Project No. ER0323			
Date: November 2002			

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STUDY REPORT

No. 115 (2002)

Energy Use in New Zealand Households - Executive Summary

Report on the Year 6 Analysis for the Household Energy End-use Project (HEEP)

Supported by:

The work reported here was jointly funded by the Building Research Levy, the Foundation for Research, Science and Technology from the Public Good Science Fund and the companies whose logos are shown above.

ISSN: 0113-3675

Energy Use in New Zealand Households – HEEP Year 6 Report
November 2002
Executive Summary

This report covers the activities of the sixth full year of the Household Energy End-use Project (HEEP). HEEP represents a major commitment by funding and research organisations to make available improved knowledge about the actual energy use of real New Zealand houses occupied by real families. This report is based on data from 100 homes, with a further 100 houses being monitored each year. Monitoring will be completed in early 2005.

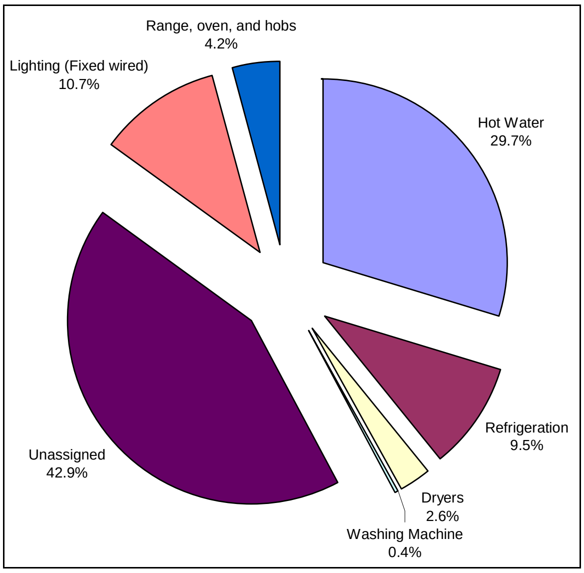
If you are interested in participating in HEEP or would like further information about obtaining outputs customised to your specific needs, please contact the HEEP team. We acknowledge the support of the funders listed on the front cover.

Background
All our homes use energy in various forms and for a wide range of end-uses, yet our understanding of household energy consumption is limited. Until HEEP was established in 1995, the most recently available data came from the 1971/72 household electricity survey.

Over the past 30 years many questions have been raised about household energy use – how warm are New Zealand houses, and has this changed over 30 years? How often are 'new' appliances used, and what is their impact on peak power or energy use? Do insulated houses use more or less space-heating energy? HEEP is starting to provide answers to these questions, and will answer many others.

HEEP covers four key topics leading to improved knowledge of the residential energy use:
- **Fuel use patterns** (all fuels – electricity, natural gas, LPG, solid fuels, solar, etc.)
- **Energy end-use** data (includes 'real time' analysis of how energy is used in the household-appliances, space conditioning, water heating, lights, etc.)
- **Occupant profiling** (number, income, socio-demographic details, etc.)
- **Household profiling** (construction, appliances, total income, etc.).

Household Energy Use



Work has been underway understanding New Zealand's energy supplies for well over 100 years. Exploration for coal, natural gas and oil deposits is expensive but is actively pursued. On the other hand, HEEP is the only activity investigating household energy demand.

The average energy use per household has grown by about 2% since 1990 but as the number of households has increased, the total household energy use has increased by 16%. If the National Energy Efficiency and Conservation Strategy (NEECS) goal of reducing this total energy use is to be achieved, it will be necessary to understand the reasons for the energy demand.

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HEEP now estimates the average Auckland, Wellington and Hamilton household energy use is 10,500 kWh/year, including electricity, natural gas and LPG. Work is continuing on the analysis of solid fuel use, but preliminary results suggest that it will not result in a sizable increase. One reason is that heating fuels are only used for a few hours per day during the four to five month heating season, so although the impact on monthly energy use may be significant, it is not for annual average energy use.

There is no statistically significant difference in average household energy use between HEEP houses in Auckland, Hamilton and Wellington. Improved estimates of household appliance energy use have been prepared. Over the three locations, hot water accounts for about 30% of electricity and gas use, lighting about 10%, refrigeration about 10%, cooking about 4% and clothes washing and drying about 3%.

HEEP Model

One output of the HEEP research will be a model of the residential energy sector. Linking together energy demand, household socio-demographics, occupant behaviour and the building's physical attributes, the HEEP model will provide a range of outputs to meet the needs of policy and implementation programmes.

The UK residential sector energy model BREDEM provides an example of the type of outputs. BREDEM shows that over the period 1970 to 1996 the average energy use per household has not increased, while the average indoor temperature has increased from 13°C to 17°C. The space heating energy consumption per house has remained stable over 36 years, despite use of central heating increasing from 34% to 87% of UK houses.

BREDEM was used to analyse the impacts of government mandated energy efficiency measures applied to UK housing. It showed that they have resulted in energy savings of roughly 37% – of which 20% is due to improved insulation, and the remaining 17% to improved heating efficiency.

In the absence of the HEEP model, only a limited evaluation can be made of the New Zealand situation. For comparison, annual energy use per New Zealand household increased from 40 GJ in 1980 to 43 GJ in 2000, and the proportion of houses with central heating has remained static at 5%. There is no evidence that internal temperatures in New Zealand homes have increased. However, their low thermal performance suggests that should the internal temperatures increase, there would be a sizable increase in energy use and in climate change gas production.

International Comparisons

Country	Household energy use (kWh/year)
New Zealand	10,500
Australia	16,400
UK	22,200
US (average)	26,700
Canada	39,700

New Zealand households use less energy than those in many other developed countries. The table shows that the average New Zealand household uses 30% less energy than Australia, close to 50% less than the UK, and 70% less than Canada. Given the climates found in these countries, some difference is not unexpected but it is likely the low New Zealand value relates to low levels of space heating energy use.

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The table below compares household expenditure on 'energy' for the five countries. For all five countries, the proportion of expenditure on stationary energy (i.e. excluding transport energy) is within the range 2.6% to 3.5%, even for countries expected to require greater indoor temperature control – either due to hot or cold external temperatures. The reasons for this apparently similar proportion of expenditure have not been investigated, but could be due to a range of factors, including energy pricing policies, house thermal performance, occupant expectations or even the expenditure survey methodology.

Country	Description	Deciles 1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	All Households
New Zealand	Domestic fuel & power	6.0%	5.5%	4.8%	4.0%	3.4%	2.8%	2.3%	2.0%	1.8%	1.5%	3.4%
UK	Fuel and power	6.5%	6.7%	5.5%	4.2%	3.6%	3.2%	2.9%	2.6%	2.4%	2.0%	3.1%
		Quintiles										
			1st		**2nd**		**3rd**		**4th**		**5th**	
Australia	Domestic fuel & power		3.7%		3.3%		2.7%		2.3%		2.0%	2.6%
USA	Nat. gas, elect, fuel oil etc		4.9%		4.4%		3.6%		3.0%		2.4%	3.5%
Canada	Water, fuel, electricity											3.3%

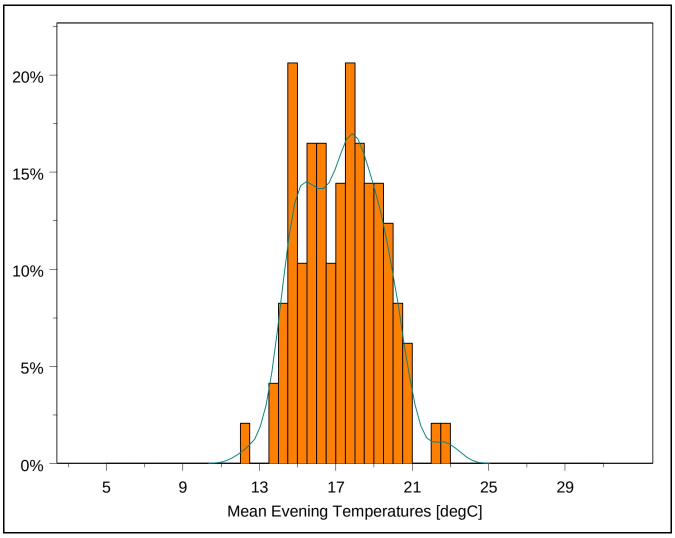
In all four countries for which expenditure against income data is available, the proportion spent on energy decreases with increasing income, with New Zealand and UK showing the largest difference (4.5%) between the lowest and highest income groups. Examination of the Statistics NZ 'Household Economic Survey' (HES) shows that over the period 1987 to 2001, the proportion of expenditure spent by low income households has increased while for higher income households it has remained static.

Indoor Temperatures

Patterns are emerging as to how houses are heated. There is some variation in the heating season length – ranging from four months in Auckland to closer to five months in Hamilton and Wellington. For most of the HEEP houses, heating starts around May and finishes in September. Hamilton houses are the warmest, followed by Auckland and then Wellington.

City	Start heating	Peak temperature	Heating period
Auckland	5:45 pm	8:30 pm	4½ hours
Hamilton	4:30 pm	7:00 pm	4¾ hours
Wellington	5:00 pm	9:30 pm	7 hours

The time of heating for the three regions are shown in the table. No obvious explanation for the differences has been found, and this will be further investigated in other locations.



The graph provides an overview of the winter evening temperatures in all the monitored houses (including non-randomly selected houses). This follows the normal (bell shaped) distribution, with an average temperature of 17.3°C and a standard deviation of 2.1°C.

Household heating is strongly zoned, e.g. while the living areas are heated, less than 50% of households heat bedrooms, and most do not heat utility rooms (bathrooms, laundry, etc).

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The winter evening temperatures measured in living rooms were compared to the range of socio-economic responses provided from the household occupant survey. No correlation was found between household income or house floor area and winter evening temperatures. This confirmed the egalitarian nature of New Zealand society – high-income households are no warmer than low-income households.

Insulation group	Average winter evening temperature	Winter evening energy use
Pre-1978	17.0 ± 0.2°C	1070 ± 280 W
Post-1978	18.4 ± 0.4°C	1130 ± 150 W

There is a significant correlation between winter evening temperatures and the age of the house. Currently, we can conclude that post-1978 houses are 1.4°C warmer on average and that their winter evening energy use is not significantly different from the pre-1978 houses. This would suggest that where it is possible to achieve warmer temperatures, New Zealanders will do so.

LPG Heaters

The number of households with portable gas heaters has increased from 2% of households in 1984 (the least popular of the eight heating types surveyed at that time) to 33% (452,800) of households in 2001 (second only to portable electric heaters). The increase in the usage of portable gas heaters is closely matched to the reduction in usage of the other two types of portable heaters surveyed: portable electric heaters (reducing from 89% of houses in 1984 to 71% of houses in 2001); and portable kerosene heaters (reducing from 11% to 1%).

HEEP has developed a special technique to permit the monitoring of time-of-use and power output of portable gas heaters. Coupled with graphical data exploration tools, this provides for the first time, detailed information on the use of LPG heaters. For this report, use data from ten heaters in nine houses was available. It was found that they are:

- mostly used on **'Low' setting**: The majority of the heaters (7 out of 10) were used the majority of the time (73% to 100%) on a 'low' setting (1.3 kW to 1.7 kW), while of the remaining three heaters, only one was used for the majority of the time at a 'high' (3.6 kW to 4.3 kW) setting.
- generally used for **short periods of time**: Only three of the heaters are used (on average) for more that one hour per day, and of the other seven heaters, six are used for on average half an hour or less per day over winter.

This does not seem to match an expectation that as LPG heaters are capable of higher power outputs than standard '3-pin plug' electric heaters (which are limited to 2.4 kW), they would be used for longer periods of time at higher settings. It was also observed that for houses with a high evening LPG heater use, electricity peaks occur before or after the heater use.

Hot Water

Hot water is a major energy use in the average New Zealand home. Previous HEEP reports found hot water energy use was on average 4000 kWh/year/house or about 44% of total energy. The average hot water standing loss is 1000 to 1100 kWh/system/year, representing about 11–12% of total energy use or 25–30% of the hot water heating energy.

The table below provides selected new information for the three types of hot water systems – electric storage, natural gas storage and natural gas instantaneous – monitored by HEEP. About 75% of the houses have electricity as the main fuel for hot water supply, 15% use natural gas and 10% use instant natural gas. Both the amount of energy and delivered hot water used for houses with natural gas systems is higher than for electric systems.

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Based on Auckland, Hamilton, Wellington HEEP monitoring	Strata weighted average	Electric storage	Natural gas - Storage	Natural gas - Instant
Age (years)	15±1	18±2	12±2	3.4±0.8
Cylinder volume (l)	158±4	152±4	150±10	-
Standing loss (kWh/day)	2.5±0.2	2.6±0.1	4±0.4	-
Used hot water energy (kWh/day)	7.3±0.6	5.3±0.4	12±2	14±1

Large reductions in energy use and Greenhouse Gas emissions can be achieved by upgrading the energy efficiency of hot water systems, and by reducing hot water consumption. EECA's "Residential Grants Programme" has implemented a range of improvements to hot water systems, which include cylinder wraps, pipe insulation and low-flow shower heads. The projects have been run by various interested groups including community groups, local energy trusts and power/lines companies, and commercial companies.

The HEEP data supports the calculation of the change in GHG emissions resulting from upgrading the insulation on the hot water cylinder, based on: the energy use/GHG emissions before upgrade; the energy use/GHG emissions after upgrade; the lifetime of upgrade and the lifetime of system if the upgrade was not put in place.

In the houses monitored to date, poorly insulated cylinders have been found far more often than expected. About 30% of cylinders are more than 25 years old, with the oldest at more than 45 years. Clearly, old cylinders are widespread in New Zealand, with around 40% C (pre 1986) or D (pre-1976) grades. With an average age of 33 years for D grade electric cylinders (and the youngest 15 years), this would suggest that old cylinders are not replaced until they are over 40 years old. This would also suggest that the benefits from retrofitting cylinder wraps may be greater than previously expected.

Of the hot water systems surveyed, very few of any age or grade had cylinder wraps or pipe lagging. Pipe lagging is likely to be equally cost effective on sizes and types of hot water systems, including gas systems. Savings for pipe lagging are approximately 120 kWh per year, giving a saving of about $16 per year, and payback from 6-18 months, depending on the cost of lagging.

Replacing a 180 litre D grade cylinder with a new A grade cylinder gives greater energy savings and GHG reductions than wrapping the cylinder. Similarly, installing a heat pump, solar water heater, or changing to gas fuel will result in energy and GHG savings. However, unless the cylinder needs to be replaced (e.g. due to age, house modifications, etc) then cylinder wrapping is by far the most cost-effective measure, as shown in the table below.

Measure	Cost	Energy savings	Simple Energy Payback	GHG savings
Cylinder wrap	$100	$88/yr	1.1 yr	$6.40/yr
New A grade	~$1200	$100/yr	12 yr	$7.30/yr
Hot Shot heat pump	~$1800	$274/yr	6.4 yr	$20/yr
Solar	$3500+	$356/yr	10 yr	$26/yr
New gas cylinder	~$2000	~$300/yr	6.7 yr	~$25/yr

HEEP results could be used to develop a decision support tool for selecting houses (or locations) most likely to benefit from improved hot water system efficiency activities.

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No simple relationship has been found between the size of the hot water cylinder and the size (floor area) of the house, but older houses often have smaller cylinders. When this is coupled with a larger number of occupants, it is not uncommon for the water temperature to be increased to unsafe levels. Tap temperatures are on average higher for electric storage cylinders than for natural-gas storage cylinders, although the storage volumes are similar. A 135-litre cylinder storing water at 75°C holds the same hot water energy as a 180-litre cylinder with water stored at 55°C, but the higher temperature is clearly unsafe for all users. Where smaller cylinders have to be replaced, consideration should be given to increased cylinder size.

Uses of HEEP

The HEEP results have already played a crucial role for energy companies to evaluate opportunities to manage their loads and deal with proposed legislative changes, for appliance supplies to understand how consumers use their products, and improving the debate over how energy is actually used in New Zealand households.

Internationally the use of theoretical or modelled data as the basis for energy-efficiency requirements is recognised as inadequate. For example, in June 2002 the US Department of Energy withdrew a proposal for changes to Energy Star windows, doors, and skylights, citing a “lack of empirical data on the role of solar heat gain in certain regions of the country”.

HEEP results are supporting the revision of the New Zealand Building Code Clause H1 : Energy Efficiency, the National Energy Efficiency and Conservation Strategy (NEECS), identifying opportunities for greenhouse gas reduction to meet the requirements of the Kyoto Climate Change Strategy, and the ‘Minimum Energy Performance Standards’ (MEPS) and labelling programmes. HEEP research will also feed into environmental performance indicators being developed by the Ministry for the Environment and Statistics NZ.

HEEP is not a longitudinal study investigating changes in patterns of energy use over time; nor does it investigate the impacts of energy-efficiency changes to houses. The HEEP results will provide critical baselines for such studies, including current health and housing research.

Monitoring and Methodology

The use of BRANZ designed and built dataloggers, coupled with trained field staff, has resulted in high-quality data for analysis. The data can be processed promptly and analysed soon after collection.

The current monitoring of 100 houses in Auckland, Waikanae and Christchurch will finished in February 2003, so the database will hold 200 houses for the HEEP Year 7 report. The 100 houses to be monitored in Year 8 are spread around New Zealand – Invercargill, Dunedin, Oamaru, Waikanae, Waikato, Tauranga and Northland. Installations for year 8 are taking place from November 2002 to February 2003, and removal 11 months later.

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Location	*Year(s) monitored*	*Number of houses*
Wellington	1999	43
Hamilton	2000	17
Auckland	2001/02	98
Waikanae	2002	10
Christchurch	2002	37
Foxton Beach	2003	10
Oamaru, Dunedin, Invercargill	2003	30
Northland, Tauranga, Waikato	2003	59
Tasman, Marlborough	2004	20
Wairoa, Gisborne, Napier	2004	30
Franklin, Rodney, Thames	2004	30
Rotorua, Taupo	2004	30
TOTAL RANDOM HOUSEHOLDS		**414**

Random selection of households started in 1999. The table shows the progress to date and future plans for the target sample of 400 randomly selected, monitored houses. Data is also held on 66 non-randomly selected houses.

Further details of the planned locations, the monitoring methodology, monitoring documentation and analysis procedures are provided in the full report.

Other issues discussed in the full report include:

- Use of the Energy intellect Limited (formerly Total Metering Limited) TMA3100 remote monitored, integrated three-phase energy meter and data logger. This is providing new data on time-of-day Power Factors.
- Further analysis of the distribution of baseload and standby power.
- The use of 'Artificial Neural Networks' understand solid fuel heater patterns of use.

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 the BRANZ web site.

Copies of the full Year 6 report are available from BRANZ, using the order form below:

Postal address: BRANZ, Private Bag 50908, Porirua City, NZ.
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