STUDY REPORT

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Energy Use in New Zealand Households – Executive Summary

Report on the Year 8 Analysis for the Household Energy End-use Project (HEEP)

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Energy Use in New Zealand Households – HEEP Year 8 Report
December 2004
Executive Summary

This is the eighth annual report on the Household Energy End-Use Project (HEEP). 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, lights, appliances, etc). The report provides:

- a review of the **importance of energy end-use data** to New Zealand energy planning
- preliminary analysis of the **emerging social data**
- information on the use of **LPG heaters**
- an analysis of **temperatures** found in New Zealand homes
- a comparison of the **space heating energy use with the ALF3** programme
- a literature review of **international demand-side energy models**
- background details to the **development of the HEERA model**.

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HEEP in action

HEEP has continued to contribute to the national energy debate in the past year. The creation of the Electricity Commission, the release of a 'Sustainable Energy' discussion paper, and the ongoing development of the National Energy Efficiency and Conservation Strategy, have all shown the need for improved understanding of energy supply and energy demand. Most importantly, understanding of energy demand can be used to identify opportunities to deal with energy supply issues, rather than taking the simplistic option of new supply investment.

The exploration of the HEEP research into previously uncharted residential energy use has already given some important insights. Some early examples are listed, and as the analysis progresses with the completion of monitoring, further insights can be expected.

- **Time-of-use profiles** – real profiles for different consumer groups
- **Domestic hot water** – quantifying losses due to cylinder and pipe insulation
- **Water conservation** – use of mains and low pressure hot water for showers
- **Winter temperatures** – living room and bedroom temperatures
- **Thermal insulation** – impact on energy use and space temperatures
- **Lighting power** – importance as a component of peak power demand
- **Appliances** – standby energy use while waiting to be used
- **Faulty appliances** –energy and cost benefits from identification and replacement.

What uses household energy?

For the past 30 years, almost all knowledge of household energy use has been based on the 1971/72 Household Electricity Study. As the title suggests, that study was concerned solely with electricity use – the use of other fuels (e.g. for water heating, cooking or heating) was recorded, but no estimate was made of that fuel use. Figure i shows electricity by end-use as found in 1971/72, and Figure ii provides comparable HEEP results for Auckland.

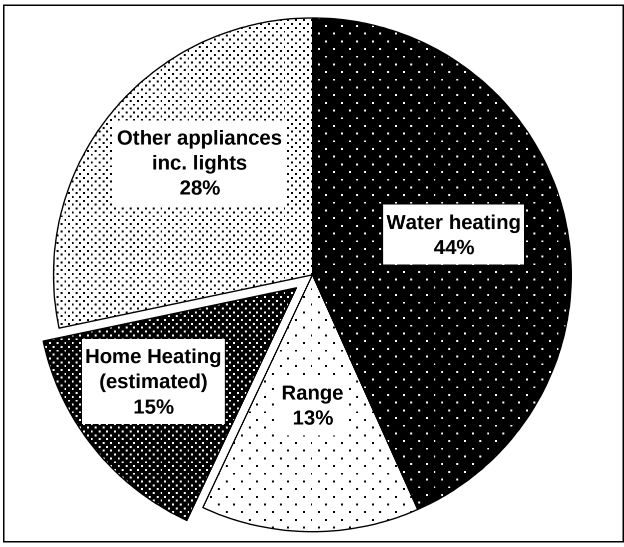

Figure i: 1971/72 NZ electricity end-uses

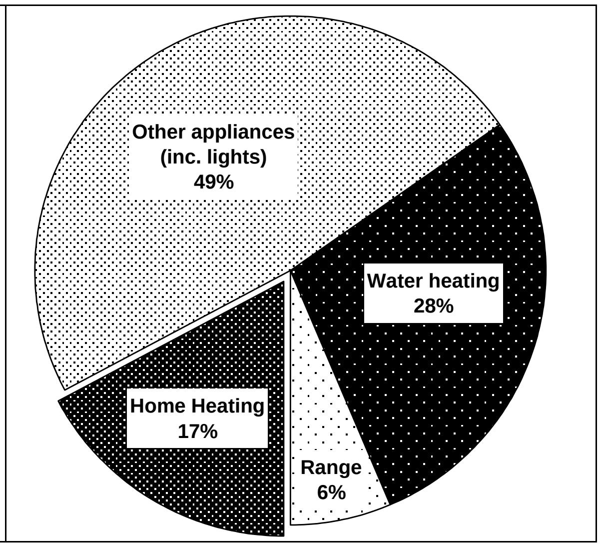

Figure ii: HEEP Auckland electricity end-uses

Whilst the household electricity use is similar (average 8,400 kWh/yr in 1971/72 compared to 7,900 kWh/yr average for the Auckland HEEP houses), the main three end-uses of electricity have shifted considerably from the pattern found in 1971/72.

A closer examination of the HEEP data finds that lighting (about 15%) and refrigeration (about 10%) each account for a sizable portion of the electricity use. The importance of these uses have not previously been recognised, possibly due to a lack of end-use data or perhaps because each is only a small power load. However, a small load turned on and used for a long time (e.g. a heated towel rail operating all day, all year) uses as much energy as a large load turned on for a comparatively short time (e.g. electric clothes dryer used 90 minutes daily).

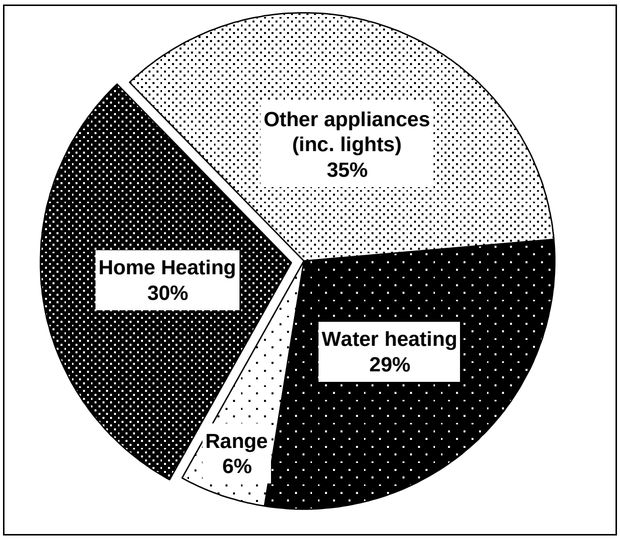

Figure iii: Residential energy end-uses – all fuels

Understanding household electricity use does not provide an adequate understanding of energy use. Although electricity can provide all house uses, very few households use only electricity. In particular, most households use more than one space heating fuel.

Figure iii gives a preliminary energy estimate based on the 300 randomly selected HEEP houses in Auckland, Wellington, Christchurch, Dunedin, Invercargill, Whangarei and Tauranga, and in locations on the Kapiti Coast, Otago, Northland and Waikato. The values may change as wet-back and solar water heating are included.

Lighting and peak power

May 2004 saw the spectre of winter power outages in the top of the South Island due to potential peak demand electricity transmission capacity constraints. HEEP identified lighting as a noticeable use of household electricity, and a significant part of peak power demand.

Analysis of the HEEP database suggested that the peak lighting load was about 200 W per house. For the 230,000 houses in the area of the South Island expected to be subject to peak power constraints, this is a peak load of 47 MW.

The HEEP surveys showed that on average there are 20 incandescent lamps, one compact fluorescent lamp (CFL) and one halogen lamp in houses. Halogen lamps can not be simply replaced by CFL, as the fittings are not suitable. Of the incandescent lamps, some will be in fittings unsuitable for CFL, not all are high use, and some are not used at peak times. A comparison of the average lighting power to the peak power load suggested that, on average, two incandescent lamps per house could be usefully replaced by CFL. This would reduce the peak power demand by 35 MW (i.e. from 47 MW to 12 MW) without reducing the service provided to house occupants.

The replacement of a 100 W incandescent lamp that is used all evening by a 25 W CFL at a cost of $10 (including GST and installation), will save the householder $16.38 per year. It will also reduce peak electricity demand at a cost equivalent to $130 per peak kW. The capital cost of the incandescent lamps, assuming a service life of 1,000 hours, is actually 50 cents higher than the capital cost of the CFL, also giving the householder a capital benefit.

In some houses more lamps could be expected to be ‘on’ at peak times – kitchen, living room, hallway, study, dining room – and these may provide additional peak power reductions, but would need to be considered on a house-by-house basis.

Faulty appliances

As the number of appliances in New Zealand homes increases, it is to be expected that some will fail. In many cases the failure will be obvious e.g. the television fails to work, and the appliance will be replaced. However, HEEP monitoring results are showing that when some appliances fail the failure mode does not alert the users to the failure. Such appliances may continue to consume more energy than necessary, but not provide the expected service.

For example, refrigeration equipment (refrigerators, refrigerator/freezer combinations or freezers) uses about 10% of household electricity. The HEEP survey has found that 55% of the refrigerators, 50% of the refrigerator/freezer combinations and 80% of the freezers are more than 10 years old (i.e. manufactured before 1994). This age is significant, as ozone depleting CFC refrigerants and blowing agents were phased out in 1994.

What happens when refrigeration appliances fail? HEEP monitoring has found that nearly one in five refrigeration appliances have a problem – approximately 10% are faulty, with a further 8% marginal. Nationwide, this is equivalent to over 400,000 appliances.

The number of refrigeration appliances with problems is so large that there is an opportunity for real benefits – not only to the individual household (through improved food storage and energy savings), but also to the nation (through reduced electricity demand) and to the wider world (through correct identification of failure and recovery of the CFC gas).

HEEP estimates that each faulty refrigeration appliance uses about 550 kWh per year more than they would if operating properly – a cost of about $90 a year per appliance. Taking into account the faulty and marginal refrigeration appliances, the unnecessary expenditure could easily reach $30 million per year. If these appliances were replaced by modern appliances using half the energy of a correctly operating old appliance, the benefits could easily double.

Emerging social data

HEEP has always undertaken a detailed survey of house occupants. HEEP currently holds socio-demographic information for 399 households that can be analysed in relation to indoor temperatures, energy use, energy consumption behaviours and, eventually, in relation to the energy performance of dwellings. Of those dwellings, the 296 for which monitoring has been completed can also be analysed in relation to total fuel use.

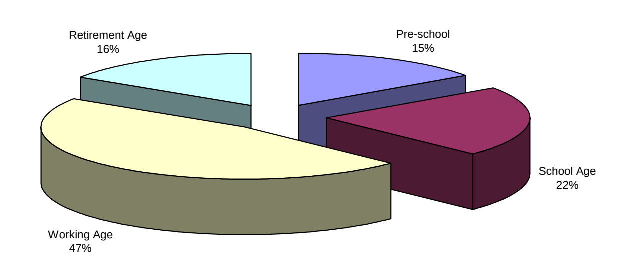

Figure iv: Age of youngest household member

The pre-dominant HEEP household is couple-with-children which make up 35.5 percent of the households, followed by couple-only households (31 percent), with one-person households at 13.1 percent.

Figure iv profiles the HEEP households in relation to critical life stages associated with the youngest household member. Just over a quarter of the households had no adult member of the household in employment (25.2 percent), while 17.4 percent were households in which all the adult members were in full-time employment. The other largest category of households is that with a mix of adults in full-time and not-in-employment.

The Luxemburg method was used to calculate equivalised household income, in order to control for household size effects. The data emerging from this analysis appear to show some connection between household income and indoor temperature, and some variation in energy use according to household composition and life stage characteristics – but these analyses are very preliminary and may be subject to change.

Nevertheless, when considering winter evening living room mean temperatures, it does appear that lower equivalised income groups are over-represented in those dwellings which might be described in comparison to other HEEP dwellings as cold or below average. Conversely higher income groups tend to be over-represented in dwellings which are hot by comparison to other living room mean evening temperatures.

By contrast, similar but again very preliminary analysis, suggests little association between mean evening living room temperatures and household life stage. Households with the youngest member in retirement appear to be slightly under-represented in the dwellings that are relatively cold and somewhat over-represented in the dwellings that are relatively warmer. Similarly, households with the youngest member being a pre-school child tend to be slightly over-represented in relatively cold households and in households with above average mean evening living temperatures. They are, however, under-represented in dwellings that could be categorised as being relatively hot.

The results of this work have the potential to play an important role in the development of the relationship between social and energy policies.

LPG heaters

The monitoring for HEEP in 2003 and 2004 has found a large increase in the number of LPG heaters. This may relate to the monitoring design which commenced in major population centres followed by minor centres, leaving minor urban and rural areas to the last two years of monitoring. The total HEEP sample now includes 157 portable, flueless LPG heaters.

There has been a small narrowing of the difference in the proportion of households with dehumidifiers in LPG owning and non-LPG heater owning households since the HEEP Year 7 report. For the current sample, 22% of houses without LPG heaters had a dehumidifier, while 31% of houses with LPG heaters had a dehumidifier.

Over 40% of the LPG heaters are used for less than five hours per week during winter months, with half the heaters spending about 90% of this time on one setting. For these heaters, about two thirds use the low or economy setting (equivalent to about 1.5 kW).

Indoor temperatures

The 1971/72 temperature study found a strong consistency in the differences between inside and outside temperatures, and concluded that this indicated that "in homes throughout New Zealand, rooms tend to be heated to certain levels above the surrounding outside air temperature, rather than to a universal absolute temperature level."

This would not appear to be the case for the HEEP sample, with the temperature differences between the inside and outside ranging from 4.6°C in the Northern North Island to 7.4°C in the Southern South Island. Excluding the Southern South Island (average 14.7°C), average living room temperatures are close to 16°C over the rest of the country. The majority of houses (72%) report heating start in April or May and finish in September or October.

HEEP analysis continues to be based on a winter heating season from June to August (inclusive) and the evening period as the time from 17:00 to immediately before 23:00. Overall, there is constant heating in the living rooms of approximately 10% of the HEEP houses, mainly in Southland/Otago, the Central North Island and the East Coast of the North Island. These areas also have a higher proportion of houses with solid fuel burners.

House age group	Winter evening living room (± SD)	Bedroom overnight (± SD)
Pre-1978	17.6 ± 0.1°C	13.2 ± 0.1°C
Post-1978	18.6 ± 0.2°C	14.5 ± 0.2°C

Table i: Winter temperatures by insulation level

Houses built after 1 April 1978 were required to include a minimum level of insulation, while insulation was not required in older houses. Table i shows a 1.0°C difference in living room evening temperatures between pre- and post-1978 houses, and 1.3°C in overnight bedroom temperatures. This temperature difference remains consistent with that reported in previous HEEP reports, although average temperatures have risen. This increase could be due to the large number of solid fuel burners in the current monitoring. Examination of the heating schedules found that occupants in pre-1978 houses do not use significantly different heating times to those in post-1978 houses.

Fuel	Temperature	Sample count
LPG	17.1 ± 0.2°C	54
Electricity	17.2 ± 0.2°C	108
Gas	18.0 ± 0.4°C	33
Solid Fuel	18.7 ± 0.2°C	152

Table ii: Winter evening living room temperatures by heating fuel

The fuel type also plays a role in establishing house temperatures. Table ii illustrates that houses heated with gas or solid fuel are warmer than electric and LPG-heated houses. Note that 'gas' includes reticulated gas and the large home gas (LPG) cylinders. LPG represents only the portable cabinet type LPG heaters, generally with a 9 kg gas bottle.

The heating system is also important, as houses with gas central heating or enclosed solid fuel burners are the warmest group with average evening temperatures over 18°C, while electric heaters or LPG have average temperatures around 17°C. Living rooms heated with open fires are the coolest, with average temperatures of 16°C.

ALF and HEEP household space heating energy use

HEEP produces estimates of annual heating energy use in the monitored houses, while the Annual Loss Factor, 3rd edition (ALF3) estimates the annual heating energy required for a residential building based on the house physical location and construction, and a selected heating schedule.

ALF3 models were prepared for 181 HEEP random houses. Only houses with electricity, natural gas and LPG heating were included, with locations from Kaikohe to Invercargill. No limits were placed on occupants, locations or any other house characteristics.

Areas identified as potentially causing differences between the HEEP estimate and the ALF3 model include the accuracy of HEEP space heating estimate methods, differences in internal energy gains due to appliances, different occupant behaviour and changes in the number of occupants, different space heating zoning and different time patterns (months of year and hours of day).

It was found that after making allowance for these differences, the energy used by households that are consistently heated is able to be estimated by ALF3 to within ±20%. This is a very acceptable result. All HEEP houses will be modelled in the coming year.

Residential energy-use model

An international literature review was undertaken of residential models in the United Kingdom, the USA, Canada and New Zealand. The results will be used to assist in the development of the Household Energy Efficiency Resource Assessment (HEERA).

The review included surveys of the condition and occupancy of housing stock, programmes to model house heating, and energy scenario models. These models include both *top-down* (emphasis on macroeconomic trends and relationships) and *bottom-up* (emphasis on physically-based engineering-type variables).

HEERA is a bottom-up type scenario model that allows the investigation of trends in energy consumption and the impact of energy efficiency options on energy use and greenhouse gas emissions from a range of viewpoints. HEERA does not currently include a macroeconomic equilibrium mechanism to provide an energy-price feedback to the demand-side. However, when the effects of policy options which change the price of the fuels need to be taken into account, and if end-use fuel-price elasticities justify it, this could be developed.

The database supporting HEERA is disaggregated at the regional, dwelling type, end-use and appliance levels. It includes variables to represent occupant socio-economic and demographic characteristics. This enables the historic and projected estimation of residential energy use, energy supply and greenhouse gas emissions. These sub-models calculate the dwelling and appliance stock, and the space heating, water heating, cooking, lighting, refrigeration, laundry and electrical appliance energy use.

Dwelling and appliance stock models simulate dwelling and appliance stock changes through a dynamic balance between the annual addition of new stock and removal of old stock.

The space-heating model simulates a dwelling's space heating requirements by taking into account its physical features (construction, heating systems, location) and uses external inputs for household operations (temperatures and heating regimes). Water heating, lighting, cooking, refrigeration, laundry and electrical appliances contribute to the space-heating internal heat gains through their models.

The rest of the models calculate the energy used by dwellings for water heating, cooking, lighting, refrigeration, laundry and electrical appliances with the use of household demographics and operation, e.g. family type, size, composition and income, water and energy use, temperatures and usage regimes.

Year 8 Executive Summary

HEEP activities and reports

Data collection will be completed in 2005, when full data from 400 randomly selected houses will be available. Until then, 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 300 randomly selected houses, as well as non-random selections. Regional coverage now includes Auckland, Wellington, Christchurch, Dunedin, Invercargill, Whangarei and Tauranga, and in locations on the Kapiti Coast, Otago, Northland and Waikato. The final year of monitoring is mainly rural locations.

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, although such analysis can be informative, it is not necessarily applicable to all situations. For example, it will not provide guidance to aspects of the:

- importance of household income or compositions on energy use
- importance of different aspects of house construction on indoor temperatures
- energy time-of-use profiles

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

The HEEP team has worked to ensure the results of the work are available to the widest possible range of stakeholders. 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 at no charge from the BRANZ website shop.

Copies of the full Year 8 report are available from BRANZ using the order form below:

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