STUDY REPORT

No. SR 141 (2005)

Energy Use in New Zealand Households – Executive Summary

Report on the Year 9 Analysis for the Household Energy End-use Project (HEEP)

Nigel Isaacs (Ed.), Michael Camilleri, Lisa French & Andrew Pollard (BRANZ Ltd),
Kay Saville-Smith and Ruth Fraser (CRESA),
Dr Pieter Rossouw (CRL Ltd),
John Jowett (Consultant)

Supported by:

FUNDED BY THE BUILDING RESEARCH LEVY

Foundation for RESEARCH SCIENCE & TECHNOLOGY
Tuāpapa Rangahau Pūtaiao

The work reported here was jointly funded by the Building Research Levy and the Foundation for Research, Science and Technology from the Public Good Science Fund.

ISSN: 0113-3675

Energy Use in New Zealand Households – HEEP Year 9 Report

Authors:
Nigel Isaacs (Ed.), Michael Camilleri, Lisa French and Andrew Pollard (BRANZ Ltd), Kay Saville-Smith and Ruth Fraser (CRESA), Dr Pieter Rossouw (CRL Ltd), John Jowett

This Executive Summary provides a selection of the results – copies of the full report can be obtained from BRANZ. Note that all **the results, monitoring and analysis methodology reported here are copyright to BRANZ Ltd** and not available for wider use without explicit permission. The results reported are subject to change as data processing proceeds.

This is the ninth annual report on the Household Energy End-use Project (HEEP). After six years of monitoring, the HEEP database now has data on a total of some 400 randomly selected houses, covering New Zealand from Invercargill in the south to Kaikohe in the north. The large majority (300) of these houses have been monitored in the past three years.

The 440 hot water cylinders, 65 wet-backs, 206 solid fuel burners, seven solid fuel ranges, 42 open fires and 175 portable LPG heaters provide a unique snapshot of how New Zealanders heat their hot water and homes. HEEP has collected at least two temperatures in each house's main living room and one in the main bedroom providing high quality data, not only on room temperatures, but also on the importance of room temperature gradients. The record is completed with detailed house occupant surveys, house physical and energy audits as well as over 8,000 photographs of the houses, appliances and monitoring equipment in place.

Nearly 14,000 appliance power measurements, label details from a further 6,000 appliances and detailed house light records provide a comprehensive overview of household electricity uses. This rich database provides an internationally unique resource for New Zealand. The possibilities for its use are wide, limited only by the imagination of potential users.

The report provides an overview of the entire project and the monitored houses; a review of the house selection methodology; an examination of the importance of selected social factors on household energy use and temperatures; a description of the development of the 'Household Energy Efficiency Resource Assessment' (HEERA) model; quantification of the space heating contribution of solid fuel burners; descriptions of the patterns of home heating (including heating season and indoor temperatures); an evaluation of the performance of the ALF computer programme; the first national estimates of residential standby and baseload power demands; and a historic review of hot water provision in New Zealand homes and analysis of current hot water energy use, including 'wet-back' supplementary water heating.

How New Zealanders live

HEEP offers a snapshot of New Zealand homes. Just over half of the HEEP houses had a solid fuel burner (52%), while fewer than one in nine had an open fire (11%). Four out of every nine houses (44%) had an LPG heater. A small number of houses had oil-based heating, and slightly more had a solid fuel range, which was often used for cooking and water heating. Only 28 of the houses had a spa or a swimming pool (7%).

The house floor areas ranged over a factor of six – from 51 m² up to 315 m², while the floor area per person varied by a factor of nearly 18 – although the highest occupancy was a small house with a number of occupants.

The most numerous electricity end-use is lights, ranging from a minimum of seven in a house up to a maximum of 143. All appliances in the house are recorded, with information on their location and power. A minimum of seven and a maximum of 82 appliances were recorded in any house, with an average of 33.

The largest numbers of a single appliance type were the 22 sewing machines in one house, but the most popular appliance is the television (averaging just under two televisions per house). The largest number of televisions in one house was nine.

Monitoring

Early HEEP monitoring was analysed to establish the required sample size. In order to estimate average space heating energy with an error of less than 10% and with 90% confidence, the required sample size was found to be 375 households nationwide. A target sample size of 400 households was set to ensure adequate numbers would be available in case of any problems e.g. any houses withdrawing from the study, or being found not suitable.

Now data collection is complete, this sample size has been found to be reasonable and provide acceptable error limits. Although not planned, it has also been found that it provides a reasonable basis for some regional energy use estimates.

Solid fuel burners and wet-backs

Previous studies of energy use in New Zealand houses have focused on the use of electricity and natural gas for space heating. These fuels are widely used, and easy to monitor and to analyse. As HEEP monitors all fuels, it has been necessary to develop appropriate systems to monitor portable LPG heaters and solid fuel burners. Analysis of space heating energy use has now been completed for all houses and all fuels.

The HEEP data shows that solid fuel burners play a major role in the heating of New Zealand homes. Solid fuel would appear to be at least as important as electricity for space heating. 'Energy Data File' estimates suggest solid fuel accounts for around 5% of domestic energy use, while the HEEP data would suggest it is over 15%.

Solid fuel burners are generally larger heat sources than portable gas or electric heaters. A not unexpected consequence is that houses heated by enclosed solid fuel burners are the warmest. Interestingly, houses heated by open fires are the coolest. The current environmental policies designed to shift away from solid fuel burners may have implications for other heating fuels.

Solid fuel burners are mostly used in the 0.5 to 4kW output range. It is likely that at these lower power outputs the emission levels differ from the full-power test measurements used for air quality certification.

Wet-back, supplementary water heaters, are not uncommon in New Zealand homes. A coil in the back of the burner feeds heat through a thermosyphon into the household hot water tank. On average, houses with wet-back systems get about 20% of the total hot water energy from the wet-back. About 5% of houses with wet-backs get all of their hot water supplied by the wet-back, although most of these systems are dedicated solid fuel water heaters. Overall, roughly 5% of the national total hot water energy is supplied by wet-backs.

There is regional variation in the hot water provided by wet-back systems. Some wet-backs provide only a few percent of the total hot water for a household, while some provide more than two-thirds. This is readily explained, because in colder climates the solid fuel burners are used more often, more intensively, and for more months of the year, so more energy is fed into the wet-back circuit. Wet-back water heating would not appear to be a good option in warm climates with short heating seasons.

Heating season

As part of the house survey, occupants are asked which months they heat and these have been used in previous HEEP reports for analysis of heating months. When the pattern of heating was evaluated based on the monitored energy use, it appeared that heating was occurring on average for one month longer than reported.

Regional Council	Start Temp. °C	End Temp. °C
Northland	15.2	15.2
Auckland	15.1	14.7
Bay of Plenty	14.2	14.2
Waikato	13.1	14.5
Gisborne/Hawkes Bay	13.7	13.8
Taranaki/Manawatu-Wanganui	13.7	13.5
Wellington	13.0	12.4
Tasman/Nelson/Marlborough	12.6	13.2
Canterbury	12.3	11.7
Otago/Southland	11.7	13.5

Table i: Heating season temperatures

The temperatures at which households start and stop their heating season were also explored, and are given by regional council area in Table i. The further south, the cooler the external temperature before heating starts. The Invercargill summer average temperature is cooler than the threshold for heating in Auckland!

All possible HEEP houses have now been modelled in the thermal simulation programme ALF3. the results will be used to develop ALF and in HEERA.

Standby and baseload

Standby and baseload power consumption has been reported in HEEP since 1999. These early estimates of standby (power used while the appliance waits to be used) and baseload (appliances that are on continuously) power consumption have been instrumental in raising awareness throughout Australasia. Now HEEP monitoring is complete, nationally representative estimates of standby and baseload power consumption can be prepared. This is a world first, as no other country in the world has undertaken a study comparable to HEEP.

Data on standby power comes from three sources within HEEP:

1. **End-use data:** 10 minute monitored energy data from individual appliances
2. **Power measurements:** spot measurements made during monitoring installation
3. **Survey:** occupant survey recording appliance numbers and use.

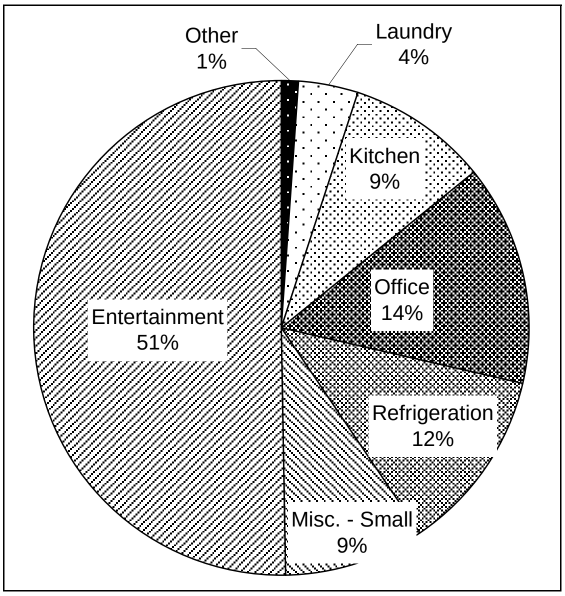

Fig i: Baseload & standby energy

By combining information from these three sources, a complete picture of household standby and baseload power consumption can be made. Figure i provides a breakdown by the main uses.

The average energy use per house for standby is equivalent to 58 W continuous i.e. the average New Zealand house is spending nearly $80 a year (at 15 c/kWh) just keeping these appliances powered-on while they wait to be used.

The top five appliance types in terms of their current standby impact on the electricity system are (in alphabetical order): fridge/freezers; home computer (includes monitor); stereo; television; and video recorders. They account for more than half the total household standby energy consumption. Three out of the top five are in the 'home entertainment' grouping.

The average house baseload and standby demand is 112 W ± 4 W continuous, equivalent to an annual cost of about $150 per year. Assuming 1.4 million houses, this is equivalent to about 150 MW of continuous load or an average Waikato hydro-power station.

This comprises standby power of 58 W ± 4 W and heated towel rail power of 21 W ± 2 W, with 33 W ± 6 W remaining. Hard-wired appliances (stove, sensor lights, etc) are 3 – 5 W. As discussed in the Year 8 HEEP report, faulty refrigeration appliances could easily account for 15 W ± 10 W per house, and the remainder of 14 W ± 12 W is not statistically different from zero. We can therefore conclude that it is unlikely that there are any other large components.

Domestic hot water

The energy used for domestic hot water can be split into two parts: a technical component that relates to the performance of the hot water generator, the piping system and the system design; and a social component that relates to patterns of use and the amount of use. HEEP has been concerned with establishing their relative importance.

Our houses represent 'snapshots' of ideas, equipment and facilities of the time they were built. Many, but not all, houses are refurbished (or even rebuilt) to more recent standards. In-house hot water is a relatively new facility in New Zealand homes – the 1945 Census found just over one-quarter lacked a hot water service but this had fallen to about 1% by the 1966 Census. Electric hot water cylinders (a New Zealand invention) were first used in 1915. By 1996, three-quarters (75%) of all homes had only electric hot water, but this reached a maximum of 82% in 1981. The 1996 Census, the most recent to collect hot water data, found 75% of houses had electricity only; 10.5% had electricity and solid fuel; 7% had gas only, and the rest had a range of different system types and combinations.

Since the 1971/72 Household Electricity Survey there have been noticeable changes in the use of showers (as noted earlier) and in the volume of electric hot water cylinders e.g. 56% of houses had 135 litre cylinders in 1971/72, but this has now fallen to 40%, while the use of larger cylinders has increased. Even so, 18% of HEEP households report they 'sometimes' run out of hot water.

Tap >60°C & Thermostat <=60°C 17%	**Tap >60°C & Thermostat >60°C** 43%
Tap <=60°C & Thermostat <=60°C 18%	**Tap <=60°C & Thermostat >60°C** 21%

Table ii: Count of thermostat setting vs tap hot water temperature

The poor performance of electric hot water cylinders identified by HEEP in 2003 has been confirmed by analysis of the full sample. Sixty percent of electric hot water cylinders deliver water at clearly unsafe temperatures (over 60°C). Only one-third of the cylinders have accurate thermostats (delivered temperature within ± 10°C of the thermostat set point), with older thermostats (marked in °F and likely to have been manufactured prior to 1975) performing with less accuracy than newer ones. One-half of the thermostats set at a safe temperature delivered unsafe water – so even if the occupants set the thermostat at a safe temperature there is an almost equal chance the delivered water is too hot.

Figure ii gives revise average total energy use and standing loss estimates for four systems types: electric storage, electric night rate storage, natural gas storage and natural gas instant.

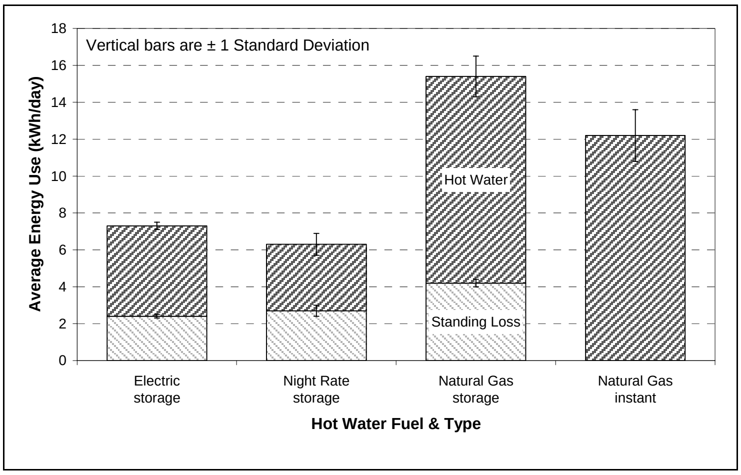

Fig ii: Energy consumption and standing losses by system type

Total energy use ranges from 7.3 (electric night rate storage) to 15.4 kWh/day (natural gas storage). Average standing losses range from 27% (natural gas storage) to 43% (electric night rate storage) of total energy use.

Energy use and standing loss data is now based on the total HEEP sample. For wet-back hot water systems, where possible, standing losses were also estimated. Newer A and B grade cylinders have lower heat losses in comparison to older, less well insulated C and D grade systems.

C or D grade cylinders fitted with an appropriate cylinder wrap have standing losses of 1.0 kWh/day (less than the unwrapped cylinders for 135 litre and 0.6 kWh/day less for the 180 litre cylinders). This would suggest that installing wraps on the approximately 240,000 unwrapped 135 litre and 160,000 180 litre systems could save about 122 GWh per year, with a retail electricity cost of about $20 million per year.

Cylinder wraps and pipe insulation could also give energy savings for A or B grade systems, although the savings would be smaller. Assuming a conservative 0.3 kWh/day saving, the potential savings for the approximately 600,000 A or B grade systems are 66 GWh per year, with a retail electricity cost of about $10 million per year.

Social drivers

The way we use our homes depends on many things – the type of home, the type of appliances, the type of people we are, just to name a few. As well there are changes in the way we behave as a society – for example in 1971/72 only 25% of houses used mainly the shower, nowadays the HEEP sample found 94% mainly use the shower.

The importance of a range of different social drivers for energy use has been explored, not only for total household energy use, but also for hot water and lighting energy use. These drivers need not only to have been collected by HEEP, but also need to be available in a long-term series to permit the scenario model to work. The key social drivers explored thus far relate to a measure of the household income (equivalised income), the life stage of the household (related to the age of the youngest person living in the house), the number of people normally living in the house, and occupancy (a constructed variable calculating crowding as a function of household size and total number of rooms).

Because of the close correlation between occupancy and household size, two sets of multiple regressions were undertaken. As Table iii shows, the explanatory power of these variable sets is not strong.

Predictor variables	Dependent variable	Adjusted R square
Equivalised income, life stage, size of household, occupancy	Log total energy use	0.225
Equivalised income, life stage, size of household	Log total energy use	0.210
Equivalised income, life stage, size of household, occupancy	Log DHW energy use	0.311
Equivalised income, life stage, size of household	Log DHW energy use	0.318

Table iii: Multiple regression analysis

When modelled together, the four selected social dynamic variables account for about 22% of the variance in total energy use, reducing to 21% when the occupancy term is dropped. For domestic hot water (DHW), occupancy accounts for about 32% of variance, but still the occupancy variable has little impact.

These results are now being used to help develop the HEERA model.

HEERA model

The main tool to come from HEEP will be an energy model of the residential sector. It will provide a very much improved understanding of energy use in New Zealand houses. The HEERA model estimates the historic and projected residential energy use, energy supply and greenhouse gas emissions (GHG) based on the economic, demographic and social drivers. The data collected by HEEP, and many other agencies such as Statistics New Zealand, provides baseline information on houses and their appliances, and the use made by different types of households of space heating, water heating, cooking, lighting, refrigeration, electrical appliance and electronic appliances.

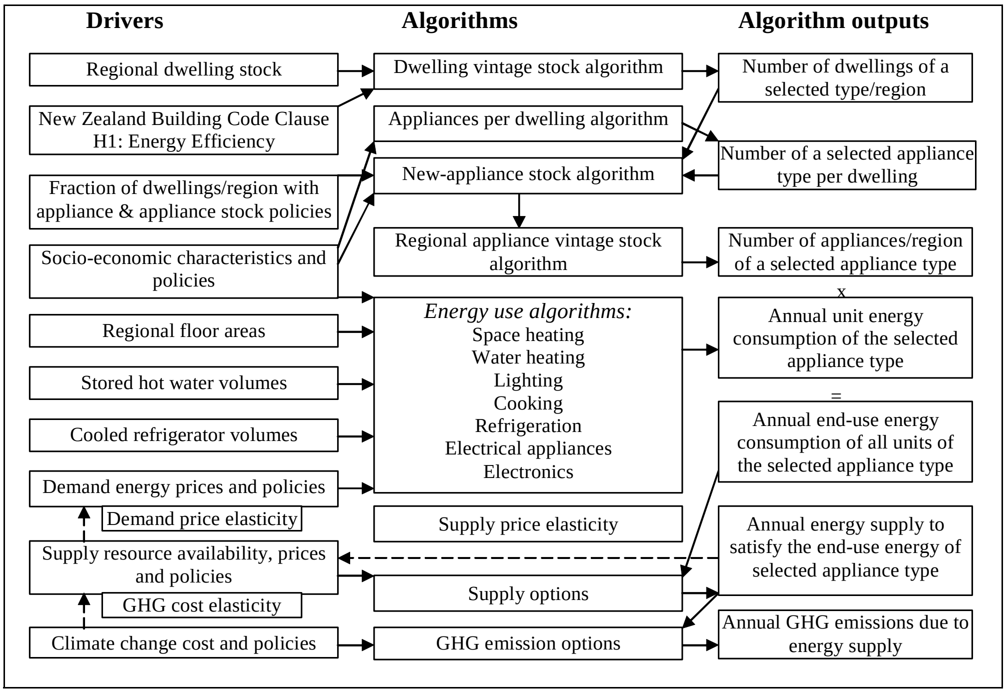

Fig iii: 'Household Energy Efficiency Resource Assessment' (HEERA) flow diagram

Over the past year the HEERA model structure has been developed (Fig iii), and historic data obtained. HEEP data has been analysed to create formulae that link together the many aspects of the model. In turn, the basic model has been tested, and used to construct a set of simple scenarios. HEERA has been implemented as a spreadsheet, and the software is now being developed for a free-standing programme.

Future

Each 1% improvement in the efficiency of energy use in New Zealand homes would result in a benefit of $17 million and reduce CO_2 emissions by 0.1%. HEEP and HEERA will provide clear guidance on the 'best' areas for action and the likely consequences, thereby maximising the potential benefits. The HEEP results will also lead to improvements in the design, construction and utilisation of New Zealand houses to enable them to meet the comfort expectations of all classes of occupants in the most energy efficient way.

Now that HEEP data collection is completed, our focus is on reporting analysis and developing the HEERA model. From its start, HEEP has received its main science funding from the Building Research and the Foundation for Research, Science and Technology. Funding continues until the end of June 2008, and is built around three objectives.

1. **Energy Use in Residential Buildings,** now completed it provided scientific support to the monitoring and data collection.
2. **Energy Demand Model** is supporting the development of HEERA, and will be completed by the end of June 2006.
3. **Promotion of Residential Energy Efficiency** commenced at the start of July 2005, and is focusing on ensuring that the new efficiencies and policy opportunities are taken up in the energy, health, housing, construction and welfare sectors.

Acknowledgements

We would like to acknowledge the support and help of the many households that have taken part in the HEEP research – 24% of the houses contacted have taken part in the project.

We offer our sympathy to those who lost loved ones during our monitoring and our delight in being able to be with those of you who celebrated times of great happiness. In addition to thanking the funding agencies named on the front cover, we would also like to thank the staff and students of the 'BBSC 331 Environmental Science' paper, School of Architecture, Victoria University of Wellington who helped with the final round of installations. Our thanks also to the many BRANZ Ltd staff who helped, including design and construction of data loggers and, of course, the HEEP field staff who have travelled over 126,000 km. Over the life of HEEP close to 1,250 people have been involved – without you, this research would not have happened.

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 at no charge from BRANZ website shop, or the HEEP page on the BRANZ website.

HEEP analysis can be commissioned. Please contact us and we will work with you to define your question and work out how HEEP analysis could best assist you. On request, your name can be included in our email list providing HEEP results several times a year.

Copies of this Executive Summary and the full Year 9 report are available through the HEEP page on the BRANZ website:

Postal address: BRANZ, Private Bag 50908, Porirua City, NZ
Phone: +64 (04) 237 1170 Fax: +64 (04) 237 1171
Email: HEEP@branz.co.nz Website: www.branz.co.nz