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ABSTRACT

Energy end use in residential buildings is a function of two parameter groups: physical factors (building characteristics, appliances, local climate, etc) and socio-demographic factors (household composition, income level, etc, as well as occupant behaviour). In 1995 the Building Research Association of New Zealand (BRANZ) and several other partners commenced the Household Energy End-use Project (HEEP) with a long term objective of developing a generalised national model of energy end-uses in houses. To maximise cost-benefits of this commercial and government funded study, energy and indoor climate data are collected at different levels of detail for different sample sizes. So far, 28 houses in one city have been logged for their electric and solid fuel consumption, and detailed indoor air temperature measurements taken. Energy and temperature data are recorded with fifteen minute resolution for half a year each. Appliance and heater energy use shows some unexpected results, although initial correlations are limited due to the currently small sample size. The paper discusses the tools and monitoring techniques as well as initial findings and their potential applications.

Keywords: energy end-uses, end-use metering and monitoring, socioeconomic factors, thermal comfort

Introduction

The last major New Zealand investigation on energy use in houses was conducted by the New Zealand Electricity Department and the Department of Statistics (New Zealand Department of Statistics, 1973). Since then new technologies have found widespread acceptance, and the living patterns and socio-demographic composition of the population have drastically changed. It would be expected that these would have had a major impact on energy consumption, but no reliable information was available.

The Household Energy End-use Project (HEEP) was established in late 1995 by a group of funding and research organizations as a long-term research activity to create a scientifically and technically rigorous, up-to-date public knowledge base of energy use and end-uses, energy services provision and key occupant, building and appliance determinants in residential buildings.

The project started with a pre-pilot in one city followed by pilot phases in two cities, and is now set to expand to other locations. This paper discusses the research approach and preliminary findings on total energy consumption, heating demand, human impact on energy consumption, specific findings on end-uses and the temperature distributions within and between houses. The published reports (Stoecklein et al. 1997a, 1997b) provide more detailed discussion.

The application of both the collected information and the future household energy model will be widespread with significant impact on the New Zealand energy industry and wider economy.

Potential users are government agencies, utilities and appliance manufacturers. Energy consultants will find the results of interest for advising their clients on energy use. This information will support legislative changes, setting of standards, demand-side management projects and other targeted energy efficiency measures by industry and government. This wide spectrum of potential application is reflected in the range of participating and funding organizations which currently include government agencies, research organizations, utilities, appliance companies and the national transmission company.

Monitoring

Energy end use in residential buildings is a function of two parameter groups: physical factors (building characteristics, appliances, local climate, etc) and socio-demographic factors (household composition, income level, etc) (Sonderegger 1978).

Data collection and the development of analysis methods has been the focus of the first two years work on the Household Energy End use Project (HEEP). This has involved the development of measurement protocols for energy, temperatures, house construction and occupant behaviour and attitudes. The collection of data has been done in blocks, with the first block of BRANZ monitoring in Wanganui (~1000 Degree Days base 15ºC) from April 1996 to July 1996 for Houses 1 - 5, the second from July 1996 to November 1996 for Houses 6 - 10, the third from February 1997 to July 1997 for Houses 11 - 18 and the fourth from July 1997 to January 1998 for Houses 19 - 29. These periods include approximately half a winter and half a summer period and can therefore be extended to cover annually representative seasons

To date electricity is the main fuel type being monitored. This is being done over a wide range of end uses. All of the houses use electricity for heating, none for cooling. Seven houses have also been monitored for solid fuel use (coal and wood), and two for natural gas use, again with the objective of developing monitoring and analysis protocols. All end uses which are analysed in this paper are electric, particularly all water heating and cooking. The only exception are above mentioned houses in which space heating is supplemented by other fuel types. Table 1 shows the national saturation of electric end uses, the saturation in the HEEP houses and the average number of actually monitored electric end uses per household in the HEEP sample.

Table 1: The national saturation of end uses, the saturation in the HEEP houses and the end use which were monitored in the HEEP houses.

Saturation Levels	Electr. Heater (total)	Night Store Heater	Air Conditioner	DHW	Electric Blanket	Washing Machine	Dryer	Fridge	Freezer	Fridge/Freezer	Microwave	Electric Range	Electric Kettle	Toaster	Dishwasher	TV	Computer	Waterbed	Dehumidifier
National	0.70	0.09	0.03	0.93	1.10	0.97	0.65	0.28	0.55	0.80	0.77	0.90	0.90	0.90	0.31	1.06	0.23	0.20	0.03
HEEP	2.18	0.39	0.14	1.04	0.68	1.04	0.61	0.39	0.86	0.75	0.86	1.00	0.96	0.96	0.25	2.25	0.64	0.07	0.04
HEEP monitored.	1.34	0.10	0.07	1.00	0.00	0.86	0.41	0.39	0.55	0.55	0.41	0.83	0.21	0.10	0.07	0.48	0.14	0.07	0.04

The following information has been collected at the stated time resolution and logging period:

- **Energy:** 15 minute resolution for a period of five months:
  Total energy and end uses as indicated in Table 1
- **Temperatures:** 15 minute resolution for a period of five months:
  Internal - 2 to 10 points around the house; external - 1 point
- **Climate data:** 1 hour resolution:
  Solar radiation, wind speed, rain fall, temperature, ground temperature
- **Surveys:** Building thermal performance; appliance numbers, types and usage;
  household demographic characteristics; household occupant attitudes and behaviours

Climate data is extracted from the National Climate Database (CLIDB), maintained by the National Institute for Water and Atmospheric Research Ltd (NIWA) (Penney 1997).

Industrial Research Limited (IRL) data collection in Christchurch (~1500 DD_{15}) has focused on the continuous monitoring of energy consumption at both electricity circuit and whole house level, with circuit level information collected on a set of 8 to 15 houses since 1994.

Daily Electrical Energy Consumption

The total energy consumption is measured along with the energy consumption at end use level at 15 minute resolution in each of the houses logged. The distribution of the daily energy demand for each Wanganui house is shown in the box and whisker plot in Figure 1. The large variations shown could not be explained by the splitting of the data into weekdays and non-weekday groups, or by the number of occupants in each house alone. This emphasises the fact that energy use is dependant on many factors, so only looking at one or two factors may not describe variation seen in the total energy use. In order for this data to assist in activities to modify energy consumption, it is important to identify the most influential factors on the household energy consumption. Analysis of earlier Christchurch data has indicated that the important factors include house size and physical characteristics, income and other social factors (Fitzgerald & Ryan 1996).

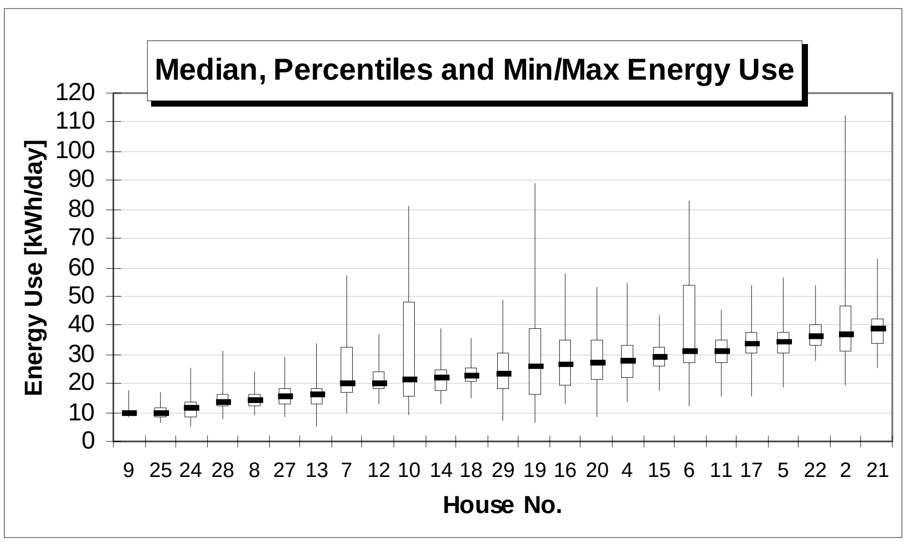

Figure 1: Wanganui houses – Total electricity use daily variation

Preliminary statistical analysis found that 71% of the variation in the total electric energy consumption (correlation of 0.84) can be ascribed through multiple regression of five of the surveyed factors: number of occupants in the household; whether or not the hot water cylinder is wrapped with an insulating blanket; the number of fluorescent and incandescent lights; and the level of household income. Correlations with other monitored data (i.e. indoor temperatures) proves to be weak which is probably due to the small current data set.

Further comparison, at end use level has been made between the Wanganui (~1000 DD_{15})and Christchurch (~1500 DD_{15}) data. In Christchurch, within the total consumption, the end-uses are measured at circuit level in the categories: DHW (domestic hot water); cooking (including range or hobs and oven); heating; washing (including dryer); lighting and other. In Wanganui many end-uses were measured separately. In order to compare the data with the Christchurch results some had to be aggregated into broader categories. Comparison across the two data sets highlighted the fact that the three houses with the largest electricity heating use have night store heaters (storage heaters under a controlled, lower cost night-time tariff), suggesting such heaters do not "save" energy, although this is in comparison to the low levels of heating in other houses. It was also found that the consumption of energy for cooking and lighting is higher in Christchurch than in Wanganui, potentially due to social and climatic factors.

Peak Load Analysis

An understanding of the individual contributions to the peak power use is of considerable value to energy suppliers as it enables the development of demand profile charging, if time based metering is not to be used, as well as identification of the potential for demand load shifting. Although national load patterns in New Zealand don't show a consistent time of day for peaks to occur, this seems to be a function of the combination of different consumer classes. Understanding the residential consumer class offers an opportunity to target specific demands which may have a disproportionate impact on the overall distribution network. For the initial analysis, the threshold for peaks was defined at the energy level which gives on average a 5 hour peak per day independent of

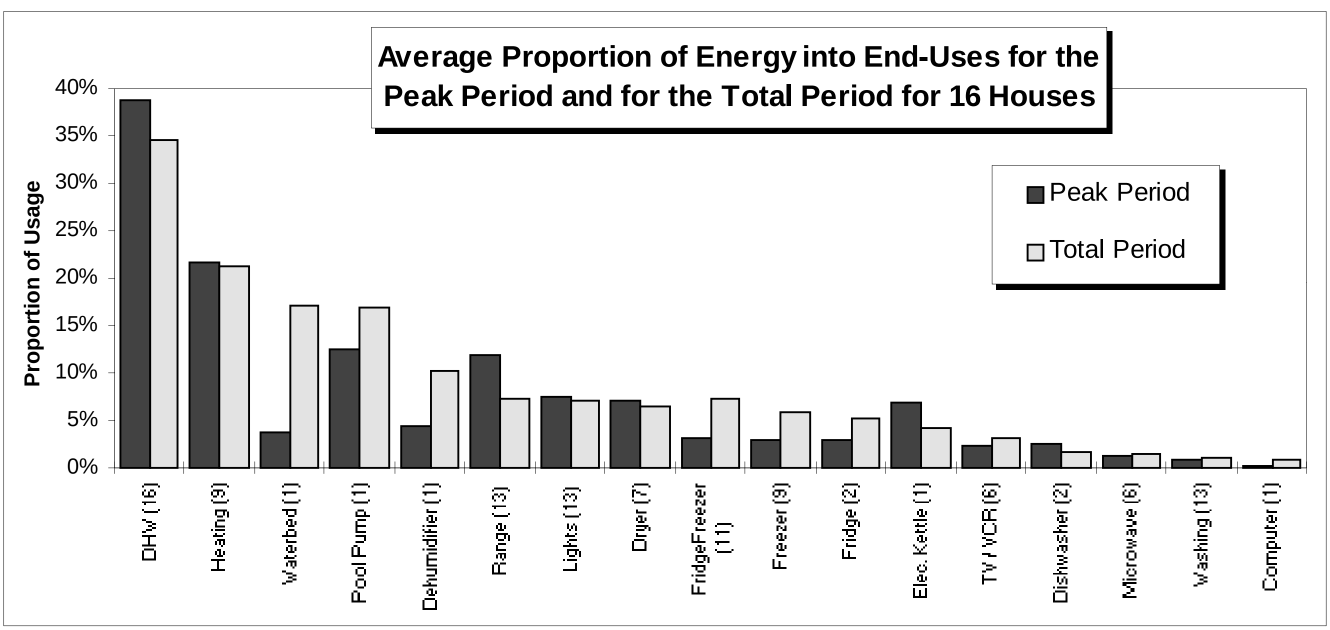

Figure 2: End-use contribution to the peak demand. Number of monitored houses in brackets.

what time of day the

peak occurred. Using this approach the frequency distribution of the peak times looks similar to the average total load profile of the household, i.e. if the average load in the household is high during the early evening hours then also the frequency of peak occurrence during this time is high. These peak times often did not concur with the predefined peak time periods used by utilities to define their various tariff levels.

Peak usage for 16 houses was examined by comparing the proportion that various end-uses contributed to energy used during the peak period with the energy used over the entire day. Figure 2 displays these proportions averaged across all the houses. Note that not all of the end-uses were measured for each house. Comparing the proportion of energy usage for the peak period with the entire day shows whether the end-use is a more or less important contribution to the peak load. End-uses like DHW, where the peak contribution is higher than the contribution for the entire day, play a bigger role in the peak. End-uses such as refrigerators, which have a smaller peak contribution than for the entire day, play a lesser role in peak consumption.

The highest peak contribution was found to be domestic hot water and heating but they also have the biggest variation between houses. Moderate, but more consistent peak contributions were made by refrigeration, TV and lighting. Moderate contributions were made to the peak by electric ranges and dryers but this time with larger variation seen between the households. Sizable peak contributions were made by specialised end-uses such as pool pumps and electric kettles however only one of each appliance was measured.

A shift in demand is possible for some of the end-uses that contribute to the peak, in particular domestic hot water and dryers. DHW is frequently under “Ripple control” which is power company controlled switching of the appliance. The contribution of dryers to the peak load could be reduced with the use of time delay switches or connection to night-switched supply.

Specific End Use Analysis

Domestic Hot Water (DHW) Analysis

Standing Losses: The majority of New Zealand houses use electric storage hot water heaters under “ripple control”. DHW electricity consumption is, on average, the second largest household energy end-use consumption after space-heating. The energy is used to both maintain the storage temperature (“stand-by losses”) and to replace hot water after draw-off (“consumed energy”).

The standing loss energy has been calculated using the following process:

1. An exploratory analysis of the hot water profile for each house found the times when no hot water was drawn by the users;
2. The hot water energy usage over this time period was averaged for all the monitored days;
3. It was then assumed that the “stand-by losses” are the same for the rest of the day;
4. The difference between total DHW energy and the “stand-by losses” was considered to be “consumed energy” used to replace drawn hot water.

This process ignores two issues - firstly the fact that the external temperature is higher during the day time than the night time and thus the standing losses may be lower, and secondly the effect of hot water draw-off during the day which leads to lower cylinder temperatures, which will also reduce the standing losses. No correction for these has been applied at this time.

Our analysis shows that the hot water heaters use on average 1020 kWh per year to replace standing heat losses. The variation of the standing losses between cylinders is relatively large with a standard deviation of 450 kWh per year. The standing losses average 40% of the total DHW energy consumption, although the proportion varies between 20 % to 70%. The initial analysis has not shown any correlations with either size, age, temperature setting and cylinder insulation level. The average energy used for heating of consumed hot water is 1890 kWh per year, with a standard deviation of 840 kWh per year.

The high proportion of energy used to maintain the water temperature due to standing losses, indicates an opportunity for a sizeable reduction in energy consumption through more effective means of cylinder insulation for new cylinders or additional retro-fitted insulation.

Demographic factors and hot water usage: It was expected that the number of occupants in the household would correlate to DHW energy consumption. The relationship between the number of occupants and the total DHW energy "consumed" (excluding the standing losses) was investigated, as well as the total DHW energy consumption and the amount of standing losses. While there was a general pattern of higher consumption with larger number of occupants the correlation was weak. The best correlation found was between total number of occupants and the amount of "consumed" DHW energy with a significant correlation of 0.76 (t-value of 5.4). Further breakdown of the occupant data into age brackets (under 18 years of age, 18 years and above) did not improve the correlation. This suggests that other factors, including the use of hot water clothes washing (opposed to cold water washing), dish washing, shower and bath usage need to be considered. The data so far suggests a marginal domestic hot water energy usage of approximately 420 kWh per year per person.

Survey versus measured data: This analysis of the hot water energy consumption requires extensive data collection, and thus the degree to which the information collected in the occupant surveys could be used to replace the measurements was investigated. As part of the survey the household occupants were asked about the frequency, duration and temperature of showers and baths each week. Survey temperatures were recorded in terms of "cool", "warm" and "hot" and this information was converted into temperatures and thus to liters of water from the cylinder to produce the water temperature. The energy required to raise the temperature of this amount of water from the supply temperature to the cylinder temperature was then calculated using

$$E = c_{water} V (T_{cyl} - T_{supply})$$

where c_{water} is the heat capacity of water, V is the volume of required hot water, T_{cyl} is the temperature the water in the cylinder is maintained at and T_{supply} is the temperature of the water supplied to the cylinder. Based on sample flow measurements an average shower flow rate of 5.6 liters per minute(1.5 Gallons/Min) was assumed for those houses where no flow measurements have been conducted. The water supply temperature level associated with each response was explored to obtain the best relationship between the survey results and measured energy use.

The analysis showed that measured and surveyed data could be reconciled only to a limited degree, as it appears that the surveyed information over-estimated one or a combination of the frequency, duration and temperature of the showers or baths.

The measured consumption generally exceeded the one calculated for bath and shower use considerably. This surplus energy use is caused by other hot water use, including basins, washing machine, dishwasher etc. No relation between the amount of hot water energy consumption for bath and showers with hot water consumption for the sum of other end-uses could be found. The data indicate that the bath/shower proportion of the DHW energy usage is large, but without further knowledge it is difficult to identify correlations between bath/shower and other hot water use.

Fridge, Freezer and Fridge-freezers

Refrigeration appliances in New Zealand are routinely provided with a "star" ratings label giving the average annual energy consumption based on standard testing procedures (Standards New Zealand 1989). The testing procedure makes no allowance for the number of times the doors are opened, the amount and temperature of the food loaded into the refrigerator or other real world effects which would moderate the amount of energy the refrigerator would consume. The test procedure attempts to compensate for these factors by undertaking the test at a high ambient temperature of 32°C.

The actual monitored energy consumed by refrigerators has been compared with the ratings label value. Where the appliance lacked a label, the model number was used to obtain an approximate value from manufacturer provided tables. The actual consumed energy has been found to be approximately 30% below the consumption given by the ratings label, suggesting that the choice of a 32°C ambient temperature is too high to account for the occupant and location dependent factors.

The energy consumption for a particular refrigerator will depend on a number of factors including the number of occupants, deterioration due to age, surrounding environment temperature and whether the appliance is stand-alone or built in. An understanding of the magnitude of these affects, for a representative selection of houses, will allow the development of strategies to reduce the amount of energy used for refrigeration.

Solid Fuel Monitoring

The use of solid fuel heaters (coal and wood burners) is wide-spread in New Zealand houses. To accurately measure the fuel usage or heat output of solid fuel burners a detailed set of measurements is required. Compared to other fuel types such as electricity, the expense for a particular level of accuracy of solid fuel monitoring is generally high. Low cost procedures are required for monitoring solid fuel usage to allow for a sufficient number of houses to be measured.

The technique developed by BRANZ is based on flue surface temperature measurements recorded by modified standard temperature data loggers to evaluate the delivered heating energy. Data is collected from two sources; firstly, modified temperature data-loggers are attached to the flue surface, and temperatures are recorded at 15 minute intervals. Secondly, the occupants complete a logbook each time the solid fuel burner is used (recording the date, time of day, the amount and type of wood and kindling burned and the duration of the burn).

The integration of the flue temperature readings over time, shown in Figure 3, represents the delivered heat energy. The actual energy output of the fuel burned over the same time is calculated from the logbook recorded weight of the fuel, taking into account its calorific value, its estimated moisture content, and the burner efficiency which is measured separately at the start of the logging period. The comparison of logged temperatures and logbook entries allows the calculation of a conversion factor between the measured flue temperature and the heating energy output. This then permits the calculation of a time series of delivered heating energy from the data-logger records. It has been found that the logbook alone does not provide an accurate record of the solid fuel burner use due to unreliability in the log book entries. The logbook entries are, however, sufficient to calculate the conversion factor between flue temperatures and heat energy output. The data logging, on the other hand, detects any use of the solid fuel heater even if it was not recorded in the logbook. The combination of both data sources appears to provide reliable and accurate time series information on heat output.

In Figure 3 the area below the line represents the energy supplied by the solid fuel burner, with a peak heat output of approximately 4 kW at 22:00 on the first day.

The measurements on the solid fuel heater output will allow cross fuel comparisons, to answer questions such as whether rooms with solid fuel heaters are heated to higher temperatures than electrically heated rooms or the cost effectiveness of different heating systems and fuel types.

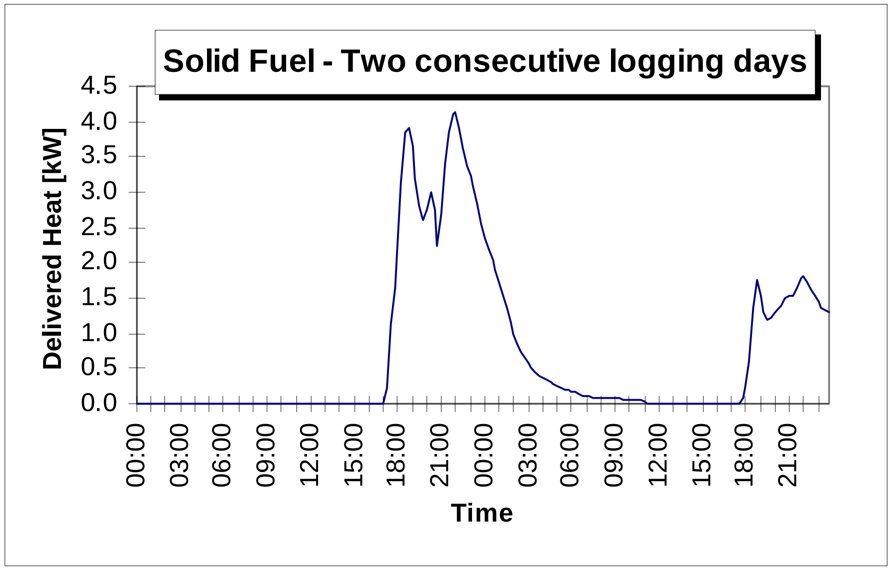

Figure 3: Example profile of two days of solid fuel burner output

Internal Temperatures

BRANZ has monitored two or three internal temperatures in each of the Wanganui houses since 1996. In 1997 temperatures were recorded at fifteen minute intervals at up to ten points within each house.

The temperate climate, a short heating season and possibly lower comfort temperatures, means the use of central heating systems in New Zealand is not common. The 1971-72 Survey of Household Electricity Consumption (New Zealand Department of Statistics, 1973) reported the average living room temperature during August and September 1971 in the “Southern North Island” region (which includes Wanganui) of 16.6°C and a corresponding average outside temperature of 11.0°C.

The HEEP project is providing an updated set of data which can be used to compare the temperatures found in 1971 with current temperatures. It was found that the average of the living room temperatures measured in five houses in Wanganui in 1996 was 16.1 °C (mean outside temperature 11.4°C) while a different set of ten houses in 1997 had an average temperature of 14.8 °C (mean outside temperature 10.5°C). As the number of houses sampled is small, no conclusive test of the significance of the difference between the two years can be undertaken, however the pattern suggests that further investigation of the functional dependence of the indoor temperatures on the outdoor temperatures is required. The results so far also seem to indicate that no large indoor temperature changes have occurred in New Zealand houses during the last 25 years.

Significant correlations were found between the Living room temperatures and outside temperatures for the fifteen houses (correlations consistently above 0.7) with the regression line slope close to 0.5°C. The quality of the fitted regression line depends on the amount of heating which is taking place within the house. More heating reduces the quality of the fit.

The dependence of indoor temperatures on the outside temperatures is illustrated in Figure 4 which shows the indoor temperatures (shown in grey) in 14 of the houses with the outside temperature (shown in black) over a period of one and a half years. The close linkage between the outside and inside temperatures holds both in the warmer months (November to May) and the cooler months (June to October). If comfort levels were being maintained during the winter period, this pattern would not be expected. Note the low average temperatures in some of the houses. We have measured prolonged periods of moving average temperatures below 15°C, which is below minimum temperature recommendations by the World Health Organization (World Health Organization 1987).

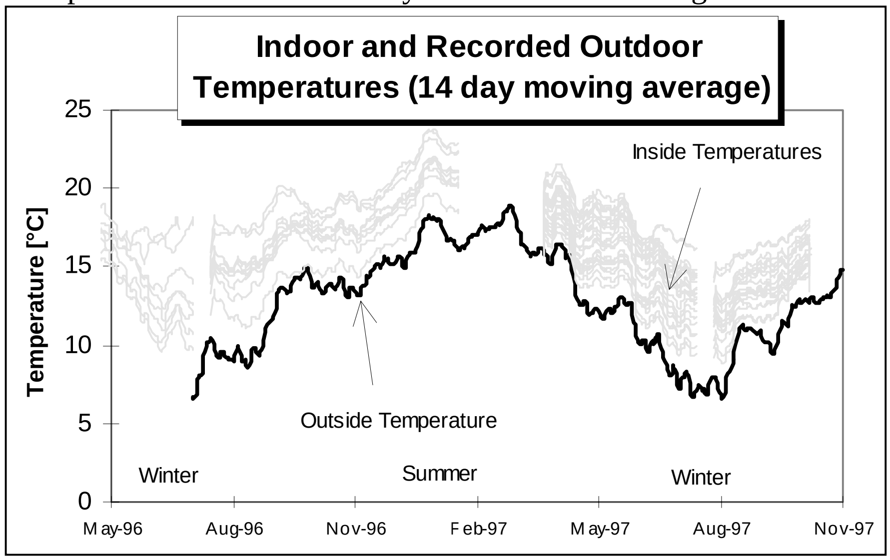

Figure 4: Indoor & outside temperatures for 14 houses.

Determinants of Indoor Temperatures

In addition to the temperature and energy measurements, the occupants of each household completed a detailed survey (Fitzgerald & Ryan 1996). The survey obtains information on the occupants, the building and the appliances used. Survey responses and temperature measurements were correlated for the eight houses in the third rotation of houses (March 1997 to June 1997) (Pollard, Stoecklein and Bishop 1997). Selected correlation results for the measured total energy use and the Living room temperatures are given in Table 2. Shading indicates a correlation at a 95% level of significance.

Table 2 illustrates that the correlation with the living room temperatures are only significant for the number of heaters owned, while total income is the only other factor with indoor temperature correlations above 0.6.

Fitzgerald and Ryan (Fitzgerald & Ryan 1996) report that the indoor temperature of the Christchurch houses correlates well with the total TV hours watched Monday to Friday, the total TV watched per week and whether the household undertakes any practices in order to conserve electricity. The indoor temperature is also negatively correlated with whether the occupants use public transport as an alternative to taking a car. They did not record the correlation of the temperatures with the total number of heating appliances used, using instead the number of each separate heating appliance type (eg nightstores, panel heaters), of which the number of enclosed wood burners was the most important with a correlation of -0.79.

Table 2: Correlations between survey results and measured data

Variable	Total ENERGY	Mean Temp. (00 to 24)	Night Temp. (00 to 07)	Morning Temp. (07 to 09)	Day Temp. (09 to 17)	Evening Temp. (17 to 24)
Number of occupants	.22	.02	.18	.16	-.13	.04
Number of occupants contributing to household income	-.08	.39	.46	.45	.30	.45
Number of adults home during day	.17	.41	.40	.39	.37	.62
Number of adults home at night	.34	.47	.41	.42	.39	.34
Total number of heaters used	.54	.91	.73	.75	.95	.85
House area	-.10	-.20	-.15	-.13	-.30	-.41
Does the household practice recycling	.45	-.03	.26	.18	-.08	-.06
House built between 1978 and 1996	.56	.19	.26	.25	.21	.24
Total income for the household	.78	.70	.69	.71	.66	.53

The sets of Wanganui and Christchurch data do not show any significant correlations that appear in both sets. Correlations indicated in one set do not show up in the other set (or at least not to a significant level). The cause of these non-matches is likely due to the small sample, but could also be due to climate variations between Wanganui and Christchurch.

Outlook

On the completion of the logging of the current Wanganui houses end-use logging will shift from Wanganui to another main population centre. Negotiations are underway with energy supply companies to start monitoring at total house level by the middle of 1998, with statistically significant information then becoming available in 1999 for that region. House selection will be based on a random sample method in each of the major power company regions. Macro level logging at street transformer or distribution point servicing up to 50 houses will effectively average the energy use profiles, and is due to commence within the next 18 months. Data will be evaluated around socio-demographic information from the national quinquennial census which is available at meshblock level each comprising of approximately 30 to 100 houses.

The HEEP project has just entered its third year of operation and already the benefits to both the commercial and private sector can be seen. As the sample increases this picture will become more representative of the entire country.

Conclusions

The Building Research Association of New Zealand has logged the energy end-uses and indoor temperatures of 28 houses during the last two years. Energy end-use time series for approximately 10 end uses and temperature time series of between two and ten indoor locations was recorded with a 15 minute resolution. Data logging of solid fuel heaters and reticulated gas appliances has been developed and tested in pilot studies. Surveys were conducted in each house covering socio-demographic, appliance and physical house properties. The objective of the investigation is the development of an energy end-use model which includes physical as well as socio-demographic energy end-use determinants.

The collected information is currently being analysed. Most of the information is not yet statistically representative, however, the following findings tend to indicate that some of the findings will be unexpected and might have the potential to lead to energy load modifications and energy efficiency targeting to particular customer and appliance groups. The results of the analysis thus far reinforce the need for the study of the socio-demographic features of the different households and the effects these have on the energy consumption.

Our findings so far include:

- Fridge/freezers and freezers consume on average only approximately 70% of what the label rating states. This implies that the standard testing procedures are not reproducing actual energy usage.
- Night store heaters are promoted by power companies in New Zealand for their cost savings. Our measurements show that the energy consumption of these heaters is considerably larger than the energy consumption of non-storage electric heaters. Whether they provide benefits in terms of an improved thermal environment has not yet been investigated.
- Domestic hot water heaters consume a large proportion of the total electricity. An average of 40% of their energy consumption is used to recover standing heat losses from the cylinder. There were no apparent patterns found linking the amount of standing losses with either cylinder size, cylinder age or thermostat set point. The correlation between number of occupants and the amount of consumed hot water energy is 0.76. The total energy for hot water heating (excluding appliance heating like dishwashers, washing machines etc.) contributes between 20% and 60% to the peak demand.
- Shower water flow rates are lower than expected. An average of 5.6 liters per minute was measured. The use of survey responses for estimating the hot water usage for shower and baths proved to be difficult. Findings indicate that approximately 50% of the consumed hot water is used in showers and baths, the rest for other uses.
- The electricity end-uses in two different climate regions in New Zealand (~1000 degree days versus ~1500 degree days with base 15°C) were compared. Indications are that neither heating nor hot water heating are significantly different between the two climates. Both lighting and cooking energy consumption tended to be larger in the cooler climate, possibly indicating the effects of different lifestyles and usage patterns.
- Indoor temperatures in the monitored houses are very low in international comparison. Temperatures are frequently under 16°C, a level which the World Health Organization considers as the lowest to avoid risks of respiratory diseases.
- Indoor temperatures in the monitored houses are closely linked to external temperatures. This suggests that New Zealand houses either cannot be heated to comfortable levels due to insufficient house and heating system performance; or that occupants are not willing to heat to higher levels either because of high energy costs or because they consider the achieved temperatures as comfortable.

We have successfully developed a method of solid fuel heater logging. The method provides time series of heat outputs of solid fuel heaters allowing us to compare the effects of different heating and fuel types on indoor climate.

The main focus of the project over the next four years will be the collection of a representative sample of the New Zealand house population allowing the development of an national energy end-use model.

Acknowledgments

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