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Energy Use in New Zealand Households

Report on Aspects of Year Four of the Household Energy End-Use Project (HEEP)

EECA
Energy Efficiency and Conservation Authority

Fisher & Paykel

Foundation for Research, Science and Technology
Tūāpapa Toha Pūtea, Whakatakoto Kaupapa Rangahau, Pūtaiao

Department of Social Welfare
Te Tari Toko i te Ora
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TRANSPOWER

WEL ENERGY TRUST

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Preface

This report covers some of the activities of the fourth full year of the Household energy Ed-Use Project (HEEP). This project is a long-term research activity to create an accurate and up-to-date knowledge base of the actual energy use by the occupants of New Zealand residential buildings.

Acknowledgments

Since HEEP commenced, funding support has been received from the following organisations:

BRANZ, and the Building Research Levy
Energy Efficiency and Conservation Authority (EECA)
Fisher and Paykel New Zealand Ltd
Foundation for Research, Science and Technology, Public Good Science Fund
Ministry of Social Policy, Te Manatu mo nga Kaupapa Oranga Tangata
PowerCo, Wanganui
TransAlta New Zealand Ltd, Wellington
TransPower New Zealand Ltd
WEL Energy Trust, Hamilton

The HEEP team is grateful to the house occupiers who responded to our questions and permitted us to monitor their homes for the best part of a year. Without their cooperation this research would not have been possible.

Note

This report is intended for those interested in energy and the services provided in New Zealand homes. This includes those involved in the energy industry, the development of social and energy policy, and housing

ENERGY USE IN NEW ZEALAND HOUSEHOLDS

Report on Aspects of Year Four of the Household Energy End-Use Project (HEEP) – BRANZ Study Report No. 98

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REFERENCE

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ABSTRACT

This report covers some of the activities of the fourth full year of the Household **Energy End-Use Project** (HEEP). The project was established in late 1994, with monitoring commencing in late 1995, as a long-term research activity to create and make available a scientifically and technically rigorous, up-to-date and public knowledge base of energy use and end-uses, energy services provision, and key occupant, building and appliance determinants in New Zealand residential buildings.

This report is limited to some of the monitoring and analysis aspects of the last year. More in depth customised analysis of the information is available to financial supporters of the HEEP investigation.

Energy Use in New Zealand Households -

Report on Year 4 of Household Energy End Use Project (HEEP)

October 2000

Executive Summary

The report covers the activities of the fourth full year of the **Household Energy End-Use Project** (HEEP). The project was established in late 1994 as a long-term research activity to create and make available a scientifically and technically rigorous, up-to-date and public knowledge base of energy use and end-uses, energy services provision and key occupant, building and appliance determinants in New Zealand residential buildings.

The HEEP Year 4 research was carried out by BRANZ and John Jowett - Applied Statistician, with funding support from the Building Research Levy, Energy Efficiency and Conservation Authority (EECA), Fisher and Paykel New Zealand Ltd, the Foundation for Research, Science and Technology - Public Good Science Fund, and TransPower New Zealand Ltd.

The objective of the HEEP project is to establish:

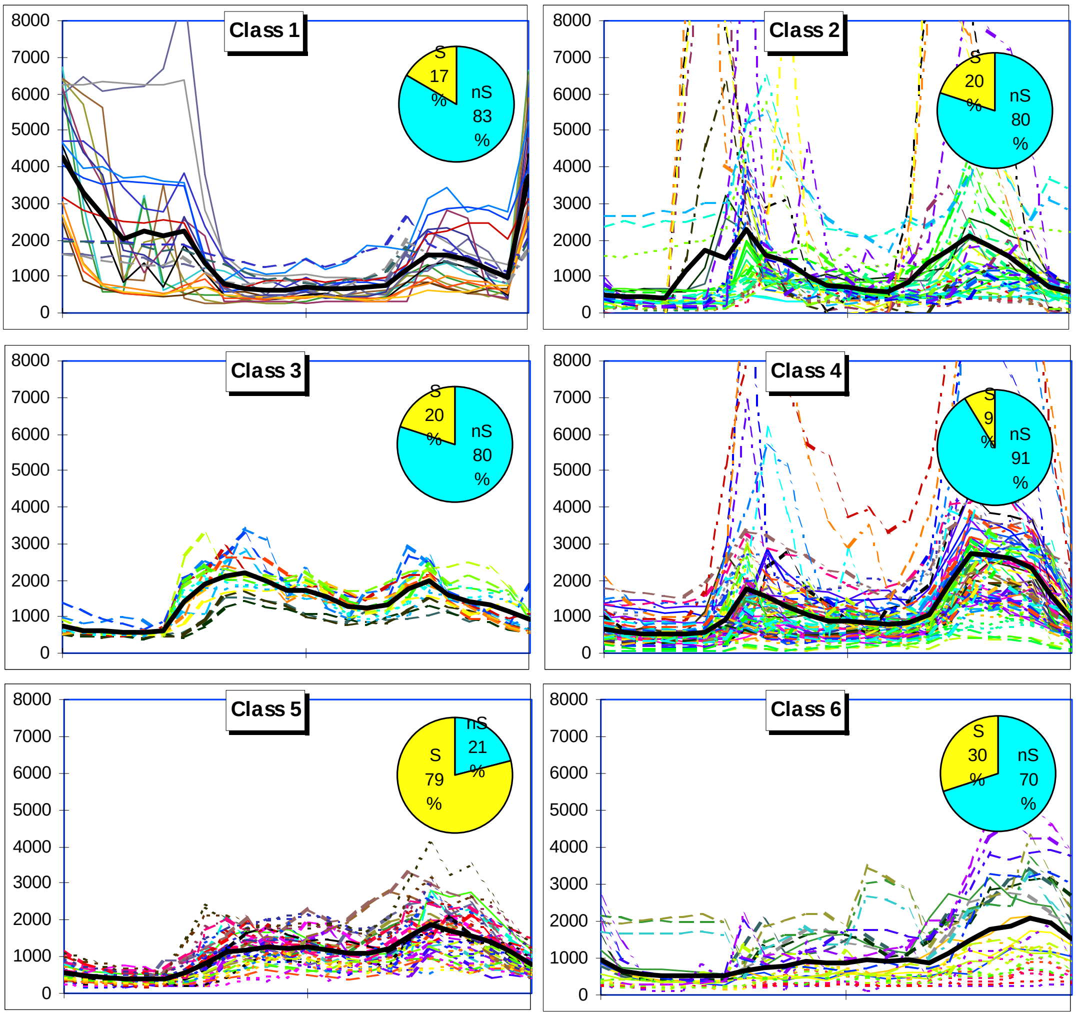
- **how much energy** is used;
- using which **type of energy** (electricity, gas etc.);
- by which domestic **appliances** (including heating and domestic hot water);
- at what **time** periods (season and time of day);
- when used by which type of **household (socio-demographic)**;
- with which type(s) of occupant **behaviour**;
- in order to deliver what level of **energy service** i.e. room temperatures etc.

Over time this will become the HEEP model. This model will allow calculation of the energy consumption of specific households groups based on their socio-demographic composition. The model is being developed by correlating household and appliance features with energy consumption characteristics, and will eventually include different national energy scenarios.

The Year 4 activities have seen the HEEP database grow to more than 100 houses. Key data logging techniques are now developed, implemented and proven to be successful. Data processing mechanisms have been developed, and the data are now available in a format permitting rapid and in-depth analysis in future years. Year 4 analysis includes improved profile analysis and correlation of the ALF3 energy use model with actual energy use.

The preliminary analysis of electricity consumption profiles in connection with socio-demographic characteristics of the occupants shows some of the potential of the information for planning energy supply, transmission and distribution networks, and also for targeting particular energy user groups with specifically targeted energy efficiency measures.

In the following graphs, the x-axis represents a 24-hour day period. The thick black line shows the average profile of the neural network selected class, against the y-axis of power. The inserted pie charts show the proportion of super annuitants (S) and non-superannuitants (nS) included in each class – in this case Class 5 has the greatest proportion of superannuitants (79%). Uses of this analysis include developing tariffs appropriate for specific classes of consumers.



Daily electricity profiles in Watts as classified using Artificial Neural Networks.

The analysis of the correlation between HEEP measurements and the thermal design Annual Loss Factor method (ALF3) provides the basis for the thermal calculation module in the HEEP model. It is crucial for many energy efficiency and social policy applications to be able to verify theoretical calculations with actual measurements. This applies not only for thermal design tools such as ALF3, but also for standard appliance rating methods, hot water cylinder energy efficiency grades and many other applications.

The analysis of the ALF3 model showed that the match between the HEEP data and the ALF3 calculation results was satisfactory (linear fit coefficients of between 0.9 and 1.1 between measured and modelled ALF temperatures with squared Pearson correlation coefficients of approximately 0.56 to 0.68.). The analysis also strongly suggested that the ALF3 assumptions of internal heat gains through appliances and occupants should be adjusted upwards.

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1. INTRODUCTION

This report covers the activities of the fourth full year of the **Household Energy End-Use Project** (HEEP) – a major commitment by a number of funding and research organisations to develop, and make available, improved knowledge of the actual energy use of real New Zealand residential buildings used by real families.

HEEP, initiated in 1994, with monitoring from late in 1995, builds on the knowledge gained from the **1971/72 Household Electricity Survey** (Statistics 1973), but with the benefits of over 25 years of subsequent experience, major advances in energy monitoring technology, and the explicit inclusion of social aspects. It also incorporates the benefits of key results and findings from the wide range of household and domestic building energy research carried out by BRANZ, and others since 1971/72.

HEEP is a long-term research project which has the aim of determining and modelling energy use in residential buildings in New Zealand. The objective of the HEEP investigations is to establish and model how much energy is used, and by which domestic appliances, including space heating equipment and domestic hot water heating equipment. In order to meet the needs of all HEEP financial participants, the energy consumption is analysed both in terms of time-of-use across the day and over the year. One important new aspect of this study, is that it does not solely focus on the technical and engineering aspects of energy use (efficiency of appliances, building, heating device etc.) but also on the socio-demographic characteristics of the household and its occupants.

For some of the energy end uses, the level of delivered ‘energy service’ – that is the tangible benefit, which the consumer receives from using energy – will also be monitored and analysed. An example is the average indoor temperature of the living room achieved when a given amount of energy is used in a given heating device.

2. BACKGROUND

2.1 Objective

The objective of the research being undertaken for the HEEP project is to establish:

how much energy is used;

using which **type of energy** (electricity, gas etc.);

by which domestic **appliances** (including heating and domestic hot water);

at what **time** periods (season and time of day);

when used by which type of **household (socio-demographic);**

with which type(s) of occupant **behaviour;**

in order to deliver what level of **energy service.**

The data collected will enable different HEEP participants to extract specific information to suit their particular needs, whether they be concerned with:

- energy supply
- energy using appliances
- socio-economics or demographics
- health
- building materials and components
- demand patterns and ability to shift energy loads.

HEEP data collection is expected to extend over several years, during which regular interim analysis results and reports will be published. Though limited to electrical energy end-uses in the first year, the project now also includes solid fuel, reticulated gas and LPG.

The project methodology has been designed to meet the research and information needs of the widest possible range of project participants, whether it is peak demand analysis, appliance efficiency or thermal comfort.

More customised analysis into specific areas is available to HEEP financial participants.

2.2 HEEP Participants

The following participants are currently involved in HEEP. Their support is gratefully acknowledged:

Building Research Association of New Zealand (BRANZ) is New Zealand’s leading building research organisation. It has over 30 years experience in research of house operation, including moisture and energy issues. BRANZ has developed a number of tools to assist with the design and operation of energy efficient housing, including the ALF (Annual Loss Factor) (Stoecklein & Bassett 1999) methodology which is a recognised verification method for the New Zealand Building Code revised Clause H1:Energy Efficiency (NZ Government 2000b) which was approved by the Government in June 2000.

Ministry of Social Welfare (formerly Department of Social Welfare, Social Policy Agency), has a mission “to provide sound and strategic policy advice to the government for the well-being of the people of New Zealand”. The Strategic Policy Group of the Social Policy Agency advises on the broad and long-term direction of policy development on welfare issues of fundamental and enduring importance. The results of the HEEP work will contribute to the development of policy and its implementation.

Energy Efficiency and Conservation Authority (EECA) was established in 1992 as an independent government agency charged with the promotion and implementation of greater energy efficiency. In May 2000 the Energy Efficiency and Conservation Act 2000 (NZ Government 2000b) established EECA as a stand-alone Crown entity with an enduring role to promote energy efficiency and renewable energy across all sectors of the economy. It also empowers regulations to implement product energy efficiency standards and labelling, as well the disclosure of energy efficiency statistics. EECA’s staff includes engineers, economists, scientists, policy experts and communications professionals in Wellington, Auckland and Christchurch. EECA also provides funding and administrative support for the project.

Fisher & Paykel is New Zealand’s leading whiteware manufacturer with manufacturing plants in New Zealand and Australia. Fisher & Paykel produce a wide range of innovative appliances and have growing world-wide exports.

Foundation for Research, Science and Technology, through the **Public Good Science Fund** (**PGSF**) implements a portfolio of investments to meet Government’s research and technology goals. The Foundation negotiates purchase agreements with purchasers/providers of non-departmental outputs, and ensures appropriate performance/accountability arrangements are in place and met. In the 1998/9 PGSF funding round, BRANZ obtained six-year funding to support the scientific evaluation of the HEEP data and the development of household energy models.

TransPower New Zealand Ltd is the New Zealand state-owned enterprise that owns and operates the network of electrical transmission lines, substations, switchyards and control centres collectively known as the national grid. TransPower NZ Ltd is one of the main funding participants in the HEEP investigation. TransPower’s main interest in HEEP relates to electric load profiling and the ability to shift that load.

TransAlta New Zealand Ltd has a wide range of interests in electricity generation, distribution and marketing. In Wellington they also supply natural gas, and it is through this energy source that they are supporting HEEP.

The WEL Energy Trust was created following legislation which resulted in the corporatisation of the New Zealand electrical supply industry. The Trust was set up following a public submission process in 1993. It is a publicly elected body, which holds a majority of the shares in WEL Energy Group, administering this on behalf of the community. As part of its functions the Trust distributes income derived from WEL Energy Group dividends and other investments.

Key research providers for HEEP include:

Fitzgerald Applied Sociology is based in Christchurch and undertakes a wide range of basic and applied social research for the public and private sectors both within New Zealand and overseas. Fitzgerald Applied Sociology is undertaking ongoing research into social factors in domestic electricity consumption at household and neighbourhood levels and has analysed some of the initial survey results.

John Jowett has had 20 years experience as a general statistical consultant, first in the Town and Country Planning Division of the Ministry of Works, then in the Applied Statistics (formerly Biometrics) Section of the Ministry of Agriculture and Fisheries. He has specialised in the design and analysis of sample surveys and field trials. At various times in his career John has been responsible for the design and analysis of several major national surveys, ranging from sample surveys on the recreation and leisure activities of New Zealanders, to the breed composition of New Zealand sheep flocks. John is conducting some of the statistical analysis necessary for an efficient data sampling strategy.

Victoria University Wellington provides extensive scientific support and feedback through the supervision of the PhD studies of Mr. Stoecklein. The draft title of the PhD thesis is "A Model of Energy End Use in New Zealand Houses". The regular input of Dr. George Baird and Mr. Michael Donn from the School of Architecture supports the research approach and methodology.

2.3 Further Information

If you or your organisation is interested in participating in any part of the HEEP work or further information on the research, please contact the staff at BRANZ:

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3. HEEP MODEL AND RESEARCH APPROACH

The overall research approach of the HEEP investigation has been covered in detail in the HEEP Year 1 Report (Stoecklein et al. 1997), and the reader is referred to that document for further detail. The envisaged model is described in some detail in the HEEP Year 2 (Bishop et al. 1998) and Year 3 (Stoecklein et al. 1999) reports. For information about data logging aspects and the general methodology the reader is also referred to the previous annual reports. Copies of these documents in PDF format are available from the BRANZ web site – http://www.branz.org.nz.

Unlike the first three annual reports, this Year 4 report covers only some of the less commercially-sensitive research aspects of the work. HEEP financial participants have access to more customised and detailed analysis results.

3.1 Current Monitoring Activities

BRANZ has completed the monitoring of 28 houses in Wanganui and 52 houses in Wellington. The data has been pre-processed and added to the HEEP database.

Currently 29 houses in Hamilton are being monitored for their energy consumptions and indoor temperatures. Seventeen of these houses were randomly selected; the other 12 are identical small units in two retirement villages. The monitoring of the 12 pensioner units is being carried out with the support of the WEL Energy Trust.

3.2 LPG Data Logging Developments

A significant and growing proportion of New Zealand houses use portable LPG heaters as a major heating source. It is estimated that there are in excess of 400,000 portable LPG heaters in New Zealand (Consumer, 1998) and approximately 25% of houses in the current HEEP study sample have a LPG heater.

Part of the HEEP objectives is to understand how the different fuels types are used and what the implications of that usage are. LPG heaters generally have a large heating capacity being rated at up to 5.0 kW, although able to be operated at lower power settings.

LPG heaters also release appreciable amounts of water vapour into the house during the heating season, when the cold outside temperatures lead the occupants to generally close doors and windows. These heaters are potentially contributing to high moisture loads in the living spaces with subsequent durability problems for the house structure and coverings and furnishings, and also potentially having adverse health implications for the occupants. LPG heaters produce about 0.11 litres of water per kWh of energy. Operating at 3.75 kW, an LPG heater will release 0.43 litres of water per hour – equivalent to the metabolic moisture release of about eight adults.

Typical carbon emission factors for LPG are 0.22 kg CO_2/kWh, which compares favourably with the carbon emissions from marginal thermal generation of electricity of 0.64 kg CO_2/kWh (Camilleri, 2000). Allowing for an average efficiency of 80% for LPG heaters versus an efficiency of 100% for most electric heaters, the LPG CO_2 emissions remain favourable compared against the marginal thermal electricity CO_2 emissions.

3.2.1 Preliminary results from the LPG monitoring in Hamilton

There are 17 LPG portable cabinet heaters in the current Hamilton HEEP sample. Of these, nine are from the random sample of seventeen houses and the other eight are from the WEL Energy Trust pensioner houses. At the time of writing, usage data from eleven LPG heaters (four from the random sample and seven from the WEL Trust sample) can be analysed over a two to three month winter period.

LPG heaters have in general two or three heating panels. The different heater settings relate to the combination of which panels are on - for example a three panel heater may operate so that setting 1 engages only panel 1, setting 2 engages panels 2 and 3 and setting 3 has all three panels operating. Of the 17 LPG heaters encountered in Hamilton, one had two settings, eight had three settings, three had four settings, one had only a continuous setting and the remaining four have yet to be determined.

Table 1: Proportion of time LPG Heater is set to each heat output

	Heater Code										
Heater Setting	1r	2r	3r	4r	5p	6p	7p	8p	9p	10p	11p
Heater Off	98.0%	97.3%	94.5%	89.3%	96.2%	81.4%	81.2%	96.4%	76.8%	90.0%	89.9%
0-1000W					3.4%	13.1%			22.9%		
1000-1500W		2.7%	5.5%	10.4%			12.3%	3.6%		0.0%	10.1%
1500-2000W	2.0%				0.4%	5.3%	6.5%				
2000-2500W									0.3%	0.0%	
2500-3000W	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%		0.0%	0.0%		0.0%
3000-3500W								0.0%			
3500-4000W		0.0%	0.0%	0.0%	0.0%	0.2%			0.0%	10.0%	0.0%
4000-4500W	0.0%										

Table 1 provides the proportion of time each heater was either ‘Off’ or in an ‘On’ setting. These settings have been grouped into 500W bands. Where no value is shown, that heater has no corresponding setting for that heat output, while a value of 0.0% indicates that the heater has a setting but no recorded usage of that setting. Table 1 shows a preference for low settings with the exception being heater 10p, which is the only heater with a preferred setting over 1500W. Figure 1 gives a histogram of the expected power of the LPG heaters when in use.

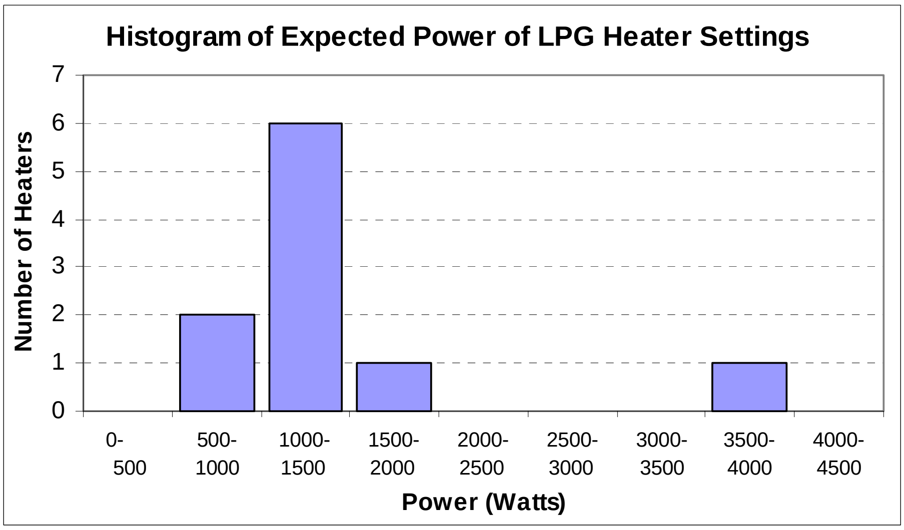

Figure 1: Histogram of the expected power of the ‘On’ setting for LPG heaters.

3.2.2 Methods to measure LPG energy consumption

Monitoring the energy use of a LPG heater can be achieved either by direct measurement of the energy production, direct measurement of the flow of gas (assuming the calorific value is known) or by an indirect method.

The energy production from the gas being burnt by a LPG heater is difficult to measure in the wide variety of situations encountered in routine HEEP monitoring. LPG heaters are portable, and even if only moved within one room, this will limit the measurement equipment that can be attached,

The quantity of gas burnt can be directly measured by gas flow measurement or by measuring the mass of gas burnt.

During the first part of the pilot study a ‘positive displacement volumetric flow’ method was investigated using commercially available gas meters (see HEEP Year 3 report, section 3.4.6 - Stoecklein et al. 1999), which are being used in the HEEP study for the measurement of reticulated gas consumption. For LPG monitoring the meters were installed between the gas bottle and the heater. As an additional gas regulator was introduced into the system there were problems with the meter sensitivity – the mechanical components of the meter were not moving due to insufficient pressure differences. As this approach proved unreliable, other methods of measuring the quantity of gas burnt were examined.

Many flow meters are not capable of recording the small volumes of gas used in LPG heaters. One very sensitive type of meter is the float-type flow meter where an indicator is suspended in a column of the gas flow. The height of this indicator is proportional to the rate of flow. Unfortunately the float-type flow meter measurement seems to have significant errors; the position of the float indicator is imprecise as well as difficult to translate into a signal that can be readily recorded. The signal is also a measure of the flow rate and not total flow, so time integration of the signal is required.

Mass flow metering, which measures calorific properties of a sample of the gas flow, provides accurate mass flow measurements. However, the sensors are expensive making this approach prohibitive for the extended monitoring of a large number of LPG heaters.

Another direct method is to determine the mass of burnt gas by measuring the change of mass (weighing) of the gas remaining in the gas cylinder or equivalently the change of mass of the entire LPG Heater and LPG Cylinder. As LPG has a high energy density, the mass of the gas burnt has to be determined precisely, which means that high accuracy and thus expensive load cells are required. Again the expense of each set-up is prohibitive.

After extensive investigation of direct methods, indirect measurement techniques were explored. The mass of gas burnt can be inferred from knowing what setting the LPG heater is on, for how long it is on that setting and the rate of mass flow for that setting.

It is possible to determine the setting of the LPG heater by recording the position of the settings switch. However, to ensure that this matches energy use, information is also required on whether the gas is flowing through the heater, i.e. whether the tap on the LPG cylinder is “on” or “off”.

Another way of determining the setting of the LPG heater that includes a measure of whether the heater is “on” or “off” is the High Temperature Method, where temperature sensors are placed in front of each heating panel. It can be determined whether each panel is “on” or “off” and consequently which setting the LPG heater is set to. The rate of mass flow for each setting is assumed to be constant and a calibration of each setting for each LPG heater is required using one of the more sophisticated measurement techniques.

The mass flow can then be converted to energy, based on the calorific value of the gas. However, the calorific value of the gas changes as the cylinder is emptied, making uncertain the composition of the gas at any specific time. Therefore calorific values must be estimated based on reported values for the constituent gases of LPG (including propane, butane, etc).

The method used for HEEP is therefore the high temperature method with the settings calibrated by recording the mass of gas burnt for each setting for each LPG heater.

3.2.3 The HEEP LPG high temperature method

The high temperature method requires the measurement of temperatures in front of each of the radiant panels. This is done with cost effective and robust thermocouples (K–Type). The thermocouple outputs are fed into a BRANZ micro-volt logger. Average temperature values are written to the micro-volt logger every five minutes.

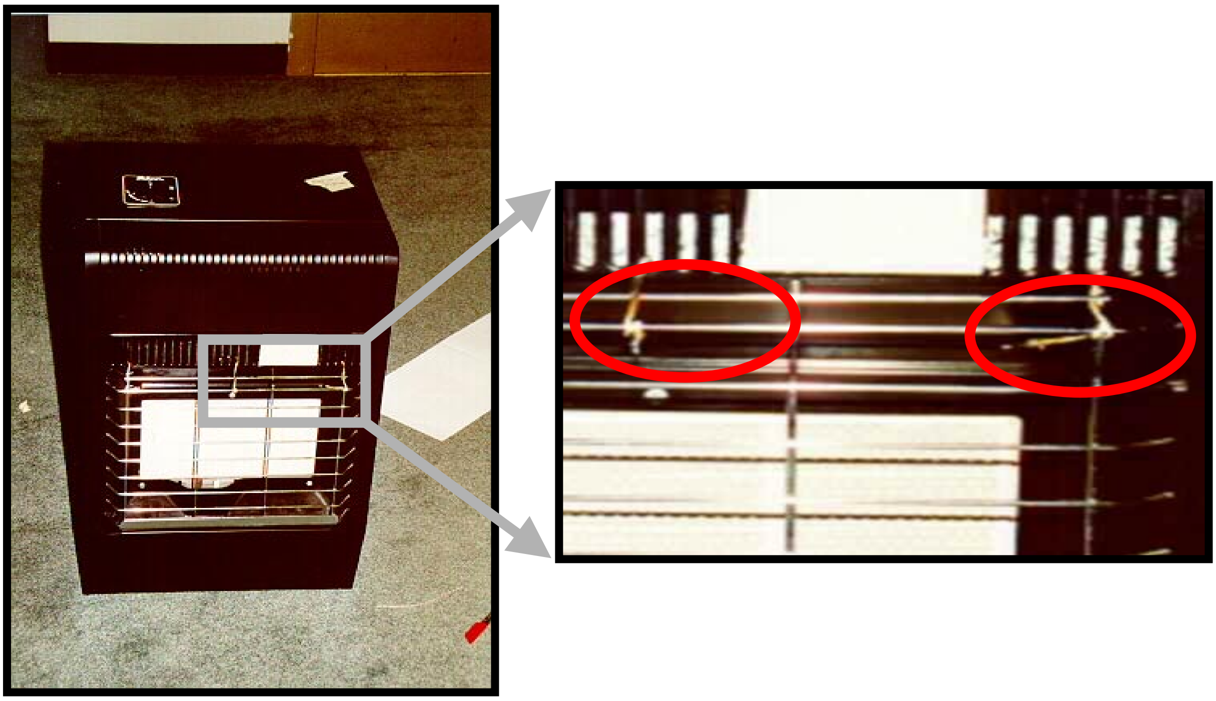

Figure 2: Thermocouple placement on LPG heater.

Unlike other data records, the outputs of the logger are therefore not directly related to an energy value, but are used to identify which of the panels are on, and thus identify on which setting the heater is running.

These settings are then matched to a calibration value of the gas flow of each of the levels for that heater. This calibration of settings against LPG flow has to be conducted individually for each heater. In the HEEP case the LPG flow during the calibration was measured using Load Cell measurements of the cylinder weight over a one-hour period for each of the heater settings. Some simple calculations allow for the estimation of the mass of gas consumed and, assuming heater efficiency and calorific value of the gas, the power output of the heater.

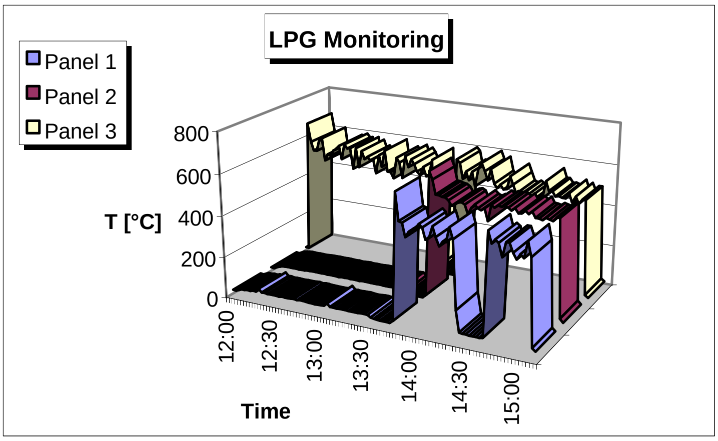

Figure 3: Sample LPG heater monitoring results.

Figure 3 shows some typical temperature readings in front of the three heating panels. The heater was run on the three different heat output settings – one element, two elements, and three elements - and the outputs from the thermocouples were recorded at two-minute intervals using a BRANZ micro-volt logger. The figure shows that the three different settings can be clearly distinguished.

Table 2: LPG calibration results

	Gas mass consumption [kg]	Burn time [hour]	Consumption rate [kg/hour]	Power [W]
Setting 1	0.124	1.27	0.098	1250
Setting 2	0.264	1.37	0.193	2470
Setting 3	0.640	2.30	0.278	3560

The results of the heater calibration can be seen in Table 2. The mass of the cylinder was determined with an accuracy of ± 0.004 kg.

The house occupants are asked to record the date when they refill the gas bottles. This information is then used to cross check the temperature time series and the calibration.

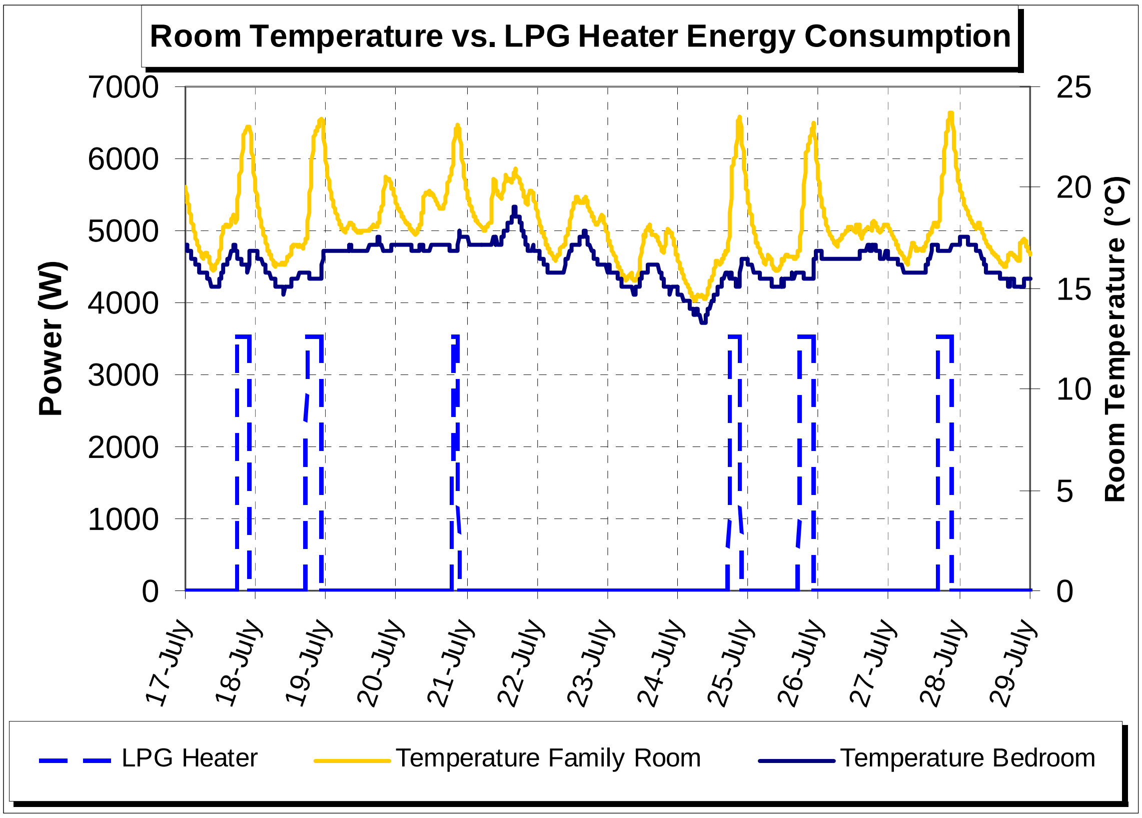

Figure 4: Measured LPG energy consumption and room temperatures.

Figure 4 shows the measured LPG power output, the temperature of the family room in which the LPG heater is located (the top temperature series) and the temperature in the adjoining bedroom. The temperature in the family room can be seen to be responding to the heat output of the LPG heater. This new, indirect high temperature method has proven to be very cost effective and sufficiently accurate for the purposes of the HEEP monitoring and analysis.

Uncertainties with the high temperature method include the fact that the mass flow rate of gas from an LPG cylinder changes as the volume of gas in the cylinder changes. Measurements of a small number of heaters indicate that the flow rate is reduced by approximately 4.5% between a full (100%) and a 20% filled cylinder. However, these changes cannot be detected in the temperature profiles because the composition of LPG gas (propane to butane) in the cylinder also changes due to the change in pressure in the cylinder. The net calorific values of propane and butane are different (46.3 MJ/kg and 45.7 MJ/kg respectively). The fluctuations in the measured temperatures seem to be more related to turbulences near the temperature sensors than to changes in the flow rate of the gas.

3.3 Data Processing Techniques

In addition to the regular measurements of energy use within each of the households, approximately 600 items of socio-demographic and physical information are also collected.

This information needs to be organised so that appropriate indexing and cross-referencing can be done with a minimum of effort. This will allow for investigation of the underlying factors of energy use as identified in the data.

A relational database has been developed using Microsoft Access. All existing data has now been imported into this new database. A number of data entry forms have been created which allow new data to be easily added to this structure.

In order to make exploratory data analysis easier, the data for each house has been divided into about twenty tables. The house identifier is a universal key field within this database. The tables give information on the occupants, their appliances and the physical properties of the house.

The occupant tables include background census information on each occupant as well as tables giving their attitudes towards energy, their behaviours that relate to energy use (when they get up and go to bed, how long they take in the shower, etc.), as well as data on their previous usage of energy (energy billing records).

The physical information about the house quantifies aspects of the building design such as size, construction details, insulation levels, orientation, ventilation and moisture.

The appliance information categorises the manner in which energy is used within the household. Details of the methods of heating the house and the manner of hot water heating are included, as are details of the other major energy uses within the house. Limited details on the smaller energy consuming appliances found in each house are also collected.

This socio-demographic, house construction and appliance data can be used in conjunction with the monitored energy and temperature data to develop a range of information appropriate to a wide range of potential users. One example is provided in the following section.

4. SAMPLE SOCIO DEMOGRAPHIC INFORMATION AND ENERGY USE CHARACTERISTICS

Determining the load profile of a particular house, based upon the socio-demographic characteristics of its occupants would allow the targeting of specific households groups for the purpose of demand-side management of peak energy deliveries with strategies such as load shifting.

The detection of profile classes using artificial neural networks (ANN) is discussed in detail in the Year 2 HEEP report (Bishop et al. 1998). It is based on an automatic process minimising the differences within each of the different profile classes. The analysis was repeated in the HEEP Year 4 analyses, including the new set of monitored houses and with a number of different socio-demographic variables. The energy load profiles of most houses vary considerably during the year, principally due to climatic factors. Space heating, which accounts for some 30-40% of household energy consumption, is used primarily over the winter season and almost not at all in summer. Because of this, the analysis was conducted on monthly average-day profiles. This provides one profile for each house for every month the house is monitored – in this analysis 239 profiles are used. Although this is quite a large number of individual profiles, they cannot be regarded as yet being representative, because the analysis is based on monthly profiles, i.e. the monthly profiles of each of the households are correlated with each other.

The 239 monthly average-day profiles were analysed using a Kohonen probabilistic neural network (Kohonen 1984). This network is capable of classifying patterns without “supervision”, i.e. it defines its own criteria, yet still allows the user to set the number of classes and some of the learning parameters.

The six profile classes determined by ANN are shown in Figure 5, with each line representing the daily electricity profile for one house averaged over one month.

The thick dark line is the average profile of all the profiles in the class, while the dashed line gives the profile’s standard deviation from the average. The horizontal axis is the time of day from 0:00 to 23:00, and the vertical axis is the relative consumption with respect to the maximum over the 24 hours.

Class 1: Typical night rate profile: High consumption over night period, flat low day consumption, medium evening.

Class 2: Morning and evening peaks approximately the same height. Morning peak comparatively short.

Class 3: Flat profile with high morning peak.

Class 4: Sharp mid morning peak, low midday and high extended evening peak.

Class 5: No morning peak, medium afternoon level and early evening peak.

Class 6: Similar to Class 5, but later evening peak.

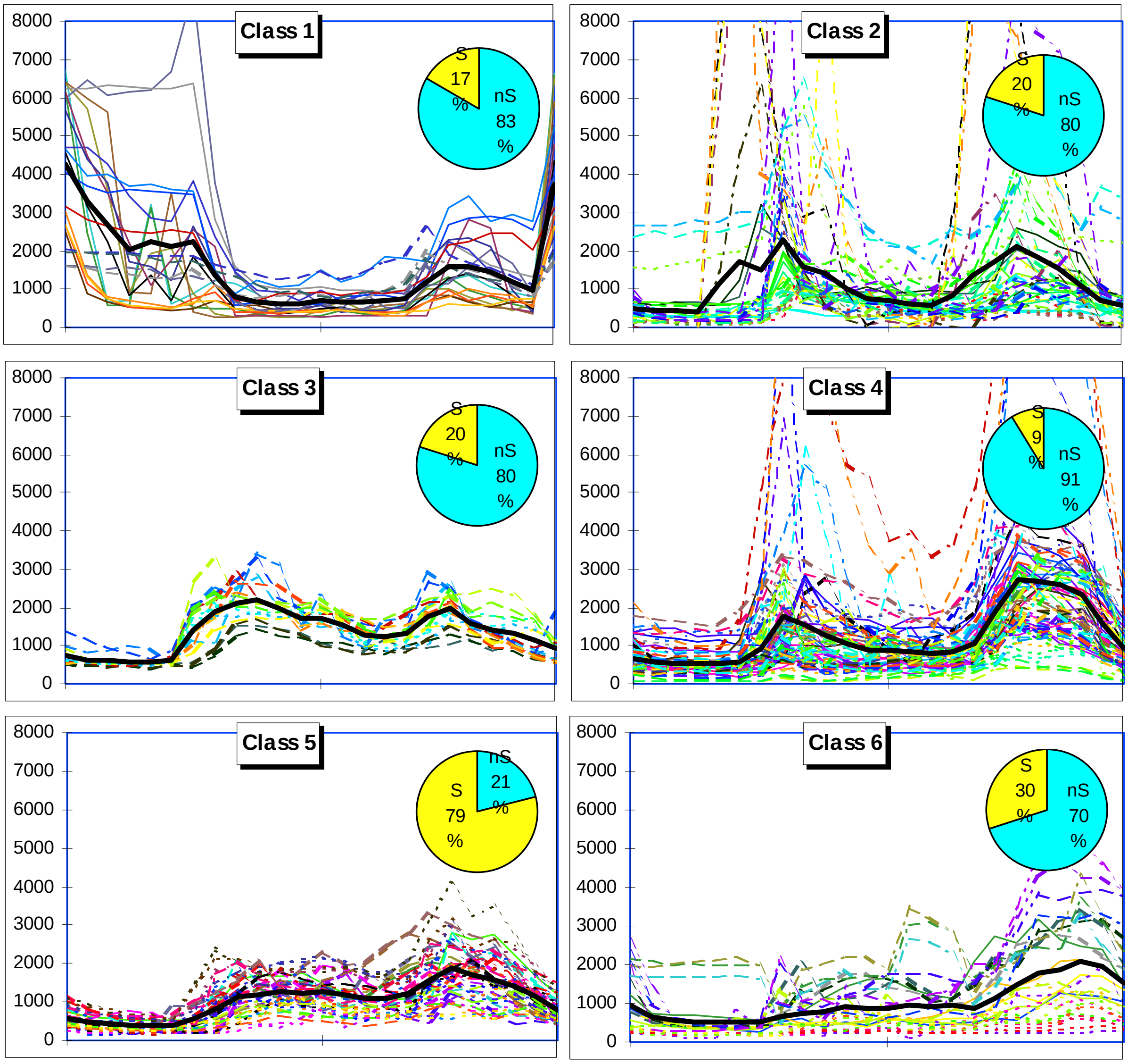

Figure 5: Daily electricity profiles in Watts as classified using an artificial neural network. The x-axis represents a 24-hour day period. The thick black line shows the average profile of the class. The inserted pie charts show the proportion of superannuitants (S) and non-superannuitants (nS) included in each class.

Combined with additional socio-demographic information the load profile classes become a very powerful analysis tool. They would, for example, permit the advance estimation of demand profiles for new customer groups, allowing more accurate cost and pricing planning.

The chart in Figure 5 also shows an example of the way in which socio-demographic data can be linked to a profile class. The inserted small pie charts show the breakdown of each profile class based on whether the occupants' main income is superannuation. Class 5 stands out because nearly 80% of its component profiles are those of superannuitants, while all other classes consist of mainly non-superannuitant profiles.

Using half-hourly wholesale electricity prices and linking these with the energy use profiles for each profile class, it is possible to determine the cost of supplying electricity to a particular class. The chart in Figure 6 shows an example of the annual average hourly supply cost of electricity for the six profiles.

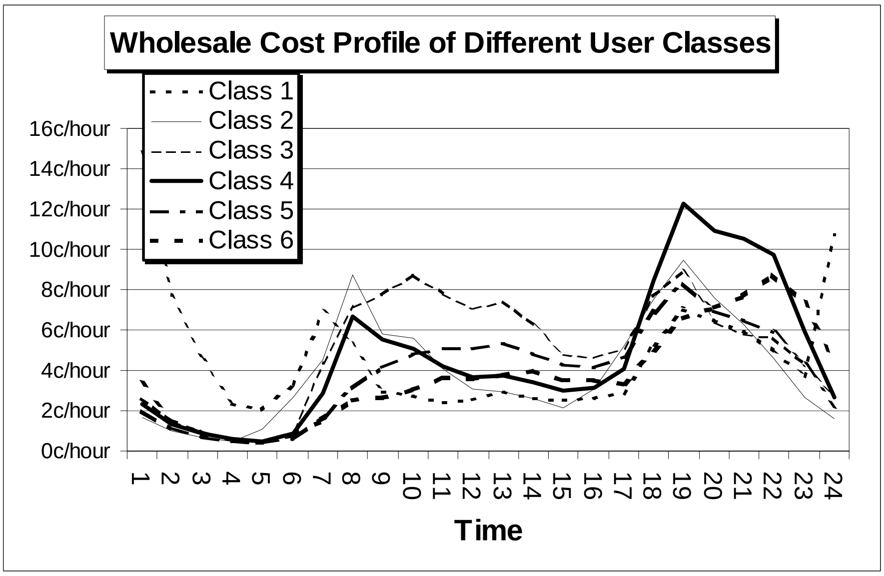

Figure 6: Supply costs of six profile classes.

The graph in Figure 7 shows the average annual wholesale electricity cost for the six different profile classes. The data indicate the annual electricity supply cost for pensioners (Class 5) is smaller than for most of the other classes. However, the unit supply cost is one of the highest.

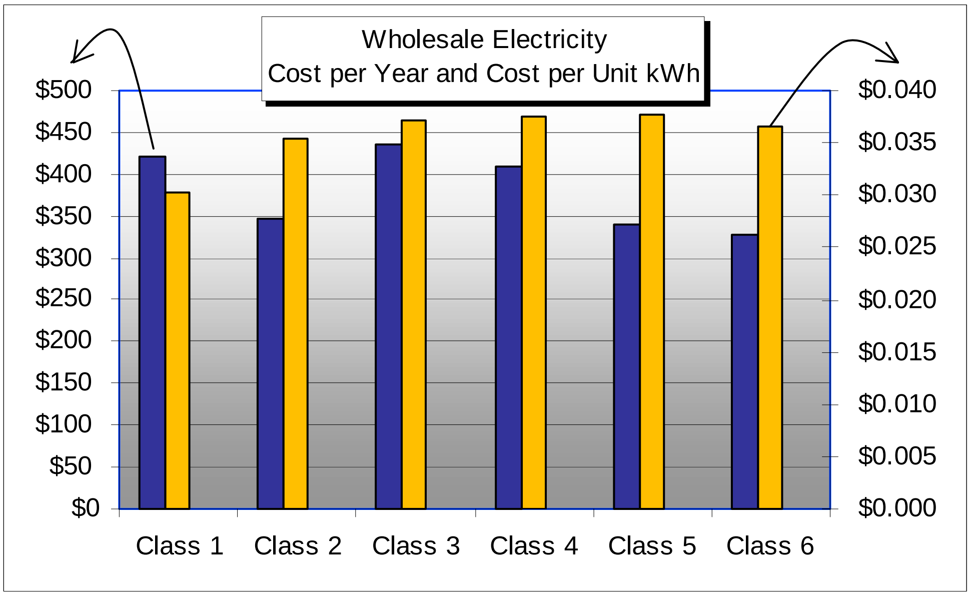

Figure 7: Wholesale electricity cost for each of the profile classes.

The next analysis step could be to investigate the appliances within each of the classes and to determine which of them contribute most to the supply cost. This approach permits the targeting of load shift and load reduction measures in a very controlled way to a specific user class (pensioners) and a specific appliance group (for example electric space heaters).

Knowing the likely profiles of particular consumer groups in a given supply area is also valuable in planning for peak demands, load shifting or pricing strategies. The targeted capture of new customer groups in new areas would be facilitated though the prior knowledge of the socio-demographic composition, and thus the likely electricity use profiles and supply cost of the new customer group.

Similar breakdowns can also be carried out with any of the other socio-demographic data collected from the households. While the analysis presented here is still preliminary due to the current small sample size, it provides clear indications of how profile classes can be analysed and used to better understand the domestic marketplace as the HEEP data base coverage increases.

The information gained from correlating socio-demographic data against profile classes demonstrates its true benefits in the ability to look at socio-demographic data and work backwards to determine a probable profile class. The use of national census data (which collects household socio-demographic information on a five-yearly basis) in conjunction with known profile classes could allow for better planning and management in the supply of energy and the transmission network capacity for specific consumer groups or locations.

5. CORRELATING ALF3 OUTPUT WITH HEEP EXPERIMENTAL RESULTS

This section summarises the results of a pilot project to develop a technique for correlating the heating energy requirements of residential houses as calculated by the ALF3 model with those measured by HEEP (Rossouw 2000).

The collection of statistically reliable information on the heating energy consumption of New Zealand houses requires large representative samples in different regions. Experimental monitoring of such a large statistical sample is not going to be feasible on an ongoing basis. Future updates of the HEEP model will therefore have to rely on building design information collected in surveys and building audits. It is therefore necessary to develop a procedure for calculating the household heating energy from a heating energy demand model, such as ALF3, in conjunction with HEEP housing survey results. This will then permit the estimation of the heating requirement of houses from design audit and survey results alone.

The ALF3 single-zone Annual Loss Factor model (Stoecklein and Bassett 1999). is a building design tool developed by BRANZ for calculating the heating energy requirements of buildings in different climate zones. It requires information on the internal temperature set points and heating schedules, conductive and air leakage heat losses, the effect of solar and internal gains and the heating requirements of thermal mass.

ALF3 allows the selection of one of four heating schedules:

- Evening only (5:00pm-11:00pm)
- Morning and evening (7:00am-9:00am & 5:00pm-11:00pm)
- Morning to evening (7:00am-11:00pm)
- Continuous (24 hours)

and one of three heating levels:

- 16°C
- 18°C
- 20°C

ALF3 does not consider the efficiency and responsiveness of the heater. It assumes that the heating level is instantly achieved with whatever heating appliances are installed. If the evening only heating schedule is used it does not therefore take account of any energy needed before 5:00pm.

The first step in this procedure was the development of a technique to determine an equivalent ALF3 heating pattern (heating schedule, heating level and heated fraction of the house area) from measured HEEP temperature profiles and surveys. A comparison was then made with the results from ALF3 and the measured HEEP house energy use data, with the results of this work providing guidance as to future investigations.

5.1 Methodology and Results

The fundamental idea of the calibration method is to determine the measured heating energy for an ALF3 heating season from actual HEEP measurements and then compare this to the ALF3 heating schedule which best matches the measured heating behaviour and the ALF3 heating level (temperature setpoint) which reports the same ALF3 heating energy as was measured. This ALF3 temperature setpoint is then compared to the measured indoor temperatures over the same time period (time of day and season).

If the ALF3 model is an accurate model, the temperature setpoints should be the same. Discrepancies can be caused by inaccuracies of the ALF3 model, the definition of indoor temperatures (stratification etc.), inaccurate building descriptions (R-values, infiltration etc.) and inaccurate estimates of the amount and contributions of solar and internal gains.

This method is similar to a calibration method used in the BREHOMES (Shorrock et al. 1991) national heating energy model for the UK.

The steps followed in the construction of the ALF3-HEEP calibration procedure were:

1. Determine the ALF3 heating patterns from the measured temperature profiles in the HEEP houses.
2. Calculate the winter season internal gains and heating energies of six HEEP houses from an analysis of the measured HEEP energy use.
3. Match the HEEP and ALF3 internal gains by modification of the number of occupants in ALF3 (this is the only user controllable way to increase or decrease internal gains in the ALF3 program).
4. Match the heating energies of the measured houses with the ALF3 result by modifying the ALF3 heating levels (temperature set points).

The HEEP houses were chosen from the Wellington region since it included heating by all the common fuels and the availability of a full set of temperature measurements. ALF3 input files were then constructed for 14 houses including region and climate specification. The Wellington regional climate was assumed for all 14 houses. For this region the ALF3 model uses 152 heating days per year from May to September. Building dimensions and roof, floor, window and wall insulation data were taken from house plans and from surveys.

Based on the available data (no solid fuel heating had been processed when the analysis was undertaken) it was decided to conduct the ALF3-HEEP correlation analysis on a subset of six houses. For those six houses, the heating patterns were derived from an analysis of the HEEP heating energy and temperature profiles. The annualised internal gains and the annualised heating energies were taken from an analysis of HEEP energy use and temperature measurements.

5.2 Modelling Assumptions

In order to model the heating energy in ALF3, a number of modelling parameters have to be determined. Because the HEEP houses are occupied by “real” people with a range of energy usage patterns, a number of adjustment methods were required to be applied in order to construct the equivalent modelling parameters in ALF3.

As an example, this includes the time of day when people are heating their houses. ALF3 allows a limited set of clearly defined heating schedules, whereas the heating behaviour in the actual houses is quite varied and because of more varied internal gain contributions the correlations with temperatures are not as simple as the ALF3 model assumes.

5.2.1 Heating periods

The daily heating period was derived from an analysis of the 24-hour profiles of the HEEP measured household heating power and the difference between the HEEP measured external and room temperatures. The temperature measurements are also used to corroborate the onset and conclusion of a daily heating period as derived from the heating power measurements.

A daily heating period is considered to start when a sharp and sustained increase in the heating power profile occurs and to be concluded when the heating power profile drops to the background level. The total daily heating energy is also calculated from this power profile.

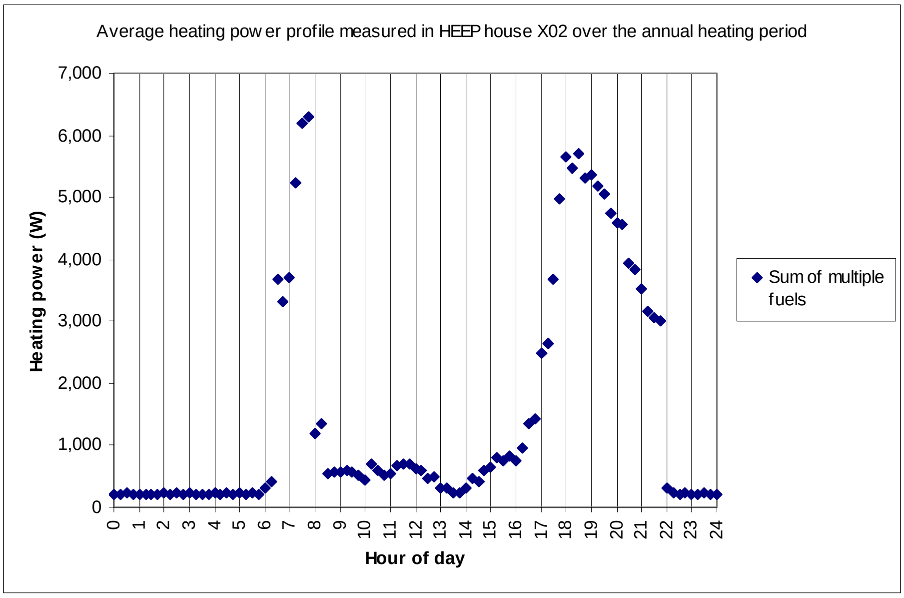

Figure 8: Average over heating season - heating power profile.

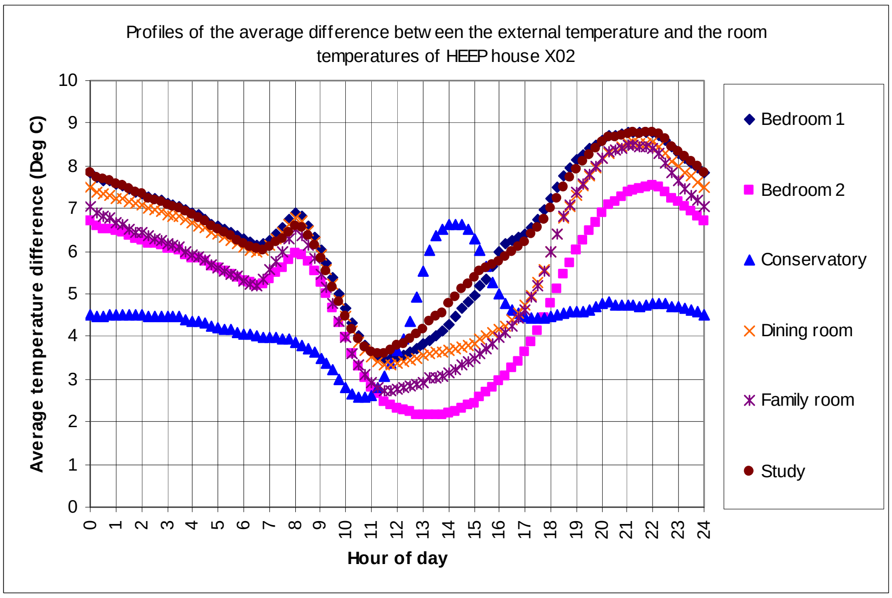

Figure 9: Average over heating season - temperature difference profiles.

This approach is illustrated in Figure 8 by the onset and conclusion of two heating periods, one from 06:30 to 08:00 and a second from 17:00 to 22:00. These heating periods are corroborated in Figure 9, which shows the temperature differences between the measured external and internal heated areas (bedrooms, dining room, family room and study).

The Daily Heating Hours (DHH) are then taken as the hours covered by these heating period(s).

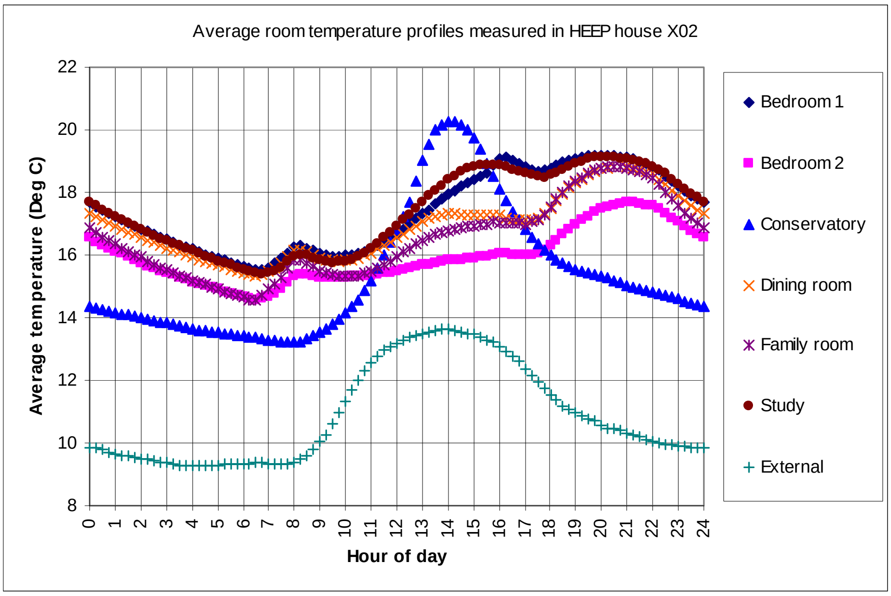

Figure 10: Average over the heating season - room temperature profiles.

The temperature set points of the heated and total areas of the houses are derived from an analysis of the 24-hour profiles of the heated room temperatures over the heating periods. Averaged temperature set points over the total daily heating periods are calculated for the rooms that are included in the heated and total areas. Using this simple averaging technique instead of weighting the temperatures by room area, or better by room volume, assumes that the room areas are approximately equal.

This simple averaging technique is illustrated in Figure 10 where averaged temperature set points of 17.8°C and 17.1°C are obtained for the heated and total areas of the house. The heated area includes bedroom 1, and the dining room, family room and study, while bedroom 2 and the conservatory are included in the total area. The observation that the average temperatures of the heated and total areas differ by almost 1 °C for simple averaging is also found for the other five houses of the sample investigated. Therefore, for the rest of this study, a heated fraction of unity is assumed and simple averaged temperatures for the total house area are used.

5.2.2 Internal gains

The net energy is defined as the delivered energy multiplied by the heater efficiency. Gas used in a cooking range and for space and hot water heating is generally assumed to have a thermal efficiency of 80%. For this study, internal gains are defined as the sum of the net energy produced by:

- *Metabolic gains.* Following the ALF3 practice, the metabolic gains power is taken as 45W per occupant. The annual metabolic gains are calculated as the product of the metabolic gains and the annual internal gains period, i.e. over the total period from which a contribution to space heating can be expected.
- *Appliance gains* from electrical and other household appliances (lighting, refrigeration, laundry, microwave oven, bathroom space heater, electric blankets and others), *excluding* space heating and hot water heating. To be included in the appliance gains, an appliance should contribute to space heating and be employed outside only *or* both inside and outside the Daily Heating Hours (DHH).

The daily appliance gains contribution to space heating can be calculated as the integral of the HEEP appliance internal gains profile over the:

- ☐ Daily internal gains period, i.e. involving both preheating and heating periods.
- ☐ Daily preheating period only, i.e. involving preheating periods only.

The *domestic hot water (DHW) cylinder standing losses* were calculated by a standard HEEP procedure. This procedure assumes that during certain times of the day no hot water is used, and therefore all the hot water energy consumption is used to recover standing losses. The most commonly used time of day to determine the standing loses is 01:00 to 04:00.

It is assumed that 50% of the DHW that is used over the annual heating period (i.e. hot water energy NOT used to recover standing losses) contributes to space heating. The daily DHW used is calculated as the integral of the HEEP DHW profile over the daily internal gains period, i.e. involving both preheating and heating periods.

5.2.3 HEEP heating energy

The daily heating energy is calculated as the integral of the HEEP heating energy profile over the daily heating hours, with the heating profile averaged over the annual heating period.

5.3 Matching of HEEP and ALF3 heating

Matching the HEEP and ALF3 internal gains and heating energies of a house is a three-step process. There are two fundamentally different approaches. The exclusive and the inclusive techniques are different in terms of the treatment of internal gains.

There is essentially no difference between the heat released into the room by a heater and the heat released as a result of energy used by any other appliance. This appliance-generated heat is part of the ‘internal gain’. Therefore, one option is to treat the internal gain during the heating periods as part of the heating energy. However, ALF treats internal gains differently to heating energy in that it applies a utilisability factor to the internal gains, whereas the heating energy is simply the balance between the heat load (sum of losses and heat-up energy) and the utilisable gains. Thus the way in which internal gains during the heating period are treated will therefore lead to different results in the ALF3 calculations.

- ***Exclusive technique*** - compare only the HEEP *heating* energy over the daily heating hours with the ALF3 calculated heating energy. In this case, the appliance gains contribution to space heating is considered as explicit internal gains which come from the total daily internal gains period i.e. including pre-heating hours and heating hours.
- ***Inclusive technique*** - compare the sum of the HEEP *heating and appliance gains* energy over the daily heating hours with the ALF3 calculated heating energy. In this case the gains from appliances used inside the daily heating hours are included in the ‘heating energy’. Only the appliance gains contribution from the daily pre-heating periods are treated as ‘internal gains’.

The three steps in the matching process are:

1. Implement in ALF3 the HEEP measured dimensions and R-values as taken from surveys and floor plans. Select an ALF3 heating schedule that is closest to the HEEP heating schedule as determined by the previously described method.
2. Adjust the number of occupants in the ALF3 model until a match between the ALF3 and the HEEP *internal gains* is obtained.

3. Interpolate the ALF3 temperature set point for the whole house to match the ALF3 and the HEEP *heating energies* over the Annual Heating Hours (AHH) (i.e. the sum of the DHH).

The results of this matching process for six houses are given in Table 3 and Table 4.

Table 3 gives the result of the exclusive technique, and Table 4 that of the inclusive technique. These results are summarised in Table 5.

Table 3: Matching ALF3 parameters to HEEP heating energies

BASIC ALF PARAMETERS	Definition	Dimensions	House 1	House 2	House 3	House 4	House 5	House 6
	Heating Schedule	Time period	7-9,17-23	7-9,17-23	17-23	7-9,17-23	7-9,17-23	7-9,17-23
MATCHING HEEP AND ALF HEATING ENERGIES BY INTERPOLATING THE SET POINT TEMPERATURE								
HEEP heating energy to be matched	H_{heep}	kWh	4,405	5,923	519	6,653	1,073	1,602
Interpolated temperature setpoint	T2-(T2-T1) *(H2-H_{heep})/ (H2-H1)	°C	17.0°C	19.8	15.1	14.9	14.7	13.3
Avg total area measured temperature	Calculated over the AHH	°C	17.1	17.3	15.9	16.3	19.4	14.4

Table 4: Matching ALF3 parameters to HEEP heating energies - inclusive **technique**

BASIC ALF PARAMETERS	Definition	Dimensions	House 1	House 2	House 3	House 4	House 5	House 6
	Heating Schedule	Time period	7-9,17-23	7-9,17-23	17-23	7-9,17-23	7-9,17-23	7-9,17-23
MATCH THE HEEP AND ALF INTERNAL GAINS BY ADJUSTING THE NUMBER OF PERSONS								
HEEP heating energy to be matched	H_{heep}	kWh	5,805	7,784	855	8,902	2,583	3,912
Interpolated temperature setpoint	T2-(T2-T1)*(H2-H_{heep})/(H2-H1)	°C	18.5	20.5	15.7	15.6	18.9	15.3
Avg total area measured temperature	Calculated over the AHH	°C	17.1	17.3	15.9	16.3	19.4	14.4

Table 5: Summary of comparisons between HEEP and ALF3 results

House reference	House 1	House 2	House 3	House 4	House 5	House 6
Measured Set Point (SP):						
Heated area (°C)	17.8	18.4	17.0	16.5	19.8	14.9
Total area (°C)	17.1	17.3	15.9	16.3	19.4	14.4
Exclusive technique						
Internal gains (kWh)	3,486	4,396	1,511	5,249	3,248	3,898
Heating energy (kWh)	4,405	5,923	519	6,653	1,073	1,602
SP: Fitted to heating energy (°C)	**17.0**	**19.8**	**15.1**	**14.9**	**14.7**	**13.3**
% SP dev from measured (Heated area)	-4.57	7.52	-11.21	-9.83	-25.88	-10.40
% SP dev from measured (Total area)	-0.67	14.36	-5.25	-8.72	-24.16	-7.85
Inclusive technique						
Internal gains (kWh)	2,086	2,535	1,175	3,000	1,738	1,587
Heating energy (kWh)	5,805	7,784	855	8,902	2,583	3,912
SP: Fitted to heating energy (°C)	**18.5**	**20.5**	**15.7**	**15.6**	**18.9**	**15.3**
% SP dev from measured (Heated area)	-2.07	-21.00	-4.98	-63.33	-5.47	12.97
% SP dev from measured (Total area)	7.84	18.62	-1.42	-4.27	-2.55	5.86

The ALF3 set point temperatures for the whole house for the exclusive and inclusive techniques are plotted against the corresponding HEEP temperatures of Table 5 in Figure 11. If the correct ratio between the HEEP heating energy and internal gains has been maintained for the houses, it is to be expected that the ALF3-HEEP temperature plot would be linear and tend to zero. This is observed in Figure 11 for the inclusive but not for the exclusive technique.

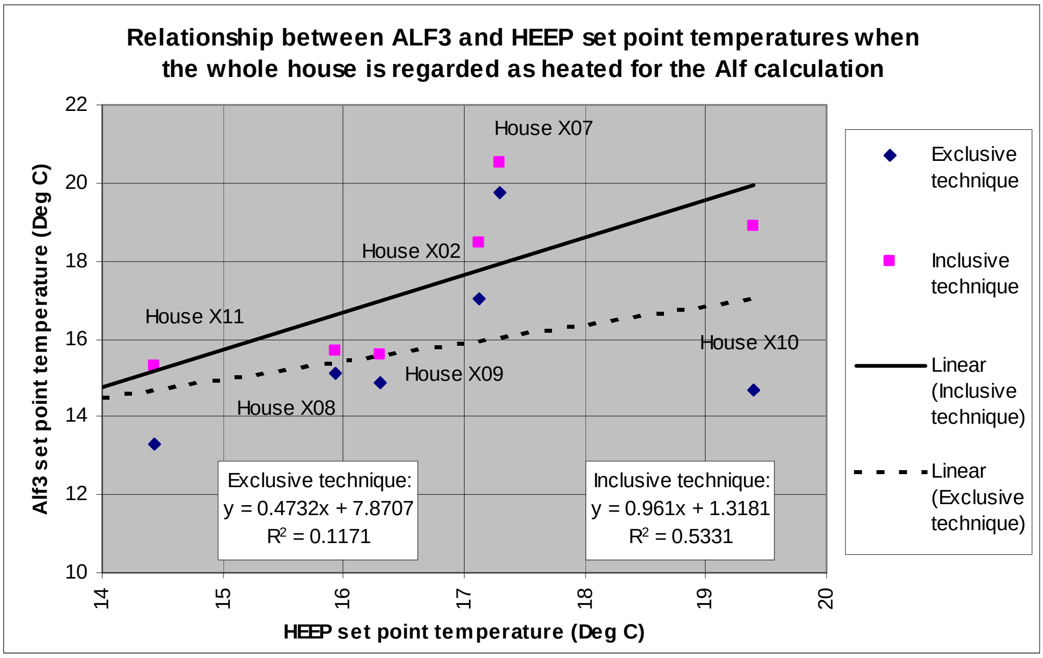

Figure 11: ALF3 vs. HEEP whole house temperatures for the exclusive and inclusive techniques.

Household X10 is a special case, since it actually is an apartment. ALF3 is only designed to calculate house heating consumption. For modelling the apartment some assumptions had to be made which may not be very accurate (losses through apartment-to-apartment walls, floors and ceilings etc.). If house X10 is excluded from the analysis and the linear fit is forced through the 0,0 point, then the linear fit coefficients are very close to 1, as shown in Figure 12 for the whole house and Figure 13 for the heated area only. The correlation coefficients are approximately between 0.55 and 0.7.

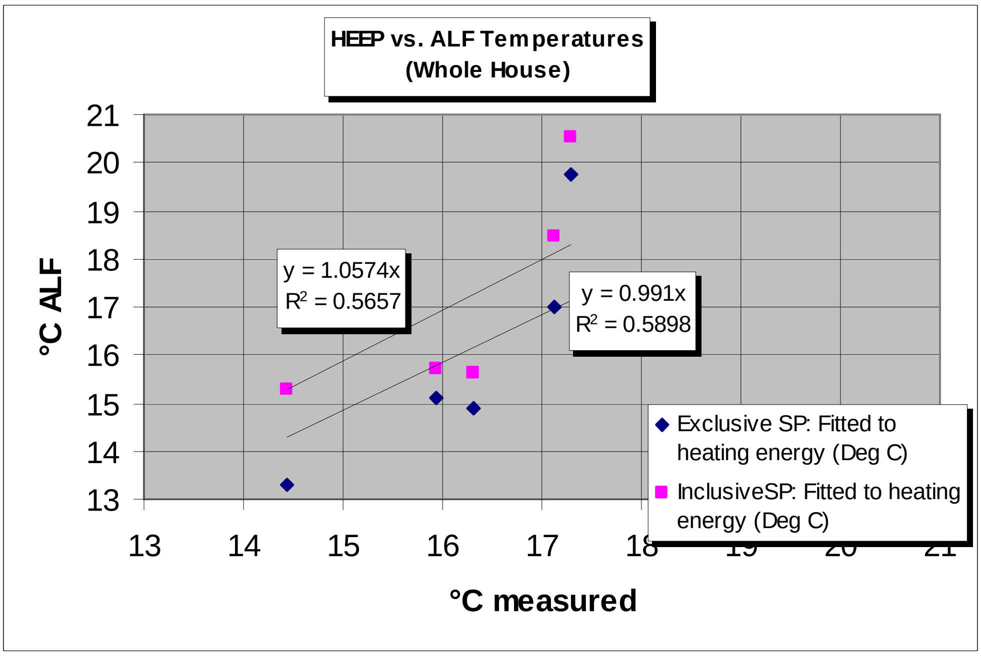

Figure 12: ALF3 vs. HEEP whole house temperatures excluding House X10.

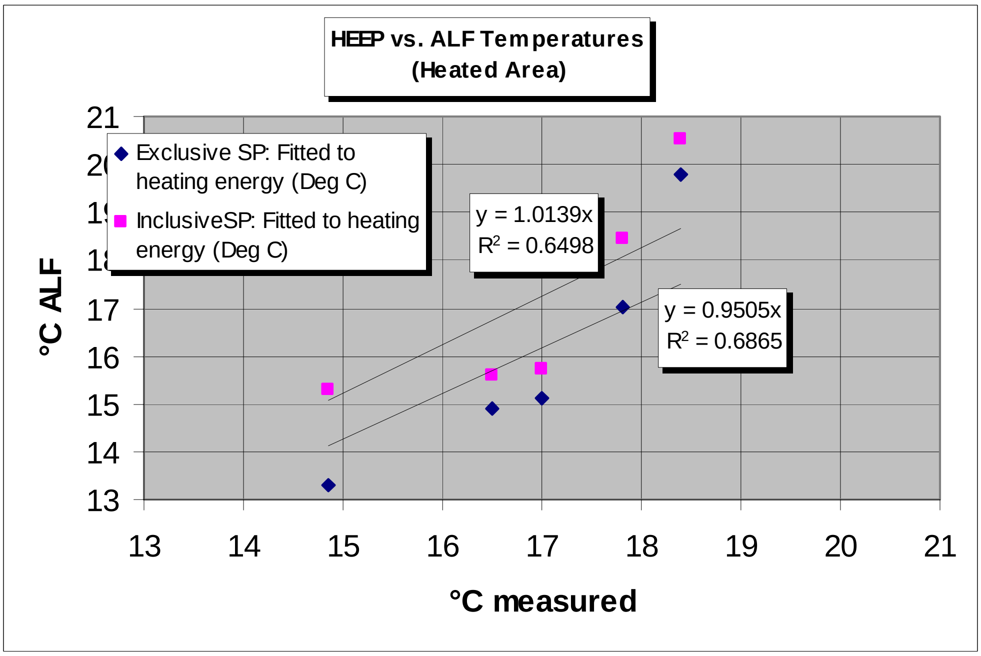

Figure 13: ALF3 vs. HEEP heated area temperatures excluding House X10.

5.4 Conclusions Correlating ALF3 Calculations and HEEP Measurements

Two techniques show promise for matching the measured HEEP data to the calculated ALF3 results.

The Exclusive *technique* involves:

> Matching the HEEP and ALF3 heating energies and internal gains, where the HEEP heating energy during the daily heating period is due to space heaters only. The HEEP appliance gains contribution to space heating covers the total daily internal gains period, including the daily heating period.

The *Inclusive technique* involves:

> Matching the HEEP and ALF3 heating energies and internal gains, where the HEEP heating energy during the daily heating period is due to space heaters and other appliances. The *HEEP* appliance gains contribution to space heating covers only the period outside the daily heating period, since the contribution over the heating period is included in the heating energy.

A comparison of the two techniques based on a sample of six houses indicates that the inclusive technique gives a closer match between the HEEP average set point temperature for the whole house and the fitted ALF3 set point. This may be due to many appliances (not usually classified as space heaters) being switched on at the same time as the space heaters. Such appliances may therefore also have to be classified as ‘space heaters’ for the purposes of heating energy analysis.

In the course of the analysis it was also found that the HEEP appliance gains are about three times that of the default internal gains in ALF3 for the exclusive technique. This would indicate that the ALF3 appliance gains contribution should be increased.

However, due to the small sample of houses used for the comparison, the relative merits of the two techniques can only be judged after applying them to a larger statistically valid sample in later HEEP years.

This study has also highlighted the need for development of a satisfactory method to calculate the heating energy of houses from HEEP solid fuel heating, and the need for an in-depth study based on a statistically representative sample to clarify the selection of HEEP set point temperatures for the heated area and the whole area of a house.

6. YEAR 5 ACTIVITIES

The current 29 houses in Hamilton will continue to be monitored until the end of 2000. Early in 2001, another set of up to 50 households will be equipped with the monitoring equipment and monitored for another full year. It is intended to start monitoring the wider Auckland region.

Analysis in the next year will initially focus on the set of 12 pensioner flats being monitored in Hamilton. Although not a randomly selected sample group, this group of flats will facilitate the investigation of the variation between the individual flats and between this group of households and the average New Zealand households monitored so far. Because the designs of the flats are largely identical, it will be possible to investigate the occupant effect on energy use patterns.

A separate study currently being conducted in Wellington investigates heating energy consumption and temperatures in a set of Wellington pensioner flats. Some of the results from this study will be compared to the findings from the Hamilton study, with support from the WEL Energy Trust.

It is intended to also monitor at least one specifically designed heavy mass construction in 2001, with support from the Cement and Concrete Association of New Zealand. This can be used as a case study to understand the potential benefits of well designed houses with high thermal mass.

The sample house selection method will be developed to ensure that the HEEP model will be representative of the whole New Zealand household population. The existing household selection procedure is described in the HEEP Year 3 report, section 3.4 (Stoecklein et al. 1999) . At that time it was planned for the data collection to cover the different regions based on practicality and logistical circumstances, as well as on industry support. The household proportion in the major electricity company areas was accordingly taken from ESA power company customer record numbers based on 1996 data, including all those power companies with a residential customer base of more than 40,000 residential customers.

Since then it has become apparent that the energy and lines company areas are changing too frequently to use them as a stable base for the regional selection unit. The new regional sampling strategy is based on household population used for the quinquennial census by Statistics New Zealand.

The HEEP energy and survey databases will be continuously upgraded, with data being entered as soon as it becomes available. For most energy data the time period between collecting the monthly raw data record and having them available in the database is now approximately two to three weeks. The house occupants survey data is collected at the start of the year and it is planned to have the data all entered in the database within two months of the interviews.

7. CONCLUSIONS

The Household Energy End Use Project (HEEP) is a long-term research programme with the objective of determining and modelling energy use in New Zealand residential buildings. A range of physical determinants of energy use, including the building and the appliances within it, as well as the socio-demographic aspects of the occupants, are included in the analysis and in the model.

The research activities in the HEEP investigation are proving to be significant cornerstones in our enhanced understanding of energy consumption in New Zealand houses. Results of this study have been quoted in various international publications and the potential to utilise the research results is significant.

The last year’s research activities have seen the HEEP database grow to more than 100 houses. Most of the data logging techniques are now implemented and proven to be successful. Data processing mechanisms have been developed and the data are now available in a common format, which will make rapid and in-depth analysis possible in the future.

Whereas in previous years the focus was mainly put on measured energy use characteristics, the past year saw an increased use of incorporating the socio-demographic data in the analysis. This analysis gives an insight into the potential of the HEEP information for the energy industry to improve understanding of their customer base and the potential for this information to assist in the planning to meet future energy supply, transmission and distribution challenges.

Finally, this HEEP Year 4 analysis explores the correlation between HEEP actual household energy use and temperature measurements and ALF3 calculations, to provide the basis for the implementation of the thermal calculation module in Year 5 and later versions of the HEEP model.

8. REFERENCES AND BIBLIOGRAPHY OF HEEP PUBLICATIONS

Bishop S., Camilleri M., Dickinson S., Fitzgerald G., Isaacs N., James B., Jowett J., Pollard A., Pool F., Ryan G., Sanders I., Stoecklein A., 1998. "Energy Use in New Zealand Households: Report on the Household Energy End Use Project (HEEP) - Year 2" Energy Efficiency & Conservation Authority (EECA), Wellington.

Camilleri, M. 2000. "Implications of Climate Change for the Construction Sector: Houses." BRANZ, SR94. Judgeford.

Consumer. 1998. "An Unflued Gas Heater in Your Home?". Consumer No. 368 March 1998.

Isaacs, N. 1999 "Building Science, Regulations & Health" Presentation to the EECA Seminar-Improving Health & Energy Efficiency Through Healthy Housing, Wellington

Kohonen, T. 1984. "Self Organisation and Associative Memory". Springer, Berlin, Heidelberg.

NZ Government 2000a "Building Amendment Regulations 2000", Wellington

NZ Government 2000b "Energy Efficiency and Conservation Act 2000", Wellington

Pollard, A. and Stoecklein, A. 1998. "Occupant and building related determinants of temperature patterns in New Zealand residential buildings" Proc. IPENZ Conf. 1998, Auckland Vol 2 pp62-66.

Pollard, A., Stoecklein, A., and Bishop, S. 1998. "Energy end use in New Zealand houses" ACEEE Summer Study 1998, Asilomar, Monterey, CA, USA.

Pollard A., 1999. "The Measurement of Whole Building Energy Usage for New Zealand Houses" Proceedings of the 1999 IPENZ Technical Conference, Auckland.

Rossouw P. A. 2000. "Development of the basics of a technique for correlating the ALF3 model output with HEEP experimental results." EERA5/3, BRANZ, Judgeford, 8 March 2000.

Ryan, G. & Fitzgerald, G. 1997. "A strategy for implementing demand side management for domestic electricity in New Zealand" Proc. IPENZ Conf. 1997 Vol 2 pp 83-88.

Ryan, Grant and Fitzgerald, Gerard. 1997. "A science strategy for implementing demand side management for domestic electricity in New Zealand" presented at 1997 IPENZ Conf., Wellington, February 1997 and Electricity Engineers Association conference, Auckland, June 1997.

Ryan, Grant. 1997. "Is there a future for domestic demand side management in New Zealand?" Current, February, 1997.

Sanders, I. and Ryan, G. 1998. "Evaluating Electricity Usage patterns for Reducing Energy Consumption and Minimising Cost" Proc. IPENZ Conf. 1998, Auckland Vol 2 pp 115-120.

Shorrock L.D., Henderson G & Bown J.H.F. 1991 "BREHOMES - A Physically Based Model of the Energy Use of the United Kingdom Housing Stock" in Proc Building Simulation 1991, pp 497-503.

Standards Association of New Zealand 1996 "Specification for Liquefied Petroleum Gas (LPG) NZS 5435:1996" Wellington.

Standards Association of New Zealand 1997 “Gas Measurement NZS 5259:1997” Wellington.

Statistics, N.Z. Department of. 1973. “Report on the Survey of Household Electricity Consumption 1971-72”, Wellington : Government Printer.

Stoecklein A. 1997 “Teenage Daughters and Other Unpredictables” BUILD February/March 1997 pp 36-38.

Stoecklein, A., Pollard, A., James, B. & Ryan, G. 1997. “Development of a Multi-Disciplinary Investigation of Energy Use in New Zealand Households” Proc. IPENZ Conf. 1997 Vol 2 pp 170-176.

Stoecklein A, Pollard A & Isaacs N (editor), Ryan G, Fitzgerald G, James B & Pool F., 1997 “Energy Use in New Zealand Households: Report on the Household Energy End Use Project (HEEP) - Year 1” Energy Efficiency & Conservation Authority (EECA), Wellington.

Stoecklein, A., Pollard, A., Isaacs, N., Bishop, S., James, B., Ryan, G. and Sanders, I. 1998. “Energy end use and socio-demographic occupant characteristics of New Zealand households” Proc. IPENZ Conf. 1998, Auckland Vol 2 pp51-56.

Stoecklein, A., Pollard, A., Isaacs, N., Camilleri, M., Jowett, J., Fitzgerald, G., Jamieson, T., and Pool, F. 1999. “Energy Use in New Zealand Households - Report on the Household Energy End-use Project (HEEP) - Year 3”. The Energy Efficiency and Conservation Authority, Wellington.

Stoecklein, A., 1999, “Just how effective is house insulation”, BUILD magazine, March/April 1999, BRANZ, Judgeford.

Stoecklein, A. and Bassett, M., 1999, “ALF3 - A Design Tool for Energy Efficient Houses”, Thermal simulation software, BRANZ, Judgeford, August 1999.

Stoecklein, A., Pollard, A., Tries, J., Camilleri, M., Isaacs, N., and Fitzgerald, G., 2000, “Understanding Energy End-Use in New Zealand Houses”, ACEEE Summer Study 2000, Monterey, USA.

Tries J., Stoecklein, A., Pollard, A., Camilleri, M., and Isaacs, N. 2000 “Understanding Energy Use in New Zealand Homes” Proceedings of EEA 2000 Conference, Auckland.

Williams, A and W Lom 1974 “Liquefied Petroleum Gases: A Guide to Properties, Applications and Usage of Propane and Butane”, Ellis Horwood Limited, Westergate, England.