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Household Energy Use in a Temperate Climate

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Household Energy Use in a Temperate Climate

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ABSTRACT

The Household Energy End-use Project (HEEP) is a multi-year, multi-discipline, New Zealand study that is monitoring all fuel types (electricity, natural gas, LPG, solid fuel, oil and solar used for water heating) and the services they provide (space temperature, hot water, cooking, lighting, appliances etc). The monitoring of 400 randomly selected houses will be finished in early 2005, with a national residential sector energy model to be completed in 2007.

The paper provides a brief background to the study and an overview of the monitoring methodology, along with preliminary results based on measured data from 200 houses. It highlights some initial findings and discusses the type of issues that can be investigated with such a comprehensive, integrated database including energy use, house physical characteristics, and socio-economic data. Examples include household energy uses, hot water standing losses, low-flow shower heads, the impact of thermal insulation on space temperatures and energy use, and uses of different heater types.

Household Energy

Energy is seen as a fundamental requirement of modern society, with debate often focused on the supply of energy from a capital-intensive energy sector with a small number of major participants. Energy supply is thus well understood, but the same cannot be said for energy demand, which is simply viewed as ever-increasing. This research is focused on understanding the how, where, when and why of energy demand – a goal that will ultimately impact not only on energy supply, but also on improving the efficiency of end-use.

The residential sector consumes 13% (60 PJ) of New Zealand's energy, and 33% of all electricity, with regular growth over 2% per year. The sector is a major contributor to peak electricity demand which must be met by thermal generation. It accounts for about 10% of CO_2 emissions (directly 1.6% and indirectly (thermal generation) at least 8%). Each 1% improvement in the efficiency of energy use in New Zealand homes would result in a benefit of $NZ17 million and reduce national CO_2 emissions by 0.1% (see Isaacs et al. 2003 for analysis details).

As consumption grows, the negative economic, social and environmental effects increase. It is becoming critical to find ways to reduce (or at worst not increase) energy demand and GHG emissions. Fundamental to this is an understanding of energy use, so increased energy efficiency and acceptable energy demand can be achieved while providing satisfactory comfort and health.

Past and Present Energy Use

Until the early 1970s, energy just disappeared into houses – no one attempted to understand the end-use demand. That decade started with two seminal studies – both with an interest in understanding the drivers for energy use and then improved energy efficiency:

- the Twin Rivers (New Jersey, U.S.A.) project monitored energy use and implemented efficiency improvements in 35 houses (Socolow 1978, Harrje 1978), and investigated the effect of occupants in a group of 248 townhouses (Sonderegger 1978).
- the New Zealand (N.Z.) Department of Statistics and N.Z. Electricity Department national study of electricity use in nearly 2000 houses, with a smaller 300 house study investigating the consequences of thermal insulation (Statistics N.Z. 1973, 1976).

Both studies found that technical changes (e.g. thermal insulation) impacted on energy use. Significantly, there was also a key social component. The past 30 years have seen huge changes in both technical and social aspects of the way houses are built and used, with largely unknown energy consequences:

- materials (e.g. large sheet particleboard for flooring has replaced strip flooring)
- the NZ building code (e.g. thermal insulation has been required since 1978)
- appliances (e.g. microwave ovens widely available from the late 1970s)
- electronic controls (e.g. TV remote controls require ‘standby’ electricity)
- work practices (e.g. retailing is now a 7-day-a-week operation)
- home office (e.g. in 2001 nearly one half of N.Z. homes had a computer)
- household characteristics, size, age, configuration and cultural diversity.

Household Energy End-use Project (HEEP)

Although the need to understand these changes had been publicly discussed since the early 1980s (e.g. N.Z. Parliament 1984), it was not until late 1995 that the Building Research Association of New Zealand, Inc (BRANZ) started the Household Energy End-use Project (HEEP) with a pilot study of 10 houses in Wanganui (Stoecklein et al. 1997).

In the first three years a pilot study of 40 non-randomly selected houses was used to develop the selection, monitoring and analysis methodology, and to provide an estimate of the number of houses required to ensure a statistically acceptable result. The work was supported by the development of low-cost data loggers to match the very limited budget

A statistical review of the pilot study data suggested a sample of about 100 houses would be required to estimate total annual household energy consumption with an error of less than 10% and with 90% confidence, and 375 houses to provide analysis of major end-uses by time-of-day. This was increased to a monitoring total of 400 houses, to allow for possible uncertainties in the pilot data and wastage (Bishop et al. 1998).

Random selection of houses started in 2000, with 41 being monitored. The following year had only 17 randomly selected houses monitored, with the remaining equipment used on a separately funded group of 11 pensioner houses. A sizable grant in 2002 provided equipment to monitor 100 houses. Eighty six per cent of the 400 randomly selected houses will have been monitored in the four-year period from 2002 to 2005 (Isaacs et al. 2003). Although the majority of monitoring has been spread over four years, it is believed that there has been no major change in the types of energy using equipment found in individual houses, or in legislation that might impact on patterns of house use.

Annual HEEP reports have been published since 1997, providing feedback to funders and the wider community (Stoecklein et al. 1997, Bishop et al. 1998, Stoecklein et al. 1999, Camilleri et al. 2000, Stoecklein et al. 2001, Isaacs et al. 2002, Isaacs et al. 2003).

Monitoring Overview

HEEP is based on the monitoring of all fuel types used in the household (electricity, natural gas, LPG, solid fuel, oil and solar energy use for water heating) and the end-uses or services they provide (space temperatures, hot water, cooking, lighting, appliances etc).

Although it is desirable to monitor all fuels and end-uses in all houses, a trade-off had to be made between the equipment capital expenditure, the statistically acceptable sample size, the desired monitoring period and the types of analysis expected to be of value to the researchers, the NZ government and the wider industry.

It was decided that in all houses the total load for the 'whole house' would be monitored – each fuel type, plus the hot water fuel and any fixed-space heating. This approach does not provide data on the individual end-uses, the monitoring of which is both more complex and expensive. One quarter of the houses are 'end-use', with metering on all permanent loads (electric or gas) including cooking, space heating and lighting. In these houses, each month a random selection of two or three electric appliances is chosen and monitored.

Table 1 summarizes the monitoring regimes. Commercial electricity or gas meters with a pulse output are used to monitor whole-house or individual appliance use. Type K thermocouples are used for LPG and solid-fuel burner monitoring, Type T thermocouples for solar water heaters and other supplementary water heating, and Dallas Semiconductor DS1624S digital thermometers (accuracy ±0.2 °C) are used to monitor at least three space temperatures. In all cases, the pulse or sensor output is fed to purpose-built dataloggers with one or more months of storage at the desired time resolution.

Table 1. Monitoring Coverage - End-Use and Whole-House

Fuel monitoring	Technique	Time resolution	End use	Whole house
Total electricity	Pulse output meter	1, 2 or 10 min	✓	✓
Total gas	Pulse output meter	1 or 2 min	✓	✓
Total LPG	Heat panel detection	5 or 10 min	✓	✓
Solid fuel	Thermocouple	10 min	✓	✓
Solar Water Heater or 'Wet' back	Thermocouple	10 min	✓	✓
DHW (electric or gas)	Pulse output meter	1, 2 or 10 min	✓	✓
Individual gas appliances	Pulse output meter	1, 2 or 10 min	✓	
Individual electric appliances	Pulse output meter	1, 2 or 10 min	✓	
Indoor temperatures – 3 locations	Temperature logger	10 min	✓	✓
External temperatures	Temperature logger	10 min	1 per region	
Occupant survey	Interview	At installation	✓	✓
Energy audit	Auditor	At installation	✓	✓
House plan (inc. construction)	Auditor	At installation	✓	✓
Hot water temperature & flow	Spot measurement	At installation	✓	✓
Appliance standby power	Spot measurement	At installation	✓	✓

Source: Isaacs et al. 2002, plus additions

It takes between two and four hours for a three-person team to instrument and survey each house, depending on its size, number of fuels, number of appliances and monitoring complexity. The energy audit involves a detailed inspection of the house, recording details of its location, construction, dimensions, hot-water system (including shower water flow rates and temperatures), and all appliances (whether connected or in storage).

Each appliance is documented, and the majority also have their standby power measured using an *Avometer M3050P* or a *ELV EM 600 Expert*[1] wattmeter fitted with an interrupted plug, allowing the appliance to be quickly plugged in and the power use checked. A set of photographs provides a record of the equipment locations, and an opportunity for later analysis. The occupant survey is conducted by a specially trained member of the installation team. As soon as possible after the installation, the survey responses are checked and loaded into a computer database.

Each house is monitored for at least 12 months (always including winter), with the following month set aside for equipment maintenance, calibration and the installation logistics. The individually monitored appliances in any given end-use house will depend on the availability of the monitoring equipment and the probability of selection established for that house. Under normal conditions three temperatures (two in the family or living room, one in the main bedroom) will be monitored, but this can be increased, depending on the house characteristics, or specific research needs.

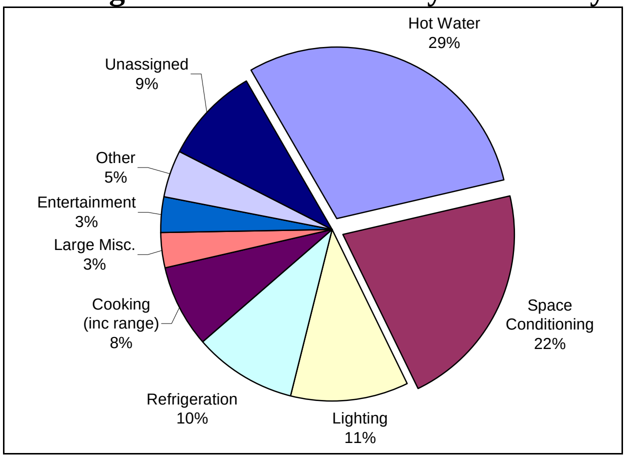
Locally employed field staff visit each month with a laptop or hand-held PC to download the data in ASCII form, and e-mail it to our central base for pre-processing, checking and loading into the S-Plus analysis database. Individual house data is included in the database once all data checking has been done – normally two or three months after monitoring is completed.

Household Energy End-Uses

Stoecklein, Pollard & Bishop (1998) provided some early results from 28 non-randomly selected houses. This paper uses monitored data from 200 randomly-selected houses. As data collection is on-going, the results will continue to be revised[2].

Figure 1 provides a breakdown by end-use for electricity and natural gas. Work is proceeding to include energy used for LPG and solid fuel – both mainly used for space heating, although also used for water heating and cooking in some houses. No statistically significant regional difference has yet been found in the total energy use – the average for electricity and natural gas is equivalent to a 1154 ± 52 W continuous load.

Figure 1. Average Household Electricity and Gas by End-Use



Source: Isaacs et al. 2003

[1] A low cost wattmeter (approx. € 40, $US 50) - see www.elv.de

[2] For the latest results, please see our web site: www.branz.co.nz/main.php?page=HEEP

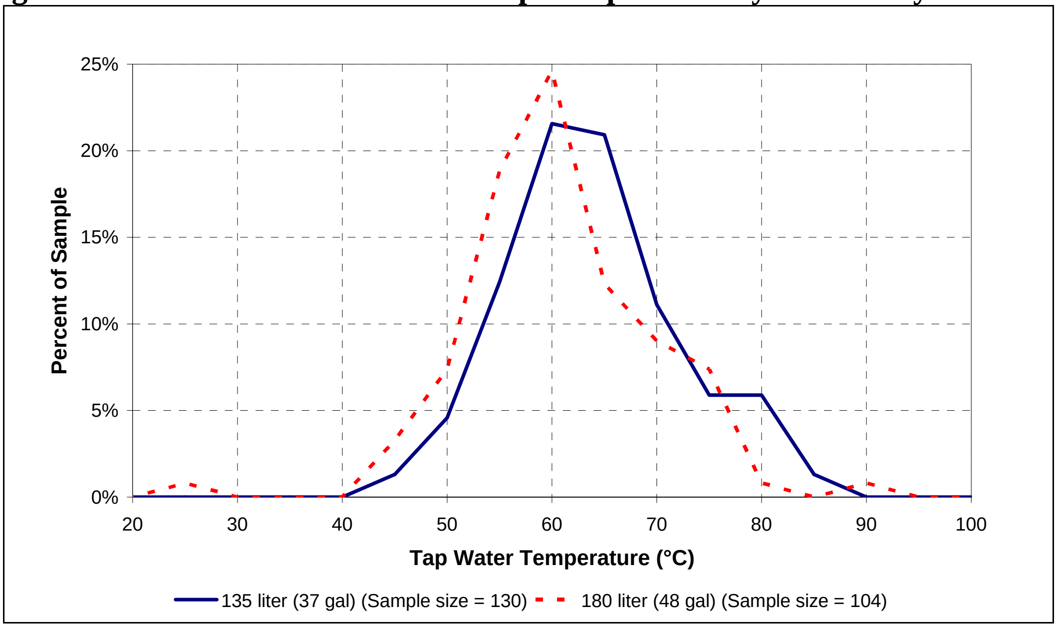
Hot Water Temperatures and Storage Cylinder Size

Figure 1 shows that hot water is the largest single household energy use. The majority of houses have relatively small (135 liter, 37 US gallon) electric, low-pressure hot-water storage cylinders. Cylinder size has been slowly increasing, with 180 liter (48 US gallon) cylinders found in 24% of the 1960s houses but in 66% of the 1990s houses. In the 1970s reticulated natural gas become available in some areas, and it is now is used by 13% of the HEEP hot water systems – often in mains pressure systems.

The performance of these styles of hot-water heating can be considered in two ways – how hot, and how much?

Figure 2 gives the temperature distribution measured for the 135 and 180 liter electric cylinders. Cylinder sample sizes are given in brackets. The two cylinder sizes have statistically different mean temperatures (z-score 3.6, p 0.01), with the mean temperature at 61°C (142°F) for the smaller cylinder and 58°C (136°F) for the larger.

Figure 2. Distribution of Hot-Water Tap Temperature by Electric Cylinder Size



Source: Isaacs et al. 2003

The analysis of the measured hot-water temperatures raises a number of energy, safety and health issues about the provision of hot water in homes, including:

- over 40% of the cylinders had UNSAFE delivered water temperatures – 43% were above 60°C (140°F), including 13% over 70°C (158°F). An acceptably 'safe' water delivery temperature would be 55°C (131°F) or less, which is required by the NZ Building Code for new installations. This is generally achieved by a 'tempering valve', which mixes hot and cold water to the desired temperature before the end-use appliance, e.g. a sink or bath.
- one-third of the cylinders had INACCURATE thermostat control – only 67% of the delivered water temperatures are within ±10% of the thermostat setting. Even if users

- select an apparently safe temperature setting, they cannot be sure the system will safely deliver.
- only 12% of the cylinders (for which thermostat and water temperature data was available) had TEMPERING VALVES to ensure water would be delivered at a ‘safe’ temperature.

Ongoing analysis is helping to identify potentially important hot-water energy, health and safety issues. HEEP will continue to monitor hot-water temperatures, ultimately developing a methodology to assist in the identification of hot-water systems that are likely to have excessively high temperature water and tools to ameliorate the possible dangers.

Hot Water Supply and Demand

Although the time taken for a shower is under the control of the user (demand), the water flow rate is established by the system in conjunction with the shower head (supply).

Mains pressure systems (either central storage or instantaneous) have only been widely available in New Zealand since the 1970s, but are increasingly being used both in new houses and as replacements for failed low-pressure cylinders. Over three-quarters (79%) of the HEEP systems are low pressure and the rest (21%) are ‘mains’ pressure. Three per cent of the 1960s cylinders are mains pressure, 9% of the 1970s, 17% of the 1980s and 26% of the 1990s.

The average measured shower flow over the entire sample is 8.2 liters (2.2 gal) per minute which is equivalent to a water-efficient AAA shower head (SNZ 2003), but this average disguises the growing importance of mains pressure systems.

The average shower flow rate for low pressure systems is 7.2 (1.9 gal) liter per min (Standard Deviation (SD) 0.2 liters (0.1 gal) per min), while for mains pressure the average is 10.6 liter (2.8 gal) per min (SD 0.6 liters (0.2 gal) per min). The highest recorded flow rates were 20 liter (5.3 gal) per min for low pressure and 30 liter (7.9 gal) per min for mains pressure systems. On average, 25% of low pressure systems had ‘warm’ shower flows over 9 liter (2.4 gal) per min, while 60% of mains pressure systems were above this threshold.

Often only the energy cost of hot water is considered, but with water becoming increasingly expensive, the cost of water is also relevant. For example, in Auckland (currently the only New Zealand city charging both for fresh water supply and sewerage removal), the supply and removal of 1 liter (0.3 gal) of water costs 0.329 NZ cents (0.87 US cents per gal).

Thus, if a shower flow of 13 liters (3.4 gal) per minute (the average for mains pressure, non-low flow showers) is reduced to 6 liters (1.6 gal) per minute, and (self-reported) shower time remains at five-minutes, this would save *11.5 cents NZ per shower (8 US cents)* in water costs.

The energy savings from the reduced flow, based on heating the water from 14°C to 39°C and an electricity tariff of 13 cents NZ per kWh are *13.2 cents NZ per shower (9.2 US cents).*

The total savings would be about *25 cents NZ per shower (17.2 US cents*) of which 46% is due to reduced water and 53% due to reduced energy use – or about 2/3 reduction (64%) in the total cost of the shower. Over a full year this equates to $NZ90 ($US63) for one five-minute shower per day. The retrofitting of a low-flow shower head (product cost about $NZ40 ($US28), has a payback of less than six months, assuming only one shower per day – obviously the payback would be far faster for two or more showers per day.

House Internal Temperatures

New Zealand has a relatively mild climate – 'temperate with sharp regional contrasts' according to the CIA World Factbook (CIA 2003) – leading to the expectation that indoor temperatures will also be temperate. The measured facts differ from this assumption.

Table 2 provides a comparison between the 1971/72 (Statistics 1976) and the current HEEP study. It should be noted that there are differences in the regional coverage, principally due to the 1971/72 selection methodology, but the key point is that temperatures were low over 30 years ago, and remain low today. There are only significant (2 tailed Z-test 95% confidence) changes in the living room temperatures for the 'Northern North Island', where the average temperature has fallen from an average of 17.7 °C (63.9 °F) to 16.2 °C (61.2 °F).

Table 2. Winter Descriptive Temperatures by Region – 1971/92 Study & HEEP Pre-1978 Houses

August-September	Northern North Island		Southern North Island		Christchurch South Island		Southern South Island	
Temperature	1971/2	HEEP	1971/2	HEEP	1971/2	HEEP	1971/2	HEEP
External								
Mean temperature (°C)	12.0°C	11.9°C	11.0°C	10.6°C	9.3°C	10.2°C	8.6°C	7.9°C
Mean temperature (°F)	53.6°F	53.4°F	51.8°F	51.1°F	48.7°F	50.4°F	47.5°F	46.2°F
Living room (± SD)								
Mean temperature (°C)	17.7±0.3	16.2±0.1	16.6±0.3	15.9±0.2	15.2±0.3	15.8±0.4	13.6±0.3	14.6±0.6
Mean temperature (°F)	63.9±0.5	61.2±0.2	61.9±0.5	60.6±0.3	59.4±0.5	60.4±0.7	56.5±0.5	58.3±1.0
Sample size	*98*	*80*	*64*	*40*	*69*	*23*	*64*	*24*
Bedroom (± SD)								
Mean temperature (°C)	16.1±0.3	15.7±0.1	15.1±0.3	14.8±0.4	13.8±0.3	14.4±0.3	12.6±0.3	11.5±0.4
Mean temperature (°F)	61.0±0.5	60.3±0.2	59.2±0.5	58.6±0.7	56.8±0.5	57.9±0.5	54.7±0.5	52.7±0.7
Sample size	*98*	*80*	*64*	*14*	*69*	*23*	*64*	*23*

Source: Statistics N.Z. 1976 & HEEP data

Table 2 includes only houses built before the 1978 regulatory requirement for thermal insulation in new houses (see Isaacs 1999). When the comparison is extended to include the insulated houses (post-1978) there are significant increases in the temperatures of the bedrooms in the southern North Island (+ 1.1 °C (2 °F) but with only five post-1978 houses in the sample) and Christchurch (+1.9 °C (3.4°F) with nine post-1978 houses in the sample).

The 'average' temperatures in Table 2 are not high. They disguise a consistent time-based heating regime. Figure 3 provides an illustration by time-of-day of the 'average' living room winter (June-August) temperatures from monitoring in Auckland, Hamilton, Wellington and Christchurch. Both internal and external temperatures follow a diurnal pattern, with the internal temperature moderated both by the building, and by heating – the 'on' being indicated by the flattening of the internal temperature around 5 p.m.

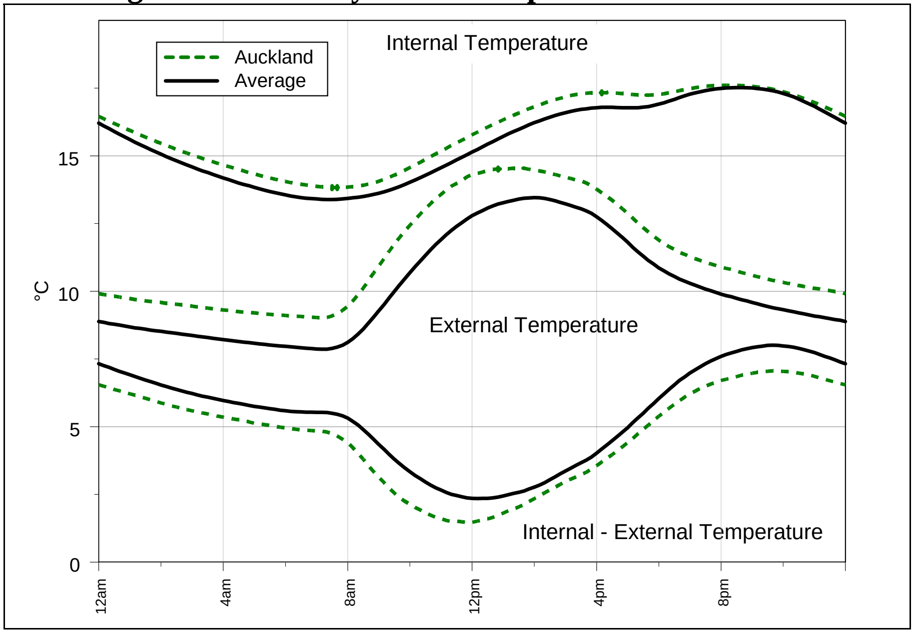
This basic pattern is seen in all regions, all house sizes and all income groups. The temperature profiles for each house were examined to determine the heating times:

- *start of heating* was defined as the time when the temperature starts to rise in the evening. Without heating, houses will cool off in the evening, so when the profile begins to rise it indicates that, on average, houses are being heated.
- *maximum rate of temperature increase* indicates that most houses are being heated.

- *peak time of maximum temperature* indicates when the comfort temperature has been reached, or when some households begin to stop heating.
- *end of heating* was determined by finding the point at which the difference between the outside and inside temperature decreases.

The results are presented in Table 3, along with average user survey responses for the heating start and finish month, and the derived length of the heating season.

Figure 3. Average Winter Family Room Temperatures – Auckland & 'Average'



Source: HEEP data

Table 3. Estimated Heating Times by Region

Region	Start time	Max rate	Peak time	End time	Bed time	Start month	End month	Length (month ± SD)
Auckland	17:50	18:40	20:20	21:50	23:00	May	Sept	4.0 ± 0.2
Hamilton	17:20	18:20	20:20	21:30	22:05	May	Oct	4.9 ± 0.6
Wellington	17:00	18:50	21:50	22:10	23:00	May	Sept	4.6 ± 0.2
Christchurch	16:20	18:30	20:50	21:50	22:30	April	Sept	5.0 ± 0.2

Source: Isaacs et al. 2003

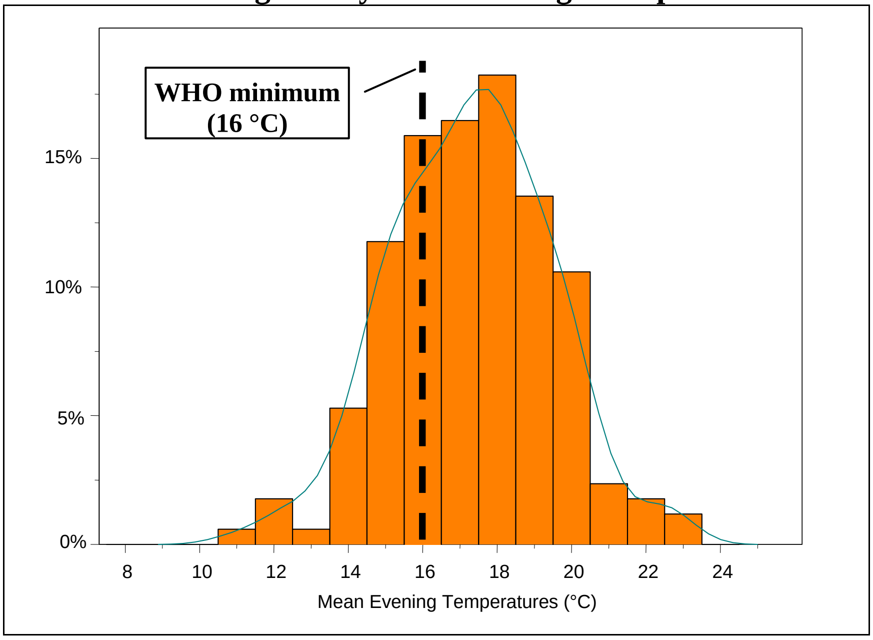
The left columns of Table 3 show that the start of heating progressively gets earlier going from north to south, by about 30 minutes for each location. The time of the maximum rate of increase of temperature is about the same in all regions, ranging from 18:20 to 18:50, with no apparent pattern. The end of heating appears to be weakly related to the household bedtimes.

The right columns of Table 3 show that the average starting and finishing heating season show significant variations by region – on average, households in cooler climates start heating earlier and finish heating later than those in warmer climates. The starting month of the heating season is weakly related to the average winter evening living-room temperatures, thus houses with warmer winter internal temperatures tend to start heating earlier in the season.

The results reported in Table 3 suggest that the New Zealand winter heating season is the period between May and September (inclusive), and during this season the living room is heated in the evening between 17:00 and 22:50.

Figure 4 provides an overview of the winter evening family room average temperatures in the randomly selected houses in Auckland, Hamilton, Wellington and Christchurch. It follows a normal (bell shaped) distribution, with an average temperature of 17.3°C and a standard deviation of 0.2°C which is somewhat warmer than the two month, all-day averages reported in Table 2. But more importantly, Figure 4 also shows that nearly 30% of the average winter evening living room temperatures are below the healthy minimum of 16°C (WHO 1987).

Figure 4. Winter Evening Family Room Average Temperature Distribution



Source: Isaacs et al. 2003

Thermal Insulation

Houses built since 1 April 1978 are required to have minimum component levels of thermal performance, generally achieved by the addition of thermal insulation, but in some cases provided as an intrinsic part of the construction technology. In general terms, the requirement is component R-values of at least: roof 1.9 m^2 °C/W (R-11 h.ft^2 °F/Btu); wall 1.5 m^2 °C/W (R-9 h.ft^2 °F/Btu); and floor 1.3 m^2 °C/W (R-7 h.ft^2 °F/Btu). Table 4 compares the temperatures and energy use for pre- and post-1978 houses.

Table 4. Winter Temperatures and Energy Use by Insulation Level

House age group	Average winter evening family room temperature	Average winter overnight bedroom temperature	Average winter evening energy use
Pre-1978 (uninsulated)	17.0 ± 0.2°C (62.6 ± 0.4°F)	13.8 ± 0.2°C (56.8 ± 0.4°F)	1680 ± 114 W
Post-1978 (insulated)	18.0 ± 0.3°C (64.4 ± 0.5°F)	14.9 ± 0.3°C (58.8 ± 0.5°F)	1590 ± 210 W

Source: Isaacs et al. 2003

Table 4 shows a very strong relationship between the age of the house and the winter temperatures, based on the 200 house sample. Currently, we can conclude that post-1978 houses are 1.0°C (1.8°F) warmer on average but that their winter evening energy use is not significantly different from the pre-1978 houses. This analysis does not yet include LPG or solid fuel heating. New Zealand households seldom heat their bedrooms overnight, and thus the benefits of higher temperatures in the post-1978 houses are achieved at no cost.

LPG Heaters

There is a wide range of possible analysis that could be undertaken on the HEEP data. The ability to link socio-demographic indicators with the house physical structure, the local climate and detailed time-of-day energy use creates a cornucopia of opportunities. The way LPG heaters are used provides just one example of a possible analysis.

Portable, unflued LPG cabinet heaters are an increasingly common method of space heating in New Zealand. The 2001 Household Economic Survey (Statistics NZ 2001) reported that 33% of households had portable gas heaters, and comparison with earlier surveys suggests they are replacing electric heaters.

Unflued LPG heaters release quantities of water vapor into the heated space – at 1 kW about 0.1 liters (0.03 gal) of water per hour, equivalent to the metabolic moisture from two adults. In the HEEP sample, about one-third (35%) of the houses with LPG heaters have a dehumidifier, whereas 21% of the houses without an LPG heater have a dehumidifier – this difference is statistically significant at the 1% level.

The patterns of LPG heater use do not reflect their ability to provide large amounts of heat. Most (72%) of the heaters are operated on a low setting (1200 to 2300 W); with only 17% mainly operated on a high setting (3200 to 4300 W). These settings are often not varied, with close to three-quarters of the heaters being used for 80% of the use-time at the one setting. Most LPG heaters are not heavily used – over 50% of the energy is used by only 20% of the heaters.

The implications for an electricity system constrained by peak power delivery are interesting. For example, what would be the consequences if, instead of using LPG heaters, householders switched to the lower (at least to the household) capital cost electric heaters? The HEEP data provides an opportunity to explore the different peak power requirements of houses with, and without LPG heaters.

Where to Now?

This paper has provided a brief overview of the background to the HEEP study, offered a view of some of the early analyses and provides some examples of future analysis. When data collection is completed in early 2005, the database will hold detailed measurements and survey results from 400 randomly selected houses, and over 60 non-randomly selected houses.

The house audit data includes information on hot-water temperature and shower flow which has started to identify the causes of dangerously hot water as well as opportunities for energy and water efficiency.

Even these early results from analysis of monitored data are showing that a sizable number of New Zealand homes have winter temperatures that are far cooler than would be acceptable in many other countries. The mandatory requirement since 1978 for minimum levels of thermal insulation in new houses appears to have resulted in a significant temperature increase, but the HEEP data will be used to further explore the drivers for these low indoor temperatures.

Results from monitoring LPG heaters have found that they are not being used to their full power capability, but often as electric heater replacements. As all fuel types are included in the HEEP monitoring, it will be possible not only to review the individual fuel uses and impacts (e.g. what is the impact on peak power demand of lighting, and what would be the consequences of shifting from incandescent to compact fluorescent bulbs), but also the possibility for fuel shifting (e.g. what would be the energy and peak power impact of shifting from solid fuel to electric heating or LPG in areas with air pollution problems).

As both household demographic and economic data are collected, these will provide the opportunity to investigate the importance of different aspects of households. For example, the sample to date shows that there is no statistical difference between the internal temperatures of high and low income households.

The data now becoming available from HEEP is huge. For example, HEEP holds spot-power measurements on each and every electrical appliance found in each house – totaling over 9,000 individual appliances. In one quarter of the houses, 'end-use' data is collected on many of these appliances. These measurements and monitored data provide information on the potential load and on the actual household use and in-use standby energy consumption. The results from analysis of the HEEP data will continue to be released over the next few years.

The ability to undertake these and many other types of analysis has come at a cost – not just financial. An important cost has been time. HEEP has been a longer study than would otherwise have been the case, with the consequence that reliable results are only now starting to be published. Even so, the results have already made their impact on New Zealand government policy and the wider community, including:

- standby power measurements have formed the basis for government action
- technical support for a national campaign to deal with a hydro-electricity shortage –*'If you sing in the shower choose shorter songs'*
- and even one of a series of cynical advertisements for a beer company: '*Save power, turn off the beer fridge – yeah, right*.'

The future will hold even more interesting opportunities for the results of the HEEP research to help improve the energy efficiency, health and well being of the community.

Acknowledgements

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This paper is dedicated to the memory of the late Prof. Helen Tippett, who supported the research in so many ways.

References

Bishop S., M. Camilleri, S. Dickinson, N. Isaacs (ed.), A. Pollard, A. Stoecklein (ed.), J. Jowett, G. Ryan, I. Sanders, G. Fitzgerald, B. James, and F. Pool 1998. *Energy Use in New Zealand Households - Report on the Household Energy End-use Project (HEEP) - Year 2* Energy Efficiency and Conservation Authority (EECA), Wellington.

Camilleri M., N. Isaacs, A. Pollard, A. Stoecklein, J. Tries, T. Jamieson, F. Pool, and P. Rossouw 2000 *Energy Use in New Zealand Households. Report on Aspects of Year 4 of the Household Energy End-use Project (HEEP)* BRANZ Ltd, Judgeford, NZ: (SR 98)

[CIA] Central Intelligence Agency 2003 *The World Factbook 2003* Available online at www.cia.gov/cia/publications/factbook/ Washington D.C.: CIA

Harrje D.T. 1978 Details of the First-Round Retrofits at Twin Rivers *Energy and Buildings 1:271-274*

Isaacs N 1999 'Performance Based Building Energy Efficiency Code' In *Proc. Global Building Model in the Next Millennium Conference* Melbourne 12 - 15 April 1999 pp 108-118 (BRANZ Conference Paper 63)

Isaacs N., L. Amitrano, M. Camilleri, A. Pollard & A. Stoecklein 2002 *Energy Use in New Zealand Households, Report on the Year 6 Analysis for the Household Energy End-use Project (HEEP)* BRANZ Ltd, Judgeford, NZ: (SR 115)

Isaacs N., L.J. Amitrano, M.J. Camilleri, A.R. Pollard, & A.A. Stoecklein 2003. *Energy Use in New Zealand Households, Report on the Year 7 Analysis for the Household Energy End-use Project (HEEP)*, BRANZ Ltd, Judgeford, NZ (SR 122)

New Zealand (N.Z.) Parliament 1984 Answer to Oral Question Transferred for Written Answer (No. 44) Mr. Butcher (M.P. Hastings) to Hon. W.F. Birch (Minister of Energy) 8 June 1984 *Parliamentary Debates (Hansard)* 456:196. Wellington : Government Printer

Socolow R.H. 1978. The Twin Rivers program on energy conservation in housing: Highlights and conclusions *Energy and Buildings 1:207-242*

Sonderegger R.C. 1978 Movers and Stayers: The Resident's Contribution to Variation across Houses in Energy Consumption for Space Heating *Energy and Buildings 1:313-324*

Statistics NZ 2001 *2000/01 Household Economic Survey – Standard Tables* Wellington: Statistics NZ

Statistics, New Zealand Department of 1973 *Survey of Household Electricity Consumption 1971-72*. Wellington: Government Printer

Statistics, New Zealand Department of 1976. *Survey of Household Electricity Consumption 1971-72 - Report on the Temperature/Insulation Study*. Wellington: Government Printer

[SNZ] Standards New Zealand 2003 *AS/NZS 6400:2003 Water efficient products – Rating and labeling* Wellington : Standards New Zealand

Stoecklein A., A. Pollard & N. Isaacs (editor), G. Ryan, G. Fitzgerald, B. James & F. Pool., 1997 *Energy Use in New Zealand Households: Report on the Household Energy End-use Project (HEEP) - Year 1* Energy Efficiency & Conservation Authority (EECA), Wellington.

Stoecklein A., A. Pollard, M. Camilleri, L. Amitrano, N. Isaacs, F. Pool and S. Clark (ed.) 2001 *Energy Use in New Zealand Households, Report on the Year 5 Analysis for the Household Energy End-use Project (HEEP)* BRANZ Ltd, Judgeford, NZ: (SR 111)

Stoecklein A., A. Pollard, N. Isaacs, M. Camilleri, J. Jowett, G. Fitzgerald., T. Jamieson, and F. Pool 1999. *Energy Use in New Zealand Households - Report on the Household Energy End-use Project (HEEP) - Year 3* Energy Efficiency and Conservation Authority (EECA), Wellington.

Stoecklein, A.A., A.R. Pollard, and S. Bishop. 1998 'Energy End-use in New Zealand Houses' In *Proceedings of the 1998 ACEEE Summer Study on Energy Efficiency in Buildings*, 1:343:354. Washington D.C.: American Council for an Energy-Efficient Economy.

[WHO] World Health Organisation 1987 *Health Impact of Low Indoor Temperatures* Copenhagen : World Health Organisation