PRACTICAL CHALLENGES IN HIGH INTENSIVE DOMESTIC MONITORING

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ABSTRACT

This paper looks at the practical challenges of measuring Beacon Pathway's Waitakere NOW Home®, over its first year of operation. A number of methods to monitor the physical services of the home were developed and included measurements of utility and rain water usage, energy end-uses, solar hot water supply and use, temperature, humidity and other physical parameters to assess the sustainability of the home. The project involved monitoring design, set up, installation, background communications, computer programming, tenant coordination, ongoing trouble shooting, data cleaning, analysis, information sharing and write up. This paper provides an insight into the complexities and demands of monitoring a real building, tenanted with real people.

KEYWORDS:

Residential Buildings; Measuring Sustainability; Monitoring Methodologies, Now Home®.

INTRODUCTION

The Waitakere NOW Home® (shown in Figure 1) was developed by Beacon Pathway (www.beaconpathway.co.nz) as a research project designed to examine practical methods of improving the sustainability of an 'average' new home using affordable technologies that are readily available now. It is neither a social housing project nor simply a collection of expensive technologies. A second new NOW Home® has been constructed in Rotorua in 2006 by Housing New Zealand following a similar philosophy.

Figure 1 The Waitakere NOW Home®

The Waitakere NOW Home® is constructed using timber weatherboards, fixed to a timber frame on a heavily-insulated concrete slab. The roof is concrete tile, and the ceilings and walls are heavily insulated. The entire building is double glazed. A solar water heater is installed, and a water tank collects water run-off from the roof. The tank water is used for non-potable water needs within the house. Most light fittings are high-efficiency compact fluorescents. The majority of the appliances belong to the tenants, however the range, fridge, dishwasher and washing machine are new efficient items supplied as chattels. The building is sited to maximise the benefits of passive solar heating, using the highly insulated envelope to trap and retain the sun's warmth – mainly via the exposed (i.e. uncarpeted) concrete slab. Further details of the NOW Home® construction and design choices can be found on the website www.nowhome.co.nz

ASSESSING THE SUSTAINABILITY OF A HOME

"To bring the vast majority of New Zealand homes to a high standard of sustainability by 2012" (Beacon, 2007)

The options decided upon during any process will result in a range of environmental, social and economic outcomes. Sustainability generally refers to decisions that have a more favourable set of environmental, social and economic outcomes than other possible decisions. There are many decisions made in the design, construction and operation of a residential building. Many of the decisions made at the design and construction stages will have long term impacts on the sustainability outcomes, since houses are around for a long time.

A house that is poorly sited so that it can not make good use of free solar gains and which has only the minimum mandatory levels of insulation will require more resources (electricity, gas, wood, coal) to be consumed, at a greater financial cost (over the lifetime of the building) to achieve the occupants same comfort expectations through greater need for space heating than would be case for an extensively insulated house which is well positioned to make good use of solar gains.

As sustainability outcomes are multifaceted there is some subjectivity in assessing which outcomes are more favourable. For example, in the preceding space heating example, the timing of the financial impacts was not considered. While installing insulation saves money over the lifetime of the building, it has an immediate financial impact when the insulation is put in – people don't like to pay the upfront cost of the insulation. Another problem that may occur is when the costs and benefits are not shared evenly such as when the building is rented out when the occupants are required to deal with the consequences of the owners' decisions. The owners' would be less inclined to install insulation as they do not receive the direct benefit from the reduced space heating by the occupants.

There are many rating tools available to assist with the assessment of the sustainability of houses (Hargreaves, 2005). While building energy tools (for a listing see www.eere.energy.gov/buildings/tools_directory/) have been well established, building environmental assessment tools only began with the development of BREEAM in 1990 but have since become a popular means of assessing the sustainability of buildings (Cole, et al. 2005).

The BRANZ *Green Home Scheme* began in 1997 and is an assessment tool for the design of new residential buildings (Jaques, 2004). The Green Home scheme includes assessments of the energy use, water use, material selection and health effects of the building. The Green Home Scheme assessment of the Waitakere NOW Home® achieved 63 credits from a potential 115. This rating placed the Waitakere NOW Home® at the top end of the 'Good' category. This compares extremely well with the typical houses currently being built in the Auckland region which usually achieve around the 10 - 15 credit mark.

Many building environmental assessment tools assess the likelihood of design and construction decisions on the long term sustainability of a building but do not provide detailed validating information on how the building actually performs *in-situ*. Beacon has focussed its sustainability objectives in five key performance areas (Easton and Collins, 2007);

- Energy
- Water
- Indoor Environmental Quality
- Waste

- Materials

Beacon has been developing its ‘High Standard of Sustainability’ (Easton, 2006) which includes benchmarks in each of these areas and the performance of the NOW Home® will be assessed against these benchmarks.

MEASUREMENT PROGRAMMES

“Things that are measured tend to improve” J K Galbraith

Many research programmes have looked to measure aspects of sustainability in residential buildings and a variety of data collection processes have been used. The type of the data collection used is primarily driven by the objectives of the research.

Sustainability within the residential built environment can be examined by making a ***broad*** range of measurements within individual households or alternatively a smaller ***focused*** set of features can be measured from a larger set of houses.

New Zealand residential energy end-use information has improved dramatically over the last ten years thanks largely to the data and analysis from the Household Energy End-use Project (HEEP) (Isaacs, et al. 2006). HEEP has collected focused data on the energy end-uses and resulting space temperatures from approximately 400 houses throughout the country. Each house was also subject to an extensive survey that included socio-demographic and behavioural questions.

Another example of a focused measurement programme is the Water End Use and Efficiency Project (WEEP) (Heinrich, 2007) which is looking to improve the understanding of residential water consumption in New Zealand.

While there have been few New Zealand examples of broad sustainable monitoring within individual households, there have been a number of overseas projects undertaking this sort of work. Two recent projects in Australia which have involved a high degree of monitoring are the Queensland government’s research house (Department of Housing, 2006) and the ‘No-Bills’ house in Tasmania (Dewsbury, 2005). In the USA, the Department of Energy’s Building America programme has undertaken a number of case studies on zero energy houses, an example of which is Norton (2005).

The behaviour of the building’s occupants is a crucial factor in the overall environmental performance. The Waitakere NOW Home® has been occupied by a two adult, two child family since the house was completed in September 2005. The performance of the home will be monitored over the construction and first two years of occupancy. Over this two year period, measurements will be undertaken on the building performance and information collected about the building and its occupants.

The occupancy survey undertaken was built upon the findings of the Queensland Research House (Buys et al. 2005) and looked to employ a minimally intrusive quarterly survey. The survey looks to examine the occupants’ experiences with the Waitakere NOW Home® using social systems-based ‘differences and effects’ based-questions which involved questions comparing the occupants’ impressions of the Waitakere NOW Home® with their previous home. After one year of asking such comparison questions the surveys began to produce similar responses and were discontinued. In order to support the monitoring a modified HEEP survey was conducted in the house to provide background behavioural information.

The gold standard in monitoring is measuring a broad range of parameters using short collection intervals (many readings per day) over an extended duration. This type of measurement produces a rich dataset which can be analysed in many different ways. While it is relatively easy to aggregate data from smaller time intervals and separate energy end-uses into broad (say monthly) averages, it is a much more difficult task to infer what is happening between the individual time records such as determining time of day information or component energy end-use information from aggregated monthly meter readings. As commented by Stoops (1998); *"it is easier to recover from bad analysis than from bad data"*.

DAQ and Data Logger Systems

The manner in which you collect the data is important. Other data measurement programmes undertaken by BRANZ, such as HEEP and WEEP, have collected the data from each of the sites by using small self-contained data-loggers. In order to monitor a large number of sites, BRANZ developed a range of low cost data-loggers, though similar loggers are available commercially (for example, the Hobo range; www.onsetcomp.com). Another method of data collection, and the one used for the NOW Home®, is to have an on-site data acquisition (DAQ) system which is capable of transferring data (via a modem) from the site back to the location where the data is to be stored and analysed (BRANZ in the case of the Waitakere NOW Home®).

An important reason for using a DAQ system instead of a data logger system in the Waitakere NOW Home® is that a DAQ system is less intrusive on the occupants. The capacity of the loggers used in HEEP was generally about 40 days and visits to each of the sites were arranged each month. As the loggers had to be located within particular rooms or connected to particular appliances or heaters, in order to collect the data from the loggers it was necessary to arrange access throughout each of the houses at each visit.

While the people in the HEEP study were generally happy to allow monthly access to their houses, towards the end of the 11-12 months monitoring period the occupants became increasingly restless with the study and frequently asked when the study would be concluding. Another possible reason for their restlessness was that no feedback was provided to the occupants until after the measurements were complete in order to minimise the likelihood of the occupants changing their behaviour in light of the results.

As the monitoring period for the Waitakere NOW Home® was set as two years, the use of monthly downloading was thought to be overly demanding and contact with the occupants would be limited to the quarterly surveys. However, in reality, visits to the house to attend to bugs in the system meant there have been a significant number of visits. In this case the extra visits seemed to have minimal impact on the occupants. It is essential to have good communication with the occupants to assist with a speedy response when 'things go wrong'.

Conversely one advantage of making regular download visits, as required with a data logger system, is that it allows regular contact with the occupants so that modifications can be made to the equipment set-up such as changing which appliances are being monitored.

Another advantage for using a DAQ system over a data logger system is that the data from a DAQ system is received all at the same time. A data logger system requires each logger to be individually offloaded with the data stored as a separate file. Many files would need to be merged together to view all of the information about the house at any one point in time. Each of the separate loggers would need to be separately configured with each logger having a separate clock.

Ensuring the quality of data within a measurement programme is an important issue and there are important differences between a DAQ system and a data logger system. The timing of when data is transferred from a modem enabled DAQ system is more flexible than for a data logger based system. For the Waitakere NOW Home® the DAQ system is set to email the previous day's data back to BRANZ at 3am each morning. An advantage of this method is that its can speed up identifying problems with the data and equipment. With a data logger system, if a logger is mis-configured or develops a flat battery or other such problem then this will not be identified until at least when the download person next visits the house.

The DAQ system in the Waitakere NOW Home® was located (see the floor plan in Figure 2) under a shelf in the hot water cupboard as it provided for a centralised location and did not take away space from the occupants (the hot water cylinder in this cupboard was installed on a shelf and the DAQ equipment was located on a trolley below this). In order to assess the computer, it was however necessary to gain full access to the house. The DAQ system also generated a large amount of localised heating as did the adjacent hot water cylinder. This caused the ambient temperature in the cupboard to be quite high which caused the ADSL modem (also located in the cupboard) to frequently lock-up. Learning from this, the equipment for the Rotorua NOW Home® was located in a full-height dedicated cupboard located in a corner of the attached garage, which (so far) seems to be a significant improvement over the Waitakere NOW Home®.

In comparing a DAQ system with a data logger system it is also important to consider the number of measurement required. Data loggers frequently provide only 1-4 channels of data and can be purchased at a modest cost. A DAQ system can provide a large number of channels of data but the cost of the system is usually higher. As the number of channels increase DAQ systems usually become better value (cost per channel of data) than data logger systems.

A DAQ system, with a high degree of processing power (these systems frequently include a computer), can have the potential to provide instantaneous feedback to the occupants of how the house is performing. The Waitakere NOW Home® DAQ system includes a Windows based computer and has the potential to include a degree of user feedback. However, after experiencing early teething problems with the data collection software, it was decided not to make further modifications to ensure that the data collection is not interrupted. Establishing what information and what additional processing of the data collected would be required, would also be a large but very useful task. Further work needs to be undertaken in this area. Some user feedback has be provided for the second year of the Waitakere NOW Home® with the installation of a remote power meter (a centameter, see www.centameter.co.nz)

Sensors used

Measurements for the Waitakere NOW Home® include dynamic physical measurements of resource use (electricity and water use), environmental factors affecting the house (outdoor temperature, humidity and solar radiation), the use of services within the house (for example, the use of lights, hot water for showering, or use of the dishwasher) as well as the resulting environment within the house (room temperature and humidity, family room CO_2 levels).

The equipment used to monitor the Waitakere NOW Home® was chosen as a collection of innovative and practical technologies. The design of a DAQ system needs to consider what sensors are used to collect the information of interest.

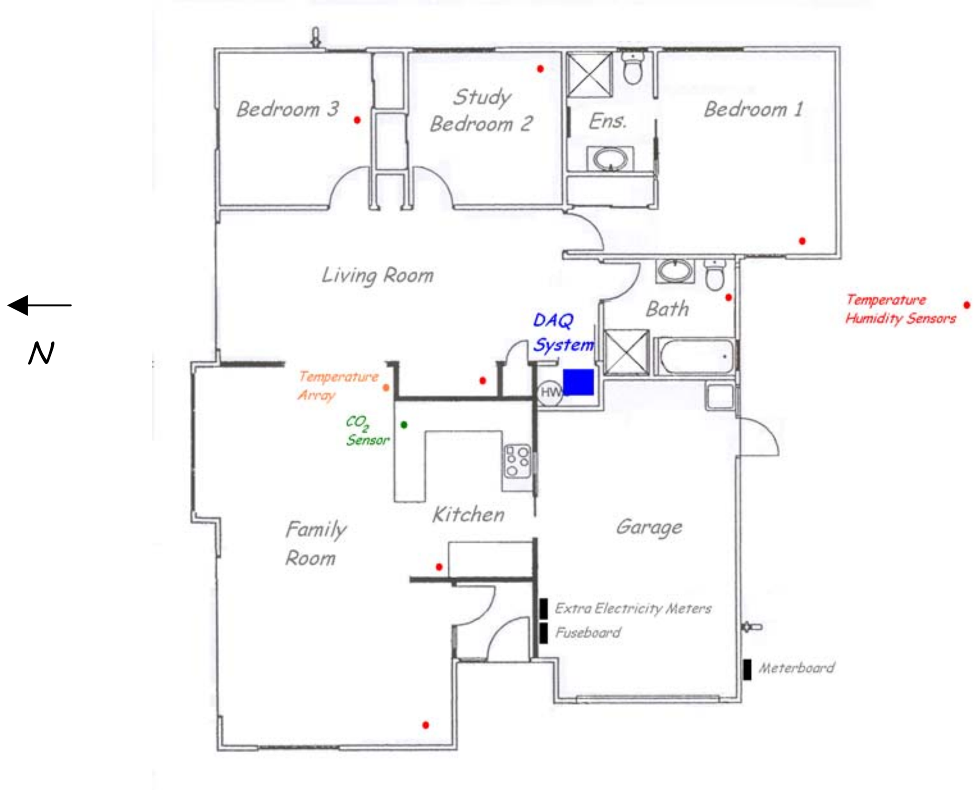

Figure 2 Floor plan of the Waitakere NOW Home® (North is to the left) showing monitoring equipment locations

The sensors have been chosen to have as minimal impact on the occupants as possible, for example a number of temperature/humidity sensors are used to measure the conditions within each of the spaces within the house. These sensors use radio communications back to the DAQ system allowing the sensors can be placed anywhere with the room rather than being constrained by the need to run wire from the sensors back to the DAQ system.

It was decided to collect end use information for both the electricity and water use. A practical low costs solution to measuring the electrical energy consumption is to make use of mass produced electronic electricity tariff meters, the type which are frequently used by electricity supply companies to meter residential electrical usage. These meters directly measure the electrical energy consumption of a connected load and usually provide a pulsed output. This approach has been used successfully in the HEEP study and the Waitakere NOW Home® makes use of the same type of meters; the Siemens S2AS meter which produces one pulse for every one Watthour of electrical energy consumption.

A second meterboard was installed in the garage alongside the fuseboard to allow electricity meters to be installed for the electrical circuits of interest. Circuits monitored were; the range, the lighting, the refrigerator, the dishwasher, the rainwater tank pump, and the solar water heater pump. Electrical meters for the total electricity used for the household and for the solar water heater booster element were measured from additional meters installed on the meterboard on the south side of the garage.

The measurement of the electrical energy consumption of individual appliances also makes use of the Siemens S2AS meters. In this case, the meters are housed inside small electrical enclosure boxes (120 mm × 120 mm × 70 mm) with a standard socket and plug connected to the appliance and a standard electrical outlet. The pulsed output of the Siemens meter is connected to a radio pulse transmitter which transfers the information from the meter back to the DAQ system. Initially three appliance metering systems were used. These were connected to the DAQ system, the washing machine (to allow for the water use of the washing machine and laundry tub to be distinguished) and a portable electric heater (which didn't receive any usage). Modifications to the DAQ system software have been made to allow for additional appliances to be metered with more appliance metering systems.

Residential water meters are also a mass produced item and as such can be quite inexpensive. The Waitakere NOW Home® makes use of the Kent PSM-T water meters (http://www.elstermetering.com/en/1242.shtml) which have also been used by many city councils to meter residential water consumption at each property. Like the S2AS electricity meters, these meters have a pulsed output for each incremental unit of consumption. For the Kent PSM-T meters, 2 pulses are produced for each litre of water passed through the meter.

The original experimental design for the Waitakere NOW Home® was to meter the total water use for the house, the rainwater use and the hot water use only however as the Waitakere NOW Home® DAQ system included a 32 channel digital (pulse) input card there were sufficient pulse inputs available to meter each of the 24 individual water end-uses within the Waitakere NOW Home®.

As the water meters need to be placed inline with what is being measured there is a degree of effort to fit these meters. Retrofitting water meters to an existing setup would require water meters to be placed in particular locations depending on the existing pipe-work which itself may require modifying. As the Waitakere NOW Home® was being constructed, there was the opportunity to install the water meters as the pipe-work for each water end-use was being installed. This allowed some degree of flexibility as to where to place the meters with the majority of the water meters being placed in the roofspace.

Since the installation of the water meters in the Waitakere NOW Home®, BRANZ has commenced a study to examine residential water use; WEEP (Heinrich, 2007). The methodology used in WEEP is to measure the total water flow into the property using a high resolution (34.2 pulses per litre) water meter (the MES-MR from ManuFlo; see http://www.manuelectronics.com.au/pdfs/MESMR.pdf) at a short collection interval (10 seconds). Disaggregation software, Trace Wizard (Heinrich, 2006), is then used to infer which water uses are being used. The availability of this software has meant that the water metering design for the second NOW Home®, the Rotorua NOW Home®, made use of this setup, installing three MES-MR meters (one of the water taken from the street main, one for the water from the raintank and one for the solar water heater) and incorporating 10 second monitoring for these three channels. These modifications significantly reduced the number of water meters that were needed and the number of pulse input channels required.

The measurement of Indoor Environmental Quality (IEQ) is a difficult task. There are many constituents of IEQ, however IPMVP (2001) identifies three important parameters; thermal comfort, lighting levels, and indoor pollutants.

The two most important contributors to indoor thermal comfort are air temperature and humidity. As mentioned earlier the temperature and humidity's throughout the Waitakere NOW Home® were measured with combined radio temperature/humidity sensors from Point Six Wireless (www.pointsix.com) and the location of the seven sensors can be seen in Figure 2. While the accuracy of the Point Six sensors is less than other sensors (±0.5°C for temperature and ±5% for humidity) the ease of placement, compact size, low cost and ease of integration in the system out-weighted the loss in accuracy. Many studies only look at temperatures and humidity's over a short time period. The Waitakere NOW Home® monitoring provides long term seasonal data on these variables.

While lighting levels are important in commercial buildings, these are less so in residential buildings. Actions in the Waitakere NOW Home® for lighting include design guidance, the use of a solar tube in the kitchen, the use of energy efficient compact fluorescent and the monitoring of total lighting needs for the building. No ongoing measurements of lighting levels were undertaken.

There are a number of indoor pollutants such as CO_2, CO, NO_x, VOCs, ozone, radon, particulates, bioaerosols, fibers and tobacco products. Carbon Dioxide (CO_2) is one source of human bioeffluents. As there are no combustion appliances in the Waitakere NOW Home® and the occupants do not smoke, the indoor CO_2 will largely be due to the exhaled air of the occupants. The indoor CO_2 levels were measured in the main living room with a hand-held dual beam infrared absorption meter, a Telaire 7001 (www.telaire.com/pdf/datasheets/telaire7001.pdf). Battery life for this meter was only 80 hours so the unit was operated from a small transformer. The unit provided a voltage output proportional to the CO_2 concentration and this again was transferred to the DAQ system with the use of a Point Six voltage radio sensor.

Measurements were made on the external conditions; the outdoor temperature (thermistor) and humidity (humidity probe) and the global horizontal solar radiation were recorded. These sensors were wired back to the DAQ system along with the other sensor located outside, which was the raintank water level sensor

In order to access the performance of the solar water heater a number of inlet and outlet water temperatures were measured in addition to the water flow in the hot water cylinder, the heating within the cylinder and the electricity used to pump fluid to the roof panel. These water temperatures were measured by attaching T-type thermocouple junctions to the copper pipes. An aluminium block was used as a reference junction, the temperature of which was measured with a thermistor. The Seeback voltage of the thermocouple was measured directly by the DAQ system.

The security system was upgraded to include a number of additional motion sensors so that there were motion sensors in each of the bedrooms and a number in the living spaces. The motion sensors produce an instantaneous voltage when motion is detected. In discussions with the security system providers, it was believed that the output of each sensor could be latched for one minute so that motion could be detected using a one minute data collection interval. As it turned out the motion sensors could only be latched for ten seconds so that only a probabilistic analysis could be applied to the data from the motion sensors.

Data from Sensors

The nature of the data from the sensors in the Waitakere NOW Home® comprises;

- Radio data from Temperature/Humidity sensors
- Radio data from pulse sensors (appliance electricity usage measurements)
- Radio data from voltage sensors (for example the CO_2 sensor)
- Wired pulse data from electricity circuits and water meter end-uses
- Wired voltage data from thermocouples, humidity probes, pyranometers, motion sensors, etc.
- Wired resistance data from thermistors,
- Wired current data from the raintank water level sensor

The Waitakere NOW Home® DAQ system incorporated a Windows-based computer with an ADSL modem so that the radio data from the Point Six sensors could be received by a radio receiver connected to the serial port of the computer. The Point Six sensors need to be polled frequently by the host computer so that data is not lost. Thus, the time interval for the Waitakere NOW Home® data collection was set to one minute. The performance of the Point Six sensors was unknown before their use in the Waitakere NOW Home® but has proven to be a very effective technology. The Rotorua NOW Home® has made more extensive use of this technology with its DAQ largely being based around the Point Six sensors. The only additional item in the Rotorua NOW Home® is a 4-channel thermocouple sensor (a NI USB-9211 http://sine.ni.com/nips/cds/view/p/lang/en/nid/13880 from National Instruments) which is used to collect water temperature measurements of the solar water heater using thermocouples. The Point Six sensors do include a thermistor sensor so the water temperature measurements could be measured with thermistors instead of thermocouples to allow for a dedicated Point Six sensor system to further simply the monitoring system.

The nature of the wired data is varied. BRANZ has previously made use of Agilent 34970A data acquisition units for the measurement of experiments on the BRANZ site (recording thermocouples, voltages, resistances and currents) however these units have lacked digital cards making monitoring pulse data impractical. The Agilent 34980A Data Logger (www.home.agilent.com/agilent/product.jspx?cc=US&lc=eng&pageMode=OV&pid=429828&ct=PRODUCT&id=429828) was a brand new, more versatile data acquisition unit that in addition to accepting analog cards that is capable of measuring thermocouples, voltages, resistances and currents, can also take digital cards that are capable of dealing with the pulse data inputs.

The cabling from the wired sensors were fed straight into the appropriate inputs on the analog/digital cards on the back of the Agilent 34980A. This required careful cable identification and extended time on-site wiring the connections up. In hindsight the cabling from the sensors could have been terminated at a junction box which could then be connected to the Agilent via some defined connection arrangement.

A LabVIEW (www.ni.com/labview/) program was developed to be run on the Waitakere NOW Home® computer to retrieve the data from the Agilent unit and the radio receiver. This LabVIEW program required low level programming of the pulse data as the digital card was designed to examine hi-speed digital data not the low speed pulse data the electricity and water meters produced. This one minute data was compiled into daily text files and emailed back to BRANZ on a daily basis via an internet connection over an ADSL line.

The DAQ system described above was not assembled and tested as a whole prior to the installation of the equipment within the house. This was due to the very new Agilent logger, which almost went straight from the manufacturer into the house. Setup and testing had been done with an early production unit on loan from the agent, which was very slightly different from the production model actually used. The other sensors used, the Point 6 radio sensors, had to be custom modified for New Zealand radio frequencies; this delayed the delivery of the equipment again eliminating any time for pre-testing before being put to use in the Waitakere NOW Home®.

The DAQ system had some teething troubles, initially centred around persistent power outages. These were cured by installing an uninterruptible power supply and modifications to the computer restart settings. Later there were some non-readings of pulse data. This fault was difficult to locate and a number of site visits to address wiring and equipment configurations as well as modifications to the LabVIEW program were required. Another fault in the setup was due to the electrician not wiring the hot water booster element into the correct meter. This fault was not initially picked up as zero boosting over summer was not unexpected (there were some initial readings giving the false impression that the system was working) however once the zeros continued into winter further investigation identified the fault.

DATA PROCESSING AND STRUCTURES

The quantity of the data from the Waitakere NOW Home® is large. Each day the approximately 80 channels of data collected at one minute intervals result in over 100,000 data points per day.

The management of such as large dataset has been challenging. Initially the one minute data was directly loaded into S-PLUS, a statistical analysis environment (http://www.insightful.com/), however after two months of data collection, the data object in S-PLUS become too large and stopped functioning. The one-minute data was instead loaded into a Microsoft Access database which could then pass data through to S-PLUS in a summary (query-based) form (selecting only the relevant channels for analysis). Again the large volume of data placed a strain on the software and after about ten months data collection, when the Access database was about 820 Mb and 35 million records long this system also stopped working.

Rather than working with raw one-minute data, the data was processed into ten-minute blocks before being stored. Converting the data into ten-minute blocks requires different treatment of data depending on whether the measurements are instantaneous (such as temperature or humidity measurements) or integrating (such as the pulse measurements or the solar radiation measurements). The data also need to be transformed from the measurements recorded by the Agilent or Point Six units into physically meaningful data, for example the thermistor resistances are translated thorough a calibration equation into a measurement of temperature whereas the thermocouple voltages required a different algorithm to calculate the thermocouple junction temperatures.

S-PLUS based HEEP tools were modified to allow the Waitakere NOW Home® data to be checked using the exploratory data analysis (EDA) graphs developed within HEEP. These type of graphs allow an extensive amount of data to be quickly examined and make working with large database

As the monitored data is static once collected, analytical processing (OLAP) may have an advantage over transactional processing (OLTP) and multiple indexing of Waitakere NOW Home® data within S-PLUS would be an advantage. In order that the data objects within S-PLUS manageable the Waitakere NOW Home® data was broken down into functional areas such as electricity, water, IEQ and solar water heating for separate analysis.

CONCLUSION

The Waitakere NOW Home® has been instrumented to provide information on how well the building and its occupants are performing from a sustainability sense and in particular the energy and water use and the indoor environmental quality (IEQ). A number of key learning's have been made along the way as to how to develop and operate a successful data collection programme.

The extent of the monitoring is an important first consideration. The Waitakere NOW Home® has looked to include many interesting and varied measurements, which has required costly equipment. The use of the Point Six radio sensors in the Waitakere NOW Home® has been particularly successful. These sensors provide an easy method to undertake a smaller number of measurements throughout a house while still maintaining a centralised data collection point. With the desire to measure more houses at lower cost, the greater use of wireless technologies, such as the Point Six sensors, is likely to occur.

The data collection equipment needs to be readily assessable for maintenance and regular visits. It is preferable to locate any regularly accessed equipment (such as a data collection computer) in areas that can be visited without gaining access to the main living areas of the house.

Once the monitoring equipment has been installed within the house it is beneficial to have an unoccupied period in which the equipment can be fully tested and problems sorted out.

As with any residential project there are have been a number of unexpected challenges with collecting data. Dealing with these challenges has required an increased number of visits to the site, which has been assisted by the friendly and obliging attitude of the occupants.

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