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Energy Use in New Zealand Households – Executive Summary

Report on the Year 7 Analysis for the Household Energy End-use Project (HEEP)

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Year 7 Executive Summary

Energy Use in New Zealand Households – HEEP Year 7 Report
November 2003
Executive Summary

This is the seventh annual report on the Household Energy End-Use Project (HEEP). Although data collection will not be completed until early 2005, the annual reports provide preliminary results from our research. Each report includes the increased house sample that becomes available when the previous year's monitoring is complete. This report includes data from 200 randomly selected houses, as well as non-random selections. Regional coverage includes the full Auckland sample, Hamilton, Wellington and Christchurch.

The funding highlight of the past year has been the allocation by the Foundation for Research Science and Technology under the 'Public Good Science & Technology' (PGST) 'Output Class 7: Research for Industry' for science funding to support the completion of the HEEP model by June 30, 2007. We also acknowledge the sponsors listed on the front cover.

Readers new to the HEEP work will find a wide range of analysis. In many cases, along with the mean, information is given on the range found in the HEEP houses. However, though such analysis can be informative, it is not necessarily applicable to all situations. For example, it will not provide guidance to aspects of

- household energy use in houses with high or low incomes
- temperatures found in older or newer houses
- behaviour and use of older or newer appliances.

Readers with interest in specific use of the HEEP data are invited to contact the HEEP team.

New Zealand residential energy use

The domestic sector consumes 13% (60 PJ) of New Zealand's energy, and 33% of all electricity, with consumption growing at over 2% per annum. The domestic sector is a major contributor to peak demand which must be met by thermal generation, with a consequent impact on greenhouse gas emissions. The residential sector accounts for about 10% of CO_2 emissions (directly for 1.6% and indirectly at least 8% from thermal electricity generation).

As consumption grows, the negative economic, social and environmental effects increase, so finding ways to reduce energy demand, GHG emissions and use energy more efficiently becomes critical. However, if strategies to reduce energy demand result in lower indoor temperatures and increased damp the outcomes may be undesirable. Mould is associated with damp and low indoor temperatures, as are a number of health problems. The problems arising from inadequate indoor temperatures and damp within the residential sector can have significant costs for households, the government and the economy.

Each 1% improvement in the efficiency of energy use in New Zealand homes would result in a benefit of $17 million and reduce national CO_2 emissions by 0.1%.

For the residential sector the goal must be increased energy efficiency and minimising energy demand while also ensuring: (a) satisfactory perceived levels of comfort; and (b) healthy temperature and moisture levels in residential dwellings.

Designing and implementing interventions to achieve that goal is inhibited by our limited knowledge of the dynamics of residential energy demand. Energy supply (electricity, natural gas, LPG, wood, coal, oil etc) is well understood and documented, but this is not true for the residential energy demand. HEEP will assist in demand management of residential energy through improved understanding of energy end-use from a range of viewpoints, including the house construction, appliance use (including the hot water system) and the socio-economic and demographic characteristics of households.

During the past 30 years since the last household electricity survey, there have been major changes in the way NZ houses are built and used:

- materials (e.g. since the 1970s, particleboard has been the main flooring material)
- building code (e.g. thermal insulation required since 1978)
- appliances (e.g. microwave ovens widely available from the late 1970s)
- consumer expectations
- work practices
- the characteristics, size, age, configuration and cultural diversity of households.

All these factors affect the complex relationship between energy demand, indoor temperature, perceived comfort, household energy costs, and the local climate.

Household energy use by end-use

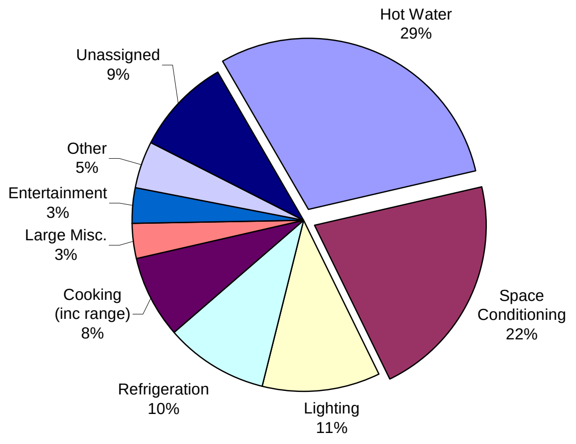

Figure i: Electricity & gas by end-use

The report provides a revised analysis of the energy used both at the total household and individual appliance levels (Figure i). No statistically significant difference has been found in total energy use between the four regions – with the strata-weighted average over the four HEEP locations for electricity and natural gas reported at 1154 ± 52 W. Note that this value currently excludes portable LPG heaters and solid fuel burners. Work is continuing on incorporating energy resulting from the use of these remaining fuels into the analysis.

As well as the strata-weighted average end-use breakdown given above, the report provides updated pie charts by region. On average, hot water is the biggest use of household electricity and gas at close to 30%, with space conditioning (heating and/or cooling) following at 22%. Lighting at 11% is one half of the energy used for space heating, while refrigeration follows in fourth place with 10%. The importance of lighting and refrigeration has not been well recognised, perhaps due to the comparatively small power load.

Indoor temperatures

Comparing the temperatures by region from the 1971/72 Household Electricity Survey with the current HEEP results does not appear to suggest that there has been any increase in average temperatures. There is a wide distribution of temperatures, and this will be subject to further investigation.

There is a significant difference in the start and finish of the heating season. Households in cooler climates, on average, start heating earlier in the year and finish heating later in the year than those in warmer climates. A similar pattern was found for the time-of-day heating pattern. The start of heating is progressively earlier going from warmer to cooler regions, being about 30 minutes earlier at each location going from Auckland at 5:50pm through to

Christchurch at 4:20pm. The time of the maximum rate of increase of temperature is approximately the same in all regions, ranging from 6:20pm to 6:50pm, with no apparent pattern. The end of heating appears to be weakly related to the household bedtimes.

The temperature distribution continues the pattern reported last year, with nearly 30% of households having average winter (June through to August, 5pm to 11pm) evening temperatures below the World Health Organisation recommended minimum of 16°C. There are also significant correlations between mean winter evening temperatures and the house age, presence of insulation, and house floor area.

House age group	Average winter evening living room temperature	Average winter overnight bedroom temperature	Average winter evening energy use
Pre-1978	17.0 ± 0.2°C	13.8 ± 0.2°C	1680 ± 114 W
Post-1978	18.0 ± 0.3°C	14.9 ± 0.3°C	1590 ± 210 W

Table i: Winter temperatures and energy use by insulation level

There is a very strong relationship between the age of the house and the winter temperatures (Table i). Currently, we can conclude that post-1978 houses are 1.0°C warmer on average and that their winter evening energy use is not significantly different from the pre-1978 houses. This difference is slightly less than that given in the Year 6 report, and the reduction has been caused in part by pre- and post-1978 houses in Christchurch having no significant difference in winter evening temperatures.

Winter energy use

Out of the 280 houses, 93 (33%) reported that the main heating is by solid fuel – second only to the use of electric heating (42%); 14% of the households report their main heating fuel is LPG, and 11% use natural gas.

The HEEP methodology for analysing solid fuel energy-use continues to be developed, and thus the heating energy analysis includes only electricity, natural gas and LPG.

The mean space heating energy use is 3650 kWh per year, with a minimum of 253 kWh/yr and a maximum of 14,120 kWh/yr. Normalised to floor area, heating energy use ranges from a minimum of 0.8 kWh/m²/yr to a maximum of 42.9 kWh/m²/yr with an average of 13.5 kWh/m²/yr.

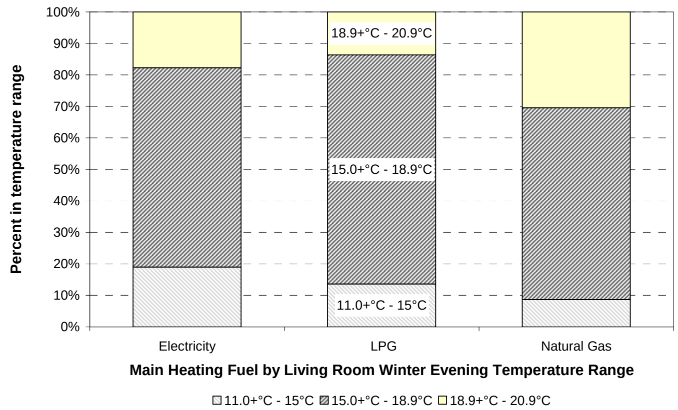

Figure ii: Temperature range by main heating fuel

There is a wide scatter of energy use by floor area and house age, neither of which show a strong relationship. Figure ii shows that houses heated by solid fuel heaters tend to have warmer winter evening living room temperatures than those heated by electricity, natural gas or LPG.

A preliminary 'heating index' has been developed to explore the impacts of different heating schedules. Houses that are heated for long hours have a higher mean winter evening living room temperature, although there is a very wide spread of temperatures for both the heating index and the energy use.

LPG heaters

30% of the HEEP sample have LPG heaters, averaging just over one per house. The operation of portable (unflued) LPG heaters also releases quantities of water vapour into the heated space. Just over one-third (35%) of the houses with LPG heaters have a dehumidifier, whereas the houses that do not have an LPG heater have about a 21% chance of having a dehumidifier – this is statistically significant at the 1% level.

The patterns of LPG heater use do not reflect their ability to provide larger amounts of heat – with the majority used at levels that are comparable with the heat that can be provided by portable, plug-in electric heaters. The heaters are predominantly operated on low setting (72%); 11% are operated on medium and 17% are predominantly operated on high setting. These settings are often not varied, with close to three-quarters of the heaters spending more than 80% of its use at the one setting. Most LPG heaters are not heavily used – over 50% of the LPG heating energy is used by only 20% of the heaters.

Health and Housing

Buildings protect the occupants from the excesses of the external climate. Although it is possible in many parts of New Zealand to achieve this through 'passive' solar design, which maximises the use of free solar energy, the majority of houses use purchased energy to ensure the indoor climate is acceptable to the occupants.

A review of international and New Zealand literature shows there is increasing evidence of a link between the consequences of energy efficiency and occupant health. Health, and other non-energy benefits of improved house energy efficiency can be of sizeable value, with one USA study suggesting they were close to being equal.

There is no simple measure of how the conditions within a building support the well-being and health of the occupants. One approach is to examine some health consequence, which should show minimum seasonality (variation across seasons) if the occupants are well-protected from the variation in the external climate.

The whole population seasonal mortality is examined for Japan, the United Kingdom, Australia, New Zealand, the United States of America and Sweden. The analysis found that over the 30 year period from 1970 to 2000 there has been a steady increase in the seasonality of mortality in the USA and Sweden, Japan and the UK have remained reasonably constant, and in both New Zealand and Australia it has been decreasing.

Age-specific monthly mortality data was obtained for New Zealand and Australia. It was found that between 1980 and 1999 in New Zealand only the 0 to 4-year age group was demonstrating a strong downward trend, although a small downward trend was apparent in the 5 to 64 and 65-plus age groups. However for all three Australian age groups, seasonality was decreasing. The reduction was greatest for the 0 to 4-year age group, but the other two groups were showing a greater decline than is the case for New Zealand.

Hot-water systems

An analysis is provided of the hot-water systems and temperatures found in the HEEP sample. Of the houses in the current HEEP database (including both random and non-random houses), 91% have one hot-water system, 8% have two systems and 1% have three systems. None have more than three hot-water systems.

The majority of the HEEP hot-water systems (79%) only have an electric storage water cylinder – an electric element is located inside an insulated tank of water, with the temperature controlled by a thermostat. Eight percent of the systems have an electric cylinder with some form of supplementary heating, either solar, wetback or a combination. Eight per cent of the water heating systems are gas storage system, 5% are instantaneous gas and less than 1% are solid-fuel-only.

Most cylinders are either 135 litres (30 gallons) (50%) or 180 litres (40 gallons) (40%), with the remainder being split almost equally between the small cylinders located close to their end-use (e.g. under the kitchen sink) and larger cylinders.

Cylinder size (volume) distribution varies by location. In the North Island sample (Auckland, Hamilton, Wellington and Wanganui) 52% of the sample cylinders are 135 litres and 37% are 180 litres or greater. In the South Island (Christchurch) the reverse is the case, with 24% of the cylinders at 135 litres and 66% at 180 litres or greater. These size distributions are likely to reflect historic energy-supplier policy, as there appears to be a shift to larger cylinders in newer homes.

The system water pressure has also changed in more recent years. More than three-quarters (79%) of the HEEP sample are low pressure and the rest (21%) are 'mains' pressure. Three percent of the cylinders from the 1960s are mains pressure, 9% in the 1970s, 17% in the 1980s and 26% in the 1990s.

Houses have a longer life than hot-water cylinders, and it is expected that as hot water cylinders fail they will be replaced, often with the same size but not necessarily with the same pressure. Even very old houses (which originally would have had low-pressure systems) are being retrofitted with mains pressure hot-water systems. About one-third (32%) of the houses, but two-thirds (65%) of the hot-water cylinders date from 1980. The oldest cylinder in the sample dates from the 1930s.

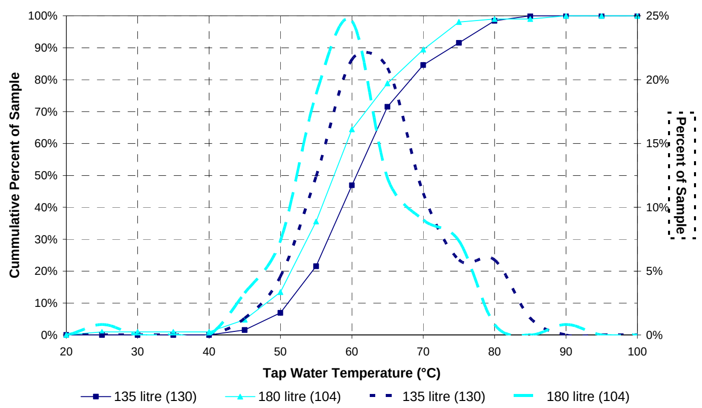

Figure iii: Tap temperature by cylinder volume (electric)

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

- **Over 40% of the cylinders had UNSAFE delivered water temperatures:** 43% of the measured water temperatures were above 60°C, including 13% with delivered water over 70°C (see Figure iii).
- **One-third of the cylinders had INACCURATE thermostat control:** 67% of the delivered water temperatures are within ±10% of the thermostat setting. However, 25% of the delivered water temperatures are more than 20% higher than the thermostat setting. In other words, even if occupants set the thermostat to what they believe to be a 'safe temperature', the tap temperature may be unsafe.
- **Even when users set the thermostat at a safe temperature, one-third of these cylinders had UNSAFE hot water delivered :** 35% of the cylinders had the thermostat set at 60°C or under, but about one-third of these houses had water over 60°C being delivered at the tap (i.e. 11% of all the cylinders in the sample). Thus, even if the householder was

attempting to ensure safe temperature water was delivered through correct setting of the thermostat, the thermostat was not providing it.

- **One out of seven houses with a tempering valve delivered hot water over 60°C**: Only 12% of the cylinders (for which thermostat and water temperature data was available) had tempering values to ensure water would be delivered at a 'safe' temperature. Of these systems, 45% were delivering water at less than 55°C, 40% between 55°C and 60°C, and 15% at a temperature above 60°C – although the maximum measured hot-water delivery temperature for a cylinder with a tempering valve was only 64°C, compared to the maximum of 87°C for one electric storage system without a tempering valve.

These results help to identify potentially important hot-water health and safety issues in New Zealand homes. The HEEP study will continue to monitor delivered and thermostat hot-water temperatures. HEEP will also work toward developing an appropriate 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.

Shower flows

The shift to mains pressure systems has a particular impact on water flow. The average shower flow of 8.2 litres per minute (l/m) measured in the HEEP shower sample – which is equivalent to a water-efficient AAA shower head – disguises the system water pressure.

The average shower flow for a low-pressure hot-water system is 7.2 l/m and for a mains pressure system is 10.6 l/m. The maximum recorded flow rates were 20 l/m for low pressure and 30 l/m for mains pressure. On average, 25% of low pressure systems had 'warm' shower flows over 9 l/m, while 60% of mains pressure system were above this threshold.

Thus, a house in Auckland that currently had a shower flow above 9 litres per minute which switched from a high flow to a low flow shower head (saving 7 litres per minute of water) and maintained a five-minute shower, could save around **11.5 cents per shower** for the costs of both the freshwater and waste water.

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 per kWh would be **13.2 cents per shower**.

The total savings would be about **25 cents per shower** (46% due to reduced water and 53% due to reduced energy), or over a full year $90 assuming one shower per day. In this case the retrofitting of a low-flow shower head (product cost about $40), would have 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.

Hot-water standing loss analysis

HEEP has regularly reported on the standing losses of hot-water systems. With the addition of the Christchurch houses and the second year of Auckland houses, the number of hot-water systems available for analysis has almost doubled. Unfortunately, with the increase in numbers there has been a large increase in exceptional and unusual cases, which have caused problems for the standing loss analysis methods.

The data currently coming in from the HEEP clusters (which are predominantly small towns and semi-rural areas) are even more unusual, as hot-water electric network load would appear to be controlled more tightly in many of these areas. As a consequence, the methods previously used to estimate standing losses have been replaced by a new method. Ideas for methods to maximise the opportunities to improve hot-water cylinder energy efficiency are also reviewed.

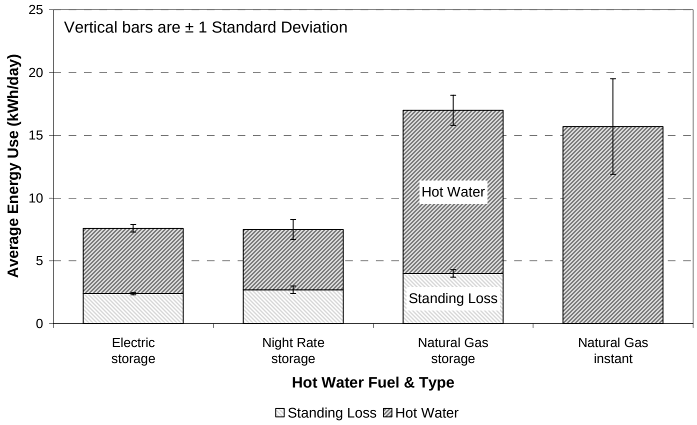

Figure iv: Energy consumption & standing losses by system type

Revised estimates of average total energy use and the standing losses are provided for four cylinder types: electric storage, electric night rate storage, natural gas storage and natural gas instant. Total energy use ranges from 7.5 (electric night rate storage) to 17 kWh/day (natural gas storage). Average standing losses range from 24% (natural gas storage) to 36% (electric night rate storage) of the total energy use. (see Figure iv)

Obtaining HEEP reports

The HEEP team has worked to ensure the results of the work are available to the widest possible range of stakeholders – including the public, special interest groups, government agencies and other researchers. References to previous HEEP reports, and other publications on the HEEP work, are given in the full report. Many of these are available for downloading from BRANZ website shop.

Copies of the full Year 7 report are available from BRANZ, using the order form below:

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