BRANZ

STUDY REPORT

No. SR 155 (2006)

Energy Use in New Zealand Households

Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)

Executive Summary

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

Supported by:

FUNDED BY THE BUILDING RESEARCH LEVY
BUILDING RESEARCH

FOUNDATION FOR RESEARCH SCIENCE & TECHNOLOGY
Tūāpapa 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 10 Report

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

This Executive Summary provides a selection of the results from the HEEP Year 10 report – copies of the full report can be downloaded from www.branz.co.nz or purchased from the BRANZ Bookshop on the website. **Note that all the results, monitoring and analysis methodology reported here are copyright to BRANZ Ltd**. This is the 10th and final Household Energy End-use Project (HEEP) annual report. A final report to be published in 2007 will bring together (and update) earlier annual reports, providing definitive results for the future.

The goal of HEEP is to understand how, where, when and why energy is used in New Zealand homes. This knowledge is being used to develop a model of the residential energy sector to help improve energy efficiency, reduce greenhouse gas emissions and identify new energy efficiency opportunities.

The HEEP database now holds energy, temperature, social and physical house data on some 400 randomly selected houses from Invercargill to Kaikohe. Monitoring began in 1997 and was completed in 2005, with the majority of the houses (300) being monitored in the last three years. Each house was monitored for about 11 months. All fuels (natural gas, electricity, solid fuel, solar water heaters, oil and LPG) are monitored for each house. The database holds 10 minute data for each fuel, living room and master bedroom temperatures, social data on the occupants and house physical house data (floor plan, hot water system etc).

This report gives an overview of the HEEP project including: importance of collecting data; a review of energy end-uses; social impacts on solid fuel use; temperature and energy use in Māori HEEP households; fuel poverty; analysis of summer and winter indoor temperatures; standby and baseload electricity use; analysis of energy use in pre-1978 and post-1978 houses; faulty refrigeration appliances; electricity power factors; the development of the Household Energy Efficiency Resource Assessment (HEERA) model; the HEEP appliance ownership model; and a brief international comparison of domestic hot water systems.

Energy end-uses

HEEP data can now be used to provide a national breakdown of residential energy use by fuel type and end-use. Figure i provides a breakdown of energy supply by fuel type. Figure ii shows that on average, across all fuel types, space heating is the largest single end-use (34%), followed by hot water (29%), appliances (13%), refrigeration (10%), lighting (8%) and cooking (6%). The most important fuel source is electricity, while the most important space heating fuel is solid fuel (wood and coal).

Low temperature heat is the main (63%) use of household energy, providing space heat (34%) and water heat (29%).

Electricity provides three-quarters (75%) of energy used for hot water, with gas (20%) and wetback (5%) providing almost all of the rest. Seventy-seven percent of household hot water cylinders are electric – the highest proportion for any country. Combined with the high proportion of low pressure systems (72%) this creates a unique situation. The shift towards mains pressure gas hot water systems is likely to have a significant impact, not only on energy but also on water use.

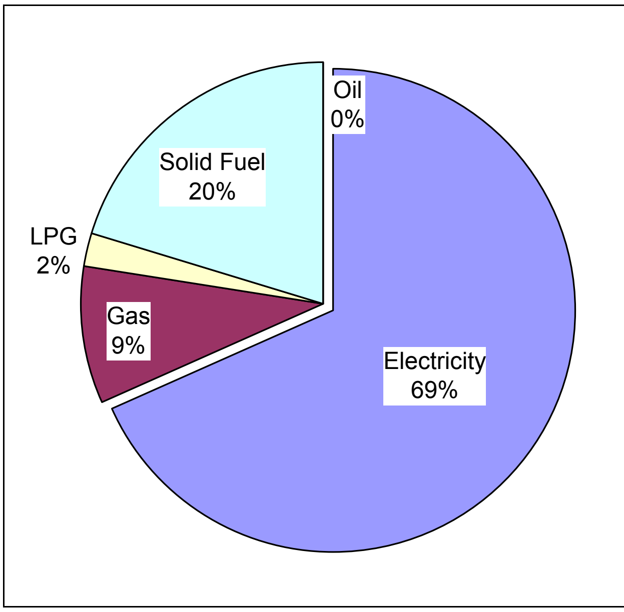

Figure i: Total energy use by fuel type

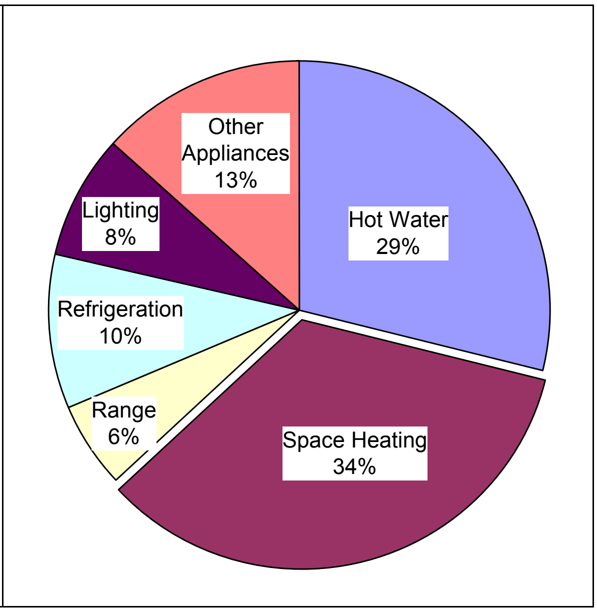

Figure ii: Total energy use by end-use

HEEP has identified solid fuel (56%) and electricity (24%) as the main space heating fuels. This has resulted in changes to the official New Zealand energy statistics (Ministry of Economic Development's (MED) Energy Data File).

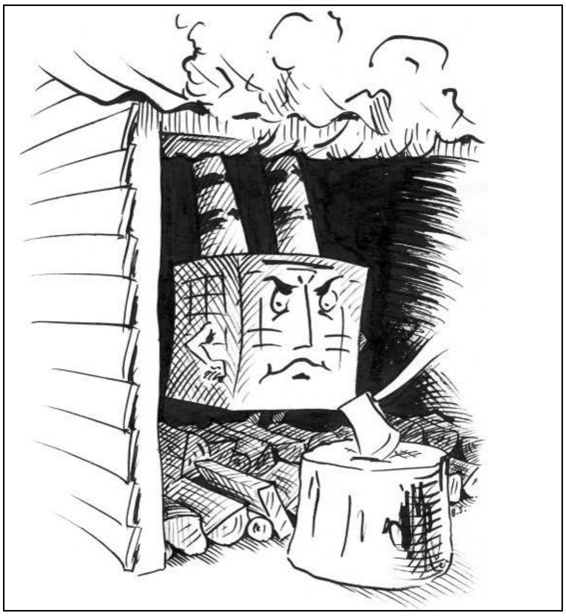

Figure iii: A power station was hiding in the wood shed

The latest year report added to the national energy supply solid fuel equivalent to a 530 MW power station feeding conventional resistance heaters, or 180 MW feeding heat pumps (COP 3) (Figure iii). This increased wood from 5% to 14% of residential energy share, while reducing electricity from 82% to 69%.

The conversion of a house from one heating fuel to another is not a simple energy switch, as winter evening temperatures relate to fuel types. Houses heated by LPG or electricity tend to be the coolest, those with enclosed solid fuel heaters the warmest. The promotion of electric heating to replace solid fuel heating may have unforeseen impacts on the electricity generation, transmission and distribution system.

Other (non-low grade heat) uses are electricity dominated: appliances (13%), refrigeration (10%), range (6%) and lighting (8%) together account for 37% of total household energy use or 54% of household electricity use.

Fuel use per household	Bottom 20% Use under kWh/yr	% of energy	Top 20% Use over kWh/yr	% of energy
Electricity	4,860	10%	10,380	35%
Gas	2,580	5%	9,900	34%
Solid fuel heating	450	1%	5,740	57%
LPG heating	180	3%	1,110	50%
All fuels	**6,940**	**9%**	**14,450**	**36%**

Table i : Fuel use – top and bottom 20%

Patterns of fuel use are skewed, with large users consuming more in total than small users. Table i shows (across all fuels) the top 20% of households use over 14,450 kWh/yr or 36% of total energy use, while the bottom 20% use under 6,940 kWh/yr or 9% of energy use.

Total energy and electricity use per household appears to vary little by region, although the end-uses and the per occupant energy use differ. The report provides regional breakdowns for total, hot water and space heating energy use by fuel, and annual average energy use per house for selected end-uses. The report also provides a comparison of household electricity uses in 1971/72 with the HEEP sample.

Faulty refrigeration appliances

While installing monitoring equipment and surveying the HEEP houses, a number of old and potentially faulty refrigeration appliances were found. Visual inspection of the monitored data confirmed that a number of refrigeration appliances stayed on continuously for long periods of time. Even though insulation degrades or gets wet, coolant leaks, door seals fail, or the thermostat or controller fails, the appliance may continue to operate (i.e. make noise and keep food cool) for years. For refrigeration appliances there may be no obvious sign that the appliance is faulty and many people may not realise there is a problem.

Refrigeration appliances (refrigerators, combination fridge freezers and freezers) use, on average, (1,119±72) kWh per household per year, or approximately 15% of household electricity. About 7% of domestic refrigeration appliances are faulty, and 9% operate marginally. HEEP tested an overseas algorithm adapted to New Zealand refrigeration appliances, and it was found to reliably identify faulty refrigeration appliances.

There are also energy savings from replacement of older refrigeration appliances with modern appliances simply due to the improved energy performance. Over the past 26 years, the sales-weighted average energy use for fridge freezers has fallen by two-thirds, reflecting the impact of energy labelling and Minimum Energy Performance Standards (MEPS).

Power factors

Each year for three years electricity meters were used in three houses that reported both real and reactive power, also providing the power factor. The mean power factor varied from 0.76 to 0.97, with an overall mean of 0.86. The lower the power factor, the higher the load on the electricity system. The report provides power factor analysis for selected time periods.

Standby and baseload

Use	Load (W)
Standby	57±4
Heated towel rails	21±2
Faulty refrigeration	15±10
Minor loads	4±1
Lights left on	7±3
Remainder	8±12
Total	**112±4**

Table ii: Standby and baseload

The HEEP data has supported the first nation-wide statistically representative study of standby and baseload electricity use for any country. The baseload of a house is the typical lowest power consumption when everything that is usually switched off is off, while standby includes energy used by appliances while waiting to be used. On average these total (112±4) W continuous, with the breakdown given in Table ii. The 95% confidence interval is from 104 W to 121 W. Assuming 1.4 million houses, this is equivalent to about 160 MW of continuous load, or about 10% of the total average residential power demand, costing $150/house/year. The full report provides a detailed breakdown of standby power for common appliances.

Pre and post-1978 heating energy use

Since 1978 all new houses have been required to be insulated, yet there has been little research on the effects of this requirement. HEEP is not a longitudinal retrofit study, but it does provide the opportunity to compare the energy use and characteristics of pre-1978 and post-1978 houses. This analysis is difficult as there are many confounding factors e.g. post-1978 houses have larger floor areas, are more likely to be in warmer climates, are less likely to use solid fuel, and are occupied by households with higher average incomes. The analysis needs to account for such factors so that the effect of the post-1978 status can be evaluated on an “all other things being equal” basis. Insulation levels in pre-1978 houses vary; most houses were built without insulation, but many have had it added since or have an addition that is fully insulated.

The analysis found that in all cases mandatory insulation was associated with less energy use. However, the larger floor areas and warmer temperatures of the post-1978 houses increased energy use taking up part, or sometimes all, of the energy reductions. Most of the energy reductions have come from non-electric fuels. The total energy savings for all fuels in the 27% of post-1978 houses would be about 2-3% of total energy consumption (all fuels), while the total electricity savings in the mainly electrically heated houses (about 8% of households) would be <1% of total electricity consumption.

The results suggest that large energy savings cannot be expected from insulation retrofit of houses in New Zealand. Savings in total energy (all fuels) of perhaps 5% are feasible, with most of that saving in non-electric fuels. Potential savings in electricity are smaller still (at about 1%). New Zealand houses and people appear to be very different from other countries where residential insulation retrofits have been used successfully and we need to develop our own knowledge and solutions. The HEEP data does permit the calculation of the minimum sample size for a future retrofit study to explore the actual energy consequences of thermal insulation.

Solid fuel

Solid fuel has a long tradition of use in New Zealand homes, and the report provides an analysis of the existence and use of solid fuel heating. Some 30 years ago, solid fuel heating was used in 59% of the houses in the 1971/72 Household Electricity Survey. For the 1976 Census solid fuel was used in 49% of houses, raising to 67% for the 1986 Census solid fuel and then falling to 54% in the 2001 Census.

Fifty-nine percent of HEEP households had a solid fuel appliance available – of these 74% were enclosed (wood or coal) burner, 17% open fire and 8% either. Two housing variables have a significant association with the availability of a solid fuel appliance – the age of the house (older houses are more likely to have a solid fuel appliance) and the number of bedrooms (the more bedrooms the more likely to have a solid fuel appliance). A greater proportion of enclosed solid fuel burners are actually used than open fires.

Māori households

The number of Māori households in HEEP is small, so no general New Zealand results can be provided. Māori HEEP households are slightly over-represented among low and medium energy households compared to all HEEP households. Overall, the energy use profile for Māori is broadly similar to that for all HEEP households. There is a difference in the mean annual gross heating energy use which is 3,827 kWh/yr across all households in the HEEP sample compared to 3,001 kWh for Māori HEEP households.

Nearly half (49%) of Māori HEEP households have mean winter evening living room temperatures categorised as 'below average' or 'cold', compared with two-fifths of all HEEP households (40%). Māori HEEP households are over-represented in the 'cold' winter evening living room category.

Fuel poverty

At its simplest, fuel poverty exists when households are not able to afford comfortable domestic warmth. Warmth, and more particularly comfortable warmth, is clearly a matter of subjective perception. Internationally, there has been a consistent problem with the measurement of fuel poverty because few surveys into energy consumption and expenditure have measured temperatures. HEEP does precisely that and, in doing so, provides a unique evidential platform for grasping the nature of fuel poverty in New Zealand.

The HEEP data reveals that while low income houses appear to value increased warmth, they are unable to achieve warm indoor temperatures (despite expending a proportion of their income on energy that overseas would place the household in the fuel poverty category). Moreover, the higher proportionate expenditure of low income householders does not assure those households a warm house or even a warm living room. Households in dwellings with very cold indoor temperatures during winter (under 16ºC) appear to spend a greater proportion of their income on energy than the HEEP households overall.

Indoor temperatures – winter and summer

The heating schedule, climate, heater type and fuel, house age and thermal insulation all play important roles in winter evening temperatures. Winter (June, July and August) evening (5 pm to 11 pm) living room temperatures average 17.9°C, although the mean range is from 10°C to 23.8°C. On average, over the three winter months living rooms are below 20°C for 83% of the time – and the living room is typically the warmest room.

Winter evening temperatures show an average rise of 0.2°C per decade of house construction i.e. houses built in 2000 are 2°C warmer than those built in 1900. Newer houses (post-1978) have winter evening living room temperatures 1°C warmer (18.6°C compared to 17.6°C) and overnight (midnight to 7 am) bedroom temperatures 1.3°C warmer (14.5°C compared to 13.2°C).

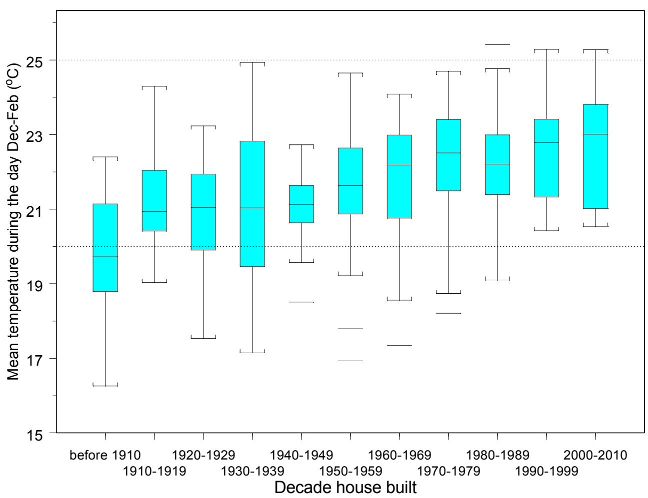

Figure iv: Summer temperatures by house age

As there is little use of air-conditioning in New Zealand houses, the house age (decade of construction) and the local climate (average external temperature) together explain 69% of the variation in mean summer living room temperatures.

Figure iv shows summer day (9 am to 5 pm) living room temperatures by decade house built. The mean summer living room day temperatures show a trend of increasing by 0.25°C per decade i.e. houses built at the end of the 20th century are 2.5°C warmer than those built at the beginning. The reasons for this increase are not obvious (e.g. areas of solar glazing, thermal insulation etc) and are being further explored.

Appliance ownership models

The HEEP appliance ownership models are an attempt to understand some of the factors that influence the type and number of appliances that households have. For example, do households with more occupants have more TVs?

A range of model algorithms have been developed from the HEEP data (including the monitored data, occupant surveys and house audit) to help understand some of the factors that influence the type and number of appliances found in households. These factors include variables based on location, income, life stage, occupant numbers, house age and tenure. Not all variables apply to all appliances and the differences can be most revealing.

Factors such as life stage, income and tenure are more important or better predictors of appliance ownership than those such as floor area and number of occupants. The number of adults and number of occupants only appear in one model each. This is perhaps surprising. Ownership of many appliances might reasonably be expected to be influenced by the number of occupants, but this does not appear to be the case – other socio-demographic characteristics appear to take precedence.

New technologies are becoming available which can have significant energy consequences. For example, the shift to digital television may see old vacuum tube technology replaced by large LCD and plasma screens. The new appliances may not use more energy per appliance, but if market penetration increases e.g. more houses having the appliance or more appliances per house, then total energy use may increase. Representing these possible futures in the HEERA model is a big challenge.

HEERA model

The HEERA model is undergoing final preparation of the database and scenario modelling software to develop a powerful analysis tool. This will support a wide range of 'what-if' type questions which, through the use of appropriate scenarios, will be able to be used for a wide range of policy analysis. Figure v illustrates the HEERA database and model structure.

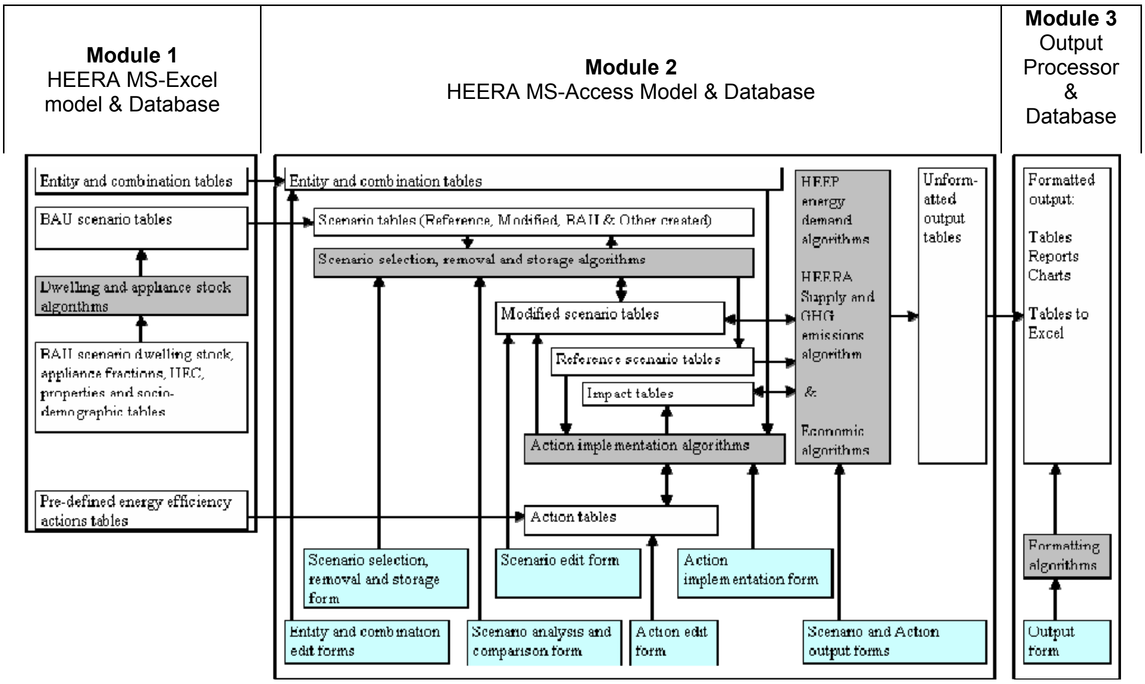

Figure v: HEERA flow diagram

Future

HEEP receives its main funding from the Foundation for Research, Science and Technology (FRST). This continues until the end of September 2007, when HEEP will terminate. The ongoing support of Building Research is also acknowledged with thanks.

HEEP now has a complete national database of some 400 houses from Invercargill in the south to Kaikohe in the north. The focus on HEEP is now on reporting analysis and developing the HEERA model. During 2007, a summary report will be prepared for publication that will provide a formal record of the research and its results.

The legacy of HEEP will be seen in the way this new knowledge of energy use in New Zealand houses which will help with energy planning for the future. The HEEP results will lead to improvements in the design, construction and utilisation of New Zealand houses to enable them to meet the year-round comfort expectations of all occupants in the most energy efficient way.

New Zealand continues to face a wide range of energy issues, not the least of which will be the problems in meeting our Kyoto targets in the first commitment period (2008 to 2012). Much of the recent debate has been electricity supply focused, but the debate needs to also consider greenhouse gas emissions, security of supply and robustness of energy options. HEEP has shown that in the residential sector energy planning is not a simple matter of selecting one fuel over another – care must be taken to ensure that policies are well based on reliable evidence, and that perverse consequences are minimised.

Obtaining HEEP reports

The HEEP team has worked hard to ensure the results of HEEP are available to the widest possible range of stakeholders – including the public, special interest groups, government agencies, universities 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 the BRANZ Bookshop on the BRANZ website, 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 questions 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 the Executive Summary and the full Year 10 report are available through the HEEP page on the BRANZ website:

Postal address: BRANZ, Private Bag 50908, Porirua 5240, New Zealand
Phone: +64 (04) 237 1170 Fax: +64 (04) 237 1171
Email: HEEP@branz.co.nz Website: www.branz.co.nz