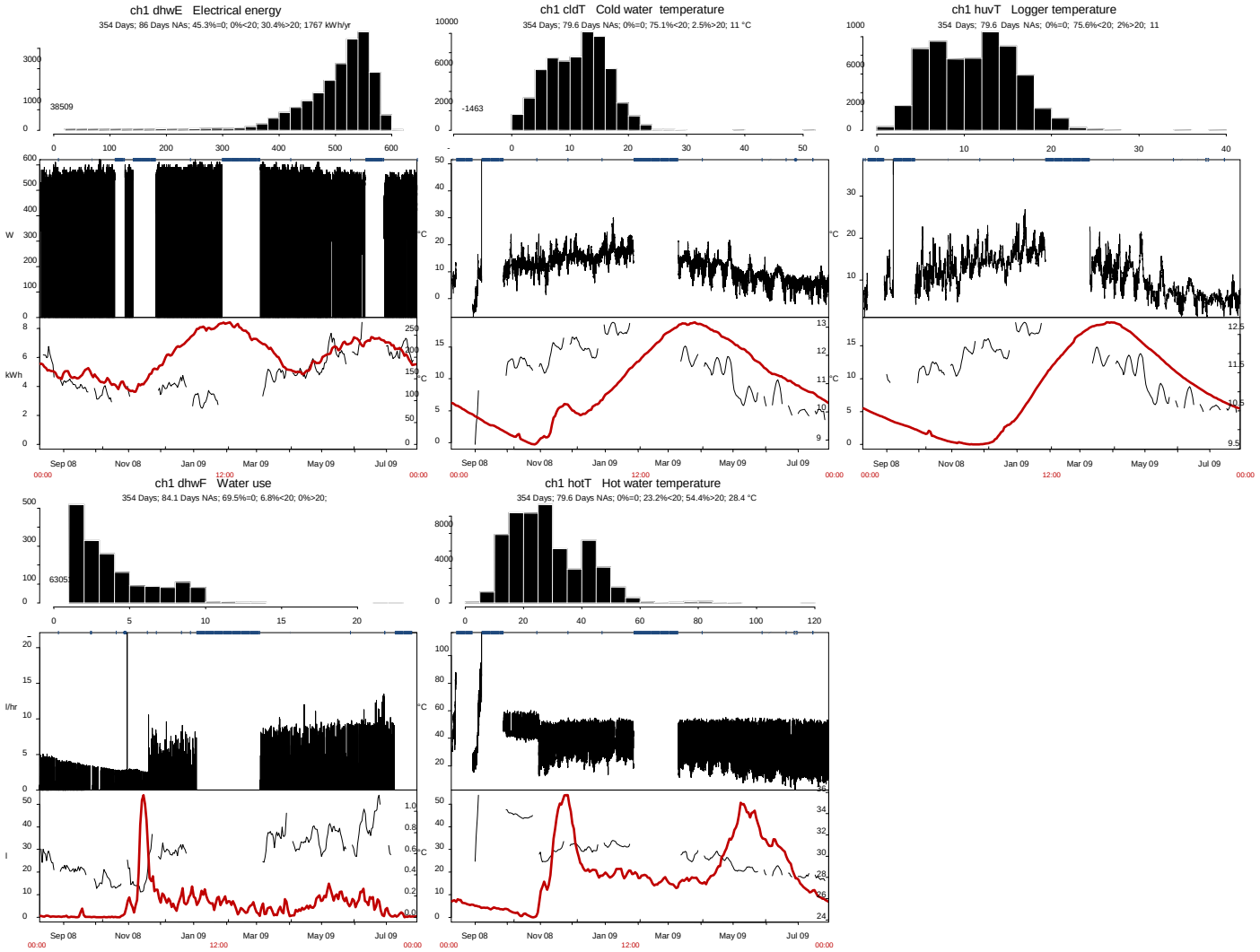


**Figure 5 EDA plots for the Christchurch system**