Energy in New Zealand Houses: comfort, physics and consumption

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Abstract

The Household Energy End-use Study (HEEP) quantified how, where, when and why energy was used in New Zealand houses, based on the monitoring of energy and end-uses in a national sample of 400 houses. Based on this data, the dynamics of space heating was found to average 34% of total household energy use. Three issues are highlighted in relation to space heating: firstly, the extent to which low indoor temperatures are associated with persistent under-heating; secondly, whether some space heating sources tend to be associated with higher (or lower) winter indoor temperatures than others; and thirdly, what the drivers of under-heating might be. An overview of the HEEP research and its' complex dataset is provided, then the range of winter indoor temperatures are compared to international benchmarks and established healthy temperature ranges. Occupants' perceptions of winter indoor temperature conditions are presented and explored in relation to heating patterns and household energy consumption. The impacts of this research have assisted with changing public policy, moving from a narrow focus on energy efficiency toward an integrated energy, environmental and health policy for the building stock and future interventions. .

Keywords:

Building stock, housing, demand temperature, space heating, fuel poverty, comfort, fuel poverty, New Zealand

(Abstract 187 words + Paper 5,897 words)

Prepublication copy of: Isaacs, Nigel, Saville-Smith, Kay, Camilleri, Michael and Burrough, Lisa (2010) **'Energy in New Zealand houses: comfort, physics and consumption'**, Building Research & Information, 38: 5, 470 — 480

Introduction

This paper explores space heating in NZ homes based on data from the Household Energy End-use Project (HEEP) (Isaacs et al. 2010). In relation to heating, the paper highlights three issues: Firstly, the extent to which low indoor temperatures are associated with persistent under-heating; secondly, whether some space heating sources tend to be associated with higher (or lower) winter indoor temperatures than others; and thirdly, what the social, economic or other drivers of under-heating might be.

An overview of the HEEP research and the complex dataset that has been generated by it is presented first. Then the dataset is used to describe the range of winter indoor temperatures. Those winter indoor temperatures are compared to international benchmarks and established healthy temperature ranges. HEEP survey data is then used to explore occupants' perceptions of winter indoor temperature conditions, and the associated heating patterns and household energy consumption. Finally the impact of HEEP research on residential sector energy efficiency policy and the importance of empirical data for policy change are considered.

HEEP's Approach to Measuring Energy Use

Research into energy use in houses has traditionally been concerned with measuring the supply of energy to a dwelling rather than the way in which energy is used in the home and the amenity (or amenities) associated with that energy use. This approach has formed the basis for energy planning and the development of energy supply policies for many years. Where data about the expectations and behaviours of residential energy users has been collected, it has generally been through self-report. The strength of HEEP is that it collected and matched independently measured energy use data, data around households and their behaviours, as well as data about the dwellings in which those households live.

HEEP was a multi-year, multi-discipline research project that involved detailed energy and temperature monitoring, occupant surveys and energy audits of some 400 randomly selected houses throughout the different climate regions. This sample size was set so that space heating energy could be estimated with an error of less than 10% and with 90% confidence (Stoecklein et al, 2001). That sampling error has been broadly been met on a national, and sometimes on a regional basis, for space heating.

HEEP used a population-weighted sampling framework based on major urban areas ('strata') and the rest of the country ('clusters'). The strata included 221 dwellings and resident households from NZ's 13 largest cities, with the remaining 178 dwellings and resident households randomly selected from 19 randomly selected area unit clusters outside the cities (Isaacs et al. 2010).

In the context of international research on residential energy use, HEEP is unique because it both used a nationally representative sample, and all energy sources and end-uses were eligible to be monitored. National surveys such as the New Zealand Household Economic Survey (Statistics New Zealand 2004), the USA Residential Energy Consumption Survey (EIA 2004) and the Indian Household Consumer Expenditure Survey (NSSO 2007) record fuel use, but do not monitor all the uses to which the energy is put. Typically, the detailed residential energy use studies have tended to exclude certain types of energy sources or focused on a limited selection of end-uses (e.g. N.Z. Department of Statistics 1973, Sandusky et al. 1993, Mackintosh et al. 1993, Sidler 2000).

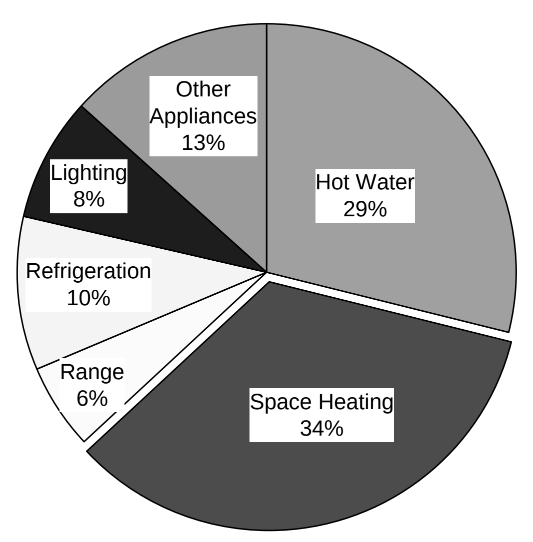
Fuels monitored by HEEP included electricity, natural gas, LPG, coal, wood, oil and solar energy used for water heating. End-uses monitored included space (air) temperatures, water heating, lighting, cooking, laundry, refrigeration, entertainment and a wide range of miscellaneous uses. Monitoring used electronic dataloggers recording at intervals of 10 minutes or less.

In addition, detailed occupant survey which asked householders a series of questions regarding household composition and socio-demographic characteristics, employment and dwelling use patterns including duration of exposure to indoor conditions during the day, and their water and energy use. Hot water and house energy audits were conducted during the installation, and changes in house occupants and equipment were recorded during the monitoring period. Further information on the data collection is available in Isaacs et al. (2010).

Monitoring commenced in 1999, with the majority (348) of houses monitored during the period 2001 to 2005. As a consequence of small changes in the survey coverage, not all questions were asked in all HEEP houses, as shown in the specific tables below. It is considered that this does not significantly alter the conclusions.

NZ Houses and Households Using Energy

Before looking at the space heating data specifically, it is useful to place space heating energy use in the broader context of household energy use. HEEP found that the average total energy use (all fuels) per household was 11,410 kWh/yr (Standard Error 420 kWh/yr). The HEEP breakdown of New Zealand household energy consumption by end-use is given in Figure 1. The largest portion is space heating at 34%, then hot water at 29%, and refrigeration, other appliances, lighting, and range at around 10% each.



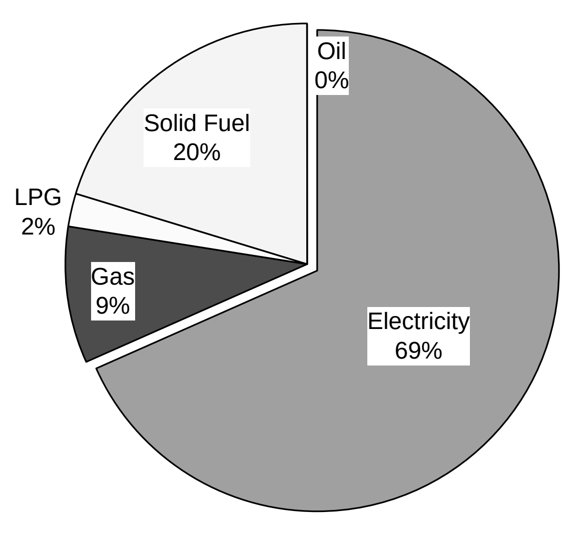


Figure 1: Total energy use by end-use. Source HEEP

Figure 2: Total energy use by fuel type. Source HEEP

The HEEP breakdown of NZ household energy consumption by fuel type is given in Figure 2. Electricity use accounts for 69% of total national residential fuel use, followed by solid fuel at 20%, mains / network (reticulated) gas at 9% and bottled LPG at 2%. Heating oil is used in very few NZ houses. The breakdown of fuel types by location varies greatly, depending on availability. In particular, mains gas supply is only available in selected North Island urban areas, reflecting the strong historical commitment to electricity.

New Zealand households use relatively little energy compared to other developed nations. On a climate corrected basis, in 1995 NZ had the lowest residential sector energy use per capita in comparison with Australia, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, U.S.A. and the UK (Schipper et al. 2000). Schipper et al. (2000) concluded that the main reason for NZ's low level of energy use was the small amount of fuel used for space heating, although it should be noted that being pre-HEEP the data under-estimates the importance of solid fuel.

Despite this, space heating is an important energy user in New Zealand dwellings. On average, NZ households use 3,820 kWh/yr (Standard Error 350 kWh/yr) used for space heating.

Winter Indoor Temperatures

New Zealand is a temperate country but has a diversity of climates, partly because it is long country which reaches from latitude 34 S to 46 S. In addition, there is some variation in outdoor temperatures associated with altitude, although this tends to affect rural dwellings and small towns.

Prior to HEEP, the only national temperature measurements were during the 1971/72 Household Electricity Survey (N.Z. Department of Statistics 1976). The available technology only provided the daily mean, so Table 1 compares, by region, daily mean HEEP 'living room' temperatures with August-September 1971 'lounge temperatures'.

August-September temperatures °C	**Northern North Island (inc. Auckland)**		**Southern North Island (inc. Wellington)**		**Christchurch**		**Southern South Island (inc Dunedin)**	
	HEEP 2001-2004	**1971**	**HEEP 1999, 2002-2004**	**1971**	**HEEP 2002**	**1971**	**HEEP 2003**	**1971**
Living room:								
Mean temperature	16.5	17.7	16.1	16.6	16.1	15.2	14.7	13.6
Standard deviation	0.1	-	0.2	-	0.3	-	0.5	-
95% Confidence interval	16.2-16.8	-	15.8-16.5	-	15.4 – 16.7	-	13.7-15.8	-
External:								
Mean temperature	11.9	12.0	9.3	11.0	10.3	9.3	7.3	8.6
Mean temperature difference	4.6	***5.7***	6.9	***5.6***	5.7	***5.9***	7.4	***5.0***
Sample size (count)	112	98	74	64	34	69	30	64

Table 1: Descriptive temperatures by region. Source HEEP & Department of Statistics (1976)

The 1971/72 temperature study found a strong consistency in the difference between inside and outside temperature (in bold italics in Table 1). That study concluded that "in homes throughout New Zealand, rooms tend to be heated to certain levels above the surrounding outside air temperature, rather than to a universal absolute temperature level".

This does not appear to be the case for the HEEP sample with the daily mean temperature differences, shown in Table 1, ranging from 4.6°C in the Northern North Island to 7.4°C in the Southern South Island. Table 1 suggests, excluding the Southern South Island, mean daily living room temperatures were close to 16°C.

Temperate outdoor temperatures might, it could be assumed, be associated with readily achievable warm indoor winter temperatures. This, however, is not the case. Table 2 gives mean winter temperatures from

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HEEP for four different periods during the day for the living room, bedroom and external ambient temperature. French et al. (2007) provides further detail on the HEEP indoor temperature distribution throughout the year. Table 4 documents the way heating is used.

Room	**Time Period** **Morning** **7 to 9 am**	**Day** **9 am to 5 pm**	**Evening** **5 to 11 pm**	**Night** **11 pm to 7 am**
Living room	13.5°C	15.8°C	17.8°C	14.8°C
Bedroom	12.6°C	14.2°C	15.0°C	13.6°C
Ambient	7.8°C	12.0°C	9.4°C	7.6°C

Table 2: Mean indoor & ambient winter temperatures and use of heating for living room and bedroom. Source HEEP

Only in the living room during the evening do these temperatures come close to achieving the World Health Organisation's (WHO) healthy indoor temperature range of 18°C to 24°C (WHO 2003).

Morning is the coldest time inside the average house, although the coldest time outside is overnight. Evenings are warmest (this is also the most common heating time). Bedrooms are on average slightly colder than living rooms, with the maximum difference occurring in the evening. This is most likely caused by heating in the living room with typically very little or none in the bedrooms.

Those low indoor temperatures have been shown to be associated with poor health (Howden-Chapman et al. 2007), excess winter mortality (Isaacs & Donn 1993), a variety of social and economic problems for residents (Trotman 2008), as well as contributing to mould and damp. Warmth, and more particularly comfortable warmth, is clearly a matter of subjective perception. There are, however, some critical thresholds around acceptable temperatures related to health. Temperatures that are (Collins 1986):

- lower than 16ºC appear to impair respiratory function
- below 12ºC place strain on the cardiovascular system
- below 6ºC place people at risk of hypothermia.

The impacts of low temperatures are exacerbated where individuals are vulnerable through illness, disability or age. Low temperatures also pose greater risks when exposure is for extended periods (Raw et al 2001). The effects of extended exposure led the Working Group appointed by the UK's Watt Committee on Energy to recommend (Hunt & Boardman 1994):

- 21ºC for 13 hours a day in living rooms

- 18ºC for eight hours at night and an additional five hours during the day in bedrooms
- 18ºC for 13 hours a day in other spaces
- 14.5ºC in all spaces at all other times.

Why Are NZ Homes Cold?

Clearly, New Zealand homes are cold because New Zealanders build and/or live in their homes in a particular way.

Understanding the nature of low temperatures in New Zealand dwellings is a necessary precursor to addressing the individual and externalised costs associated with cold indoor temperatures. In addition, to the impact of outdoor temperatures there are three critical physical factors. They are:

- Thermal properties of the dwelling.
- Heating sources and appliances.
- Heating practices.

Thermal Properties of Dwellings

The addition of thermal insulation has been a mandatory requirement for New Zealand houses since 1 April 1978. It should be noted that the quality of the insulation installation or the airtightness of the houses were not investigated in the HEEP research. The New Zealand House Condition Survey found that 79% percent of New Zealand houses had over 50% of the ceiling insulated, 34% over half the walls and 21% over half the floor insulated (Clark et al., 2005).

What HEEP found is that dwellings built after 1978 have lower average heat losses (3.8 W/°C/m² compared to 5.2 W/°C/m²). Winter (defined as June to August) evening living room temperatures in the insulated post-1978 houses are on average 1°C warmer (18.6 °C compared to 17.6 °C). In bedrooms, the overnight average temperature difference is 1.3°C (14.5 °C compared to 13.2 °C).

Even the relatively minimum insulation requirements introduced in 1978 have had an amenity impact. Moreover, insulation would have generated lower energy consumption over the housing stock if the floor size of post 1978 dwellings (average 132 m²) had remained similar to dwellings pre-1978 (average 119 m²). Under those circumstances, the post-mandatory insulation houses would require about 20% less energy to heat to the same temperature.

Two issues arise here. Firstly, post-1978 dwellings have a larger floor area than pre-1978 houses. Consequently, the energy consumption minimisation potential has not been achieved. Second, even post-1978 HEEP houses were not reaching desirable indoor temperatures.

Heating Sources and Appliances

Fuel sources and heating appliances can impact significantly on energy use, the exposure to different cost structures and affordability problems of different households, and heating behaviours. For example in the U.K. the proportion of homes with central heating has risen from 31% in 1970 to 91% in 2006 (Utley & Shorrock 2008). The high penetration of central heating is assumed to give stable indoor winter temperatures, leading to the validity of generic energy savings advice such as “turning your central heating down by one degree could cut your heating bills by up to 10 per cent” (U.K. Directgov 2010). Where stable temperatures are not maintained, such advice is not likely to be valid.

Data on the space heating systems used in New Zealand homes is available for 1984 to 2004 and reports a consistent 5% of households with central heating (Statistics New Zealand 1984, 2004). The rest use either fixed (e.g. open fire, night store electric heater etc) or portable (electric heaters, LPG cabinet heater, etc) heating appliances. The availability of different heating appliances varies with the house age and size, with older and larger houses more likely to have a solid fuel appliance (enclosed wood or coal burner or open fire). Over half (55%) of North Island and 71% of South Island houses had a solid fuel appliance.

Since the completion of HEEP, there has been an increasing market penetration of heat pumps which can be, and often are, used in one room in a manner similar to central heating (French, Isaacs & Camilleri 2008)

What HEEP provided was a better understanding of the range of heating appliances in New Zealand and the indoor temperatures achieved when different heating appliances were used as the primary means of heating.

Table 3 shows average winter evening (5 pm to 11 pm) living room temperature by heater type. Living rooms heated by open solid fuel fires are coolest, averaging 16°C, followed closely by portable electric heaters at 16.9°C. Rooms heated by enclosed solid fuel burners are the warmest, averaging 18.8°C, but these offer little temperature control beyond limiting the feeding of additional fuel.

Heater type	Temperature (°C)	Std. error of mean (°C)	Sample count
Open solid fuel	16.0	0.6	11
Electric (1 – 2.4 kW)	16.9	0.3	83
Portable LPG (2 – 6 kW)	17.0	0.2	54
Fixed electric (2 – 3 kW)	17.8	0.3	18
Heat pump (2 – 8 kW)	18.0	0.4	4
Gas (2 – 8 kW)	18.1	0.5	28
Gas central (10+ kW)	18.3	0.6	8
Solid or liquid fuel central (10+ kW)	18.5	0.7	2
Enclosed solid fuel (4 – 25 kW)	18.8	0.2	142

Table 3: Winter living room evening average temperatures by heater type. Source HEEP

Heating capacity is a significant driver of achieved indoor temperatures and this is most obvious where enclosed woodburners are used. Typical power outputs are given in Table 3 e.g. enclosed solid fuel burner heat output can range from 4 kW to 25 kW, although HEEP houses were found to run their solid fuel burners from 3 to 5 kW. It is not surprising that houses with higher power output heaters achieved higher temperatures.

No significant difference in temperatures between regions was found for electricity or LPG-heated houses. There are higher numbers of solid fuel burners in the colder regions, which with their higher outputs did achieve higher temperatures in the colder regions.

It is notable that where solid fuel burners (usually enclosed wood burners) are used these are usually in living spaces and they are rarely used for heating other areas except through flows through open doors to cooler corridors and bedrooms. This appears to encourage a more widespread pattern of heating practice in New Zealand, that of not heating bedrooms. That practice is a national practice and is found in both colder as well as warmer climate zones. Some solid fuel heaters have a heat exchanger fitted (known in the UK as a ‘back boiler’), which could be used for hydronic heating but are in practice used to provide potable hot water.

Heating Seasons and Patterns

Broadly, New Zealand householders respond to climate in their heating seasons – that is, the period over which they heat – and their heating patterns. Both heating seasons and heating patterns were explored through data collected as part of the HEEP installation survey in which occupants were asked about the hours the house was occupied during weekdays and weekends, and the number of people normally present, heating system(s) and their pattern(s) of use. Data is also available through analysis of the direct measurement of heating appliances and room temperatures.

Figure 3, based on occupant survey responses, gives the length of the reported heating season with the number of houses in each band given in brackets on the y-axis e.g. 6 houses reported heating starting in January and continuing throughout the year. Survey data was available for a total of 360 houses. It shows that households that start heating early in the season also finish later in the season.

Where heaters were monitored separately, the heating season could be determined by examining the fuel usage data. 261 houses had separately monitored solid fuel (wood and/or coal), gas, LPG or fixed electric heating, although many of these houses also had portable electric heaters. Portable electric heaters were monitored on a month-by-month basis in one-quarter of the houses. They were included in the total electricity consumption, but other large electricity uses had to be taken into consideration, and careful comparisons made between winter and summer use to determine the heater use. There is the potential for errors in this method, with some houses expected to have a slightly longer or shorter heating season, but for the number of houses and the use of the comparison to identify major differences, the consequences are any errors are expected to be limited.

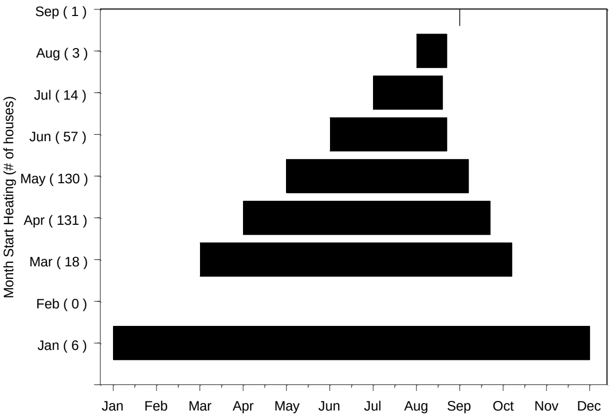

Figure 3: Length of reported heating season. Source HEEP

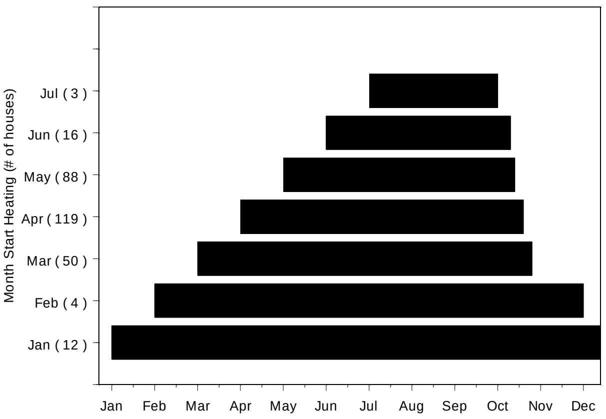

Figure 4: Monitored length of heating season. Source HEEP

Figure 4 gives the monitored length of the heating season for 292 houses. While six houses reported whole year heating, analysis of the monitoring data found 12 houses actually heated for the whole year – approximately 4% of the total number of houses. In general, and unsurprisingly, these were in the cooler parts of the country (Central North Island and South Island).

Conversely, 10 houses in the sample (not shown in Figure 4) did not appear to heat. In general, these were in the warmer parts of the country (Auckland and further north).

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When the pattern of heating is evaluated based on the monitored energy use, it appears that, overall, occupants heated for a longer period than self-reported. Divergence between actual and reported behaviour is not uncommon. Dembkowski (1998) highlighted the importance of understanding that divergence in the context of environmental policy. Such divergences are often deeply embedded in the dynamics of social interaction and culture. They can, of course, arise out of mis-measurements or even lag times between reported behaviour and intentions and direct monitoring of behaviours.

Certainly, one might explain the divergence between reported heating and the apparent heating behaviour in those terms. It might be, for instance, that the monitored year was a colder year than householders were predicting when they reported on their heating behaviours – although Table 1 shows the ambient temperature was in some cases higher, and in others lower, than for the 1971/2 study. But it may be that New Zealanders have taken on a sort of cultural pride in under-heating and understate how much they heat. Alternatively, perhaps New Zealanders get so little benefit from heating, that they perceive that they are heating less than they are in reality.

Both the latter are real possibilities given that there is a statistically significant association, at the national level, between the length of time householders claim to heat and the extent of divergence between reported heating and actual heating.

The greatest divergence between reported heating and actual heating occurred in houses in which the householders claimed to heat only for 4 months or less. Occupants who reported heating five months or more were found to heat for a period closer to the number of months they reported. On average, occupants heated for just over one month (1.1 month) longer than they reported.

Table 4 provides statistics from the occupant self-reported heating schedules. The living room, normally the location of the main heater, is most commonly heated zone with all but about 8% of households heating at some time during the weekday and weekend evenings. The large majority of households (89%) heat the living room during weekday evenings. Half of the households do not heat the bedroom during weekdays, while 39% heat during the evening and 16% heat overnight. Two thirds of households do not heat utility zones (e.g. bathrooms, laundries, hallways) during the weekdays. The proportions for all zones are very similar for the weekends.

Heating Time	**Living**		**Bedroom**		**Utility**	
	Weekday	**Weekend**	**Weekday**	**Weekend**	**Weekday**	**Weekend**
Morning (7 am to 9 am)	37%	38%	16%	15%	16%	15%
Day (9 am to 5 pm)	26%	36%	8%	10%	11%	14%
Evening (5 pm to 11 pm)	89%	86%	39%	38%	28%	26%
Overnight (11 pm to 7 am)	18%	18%	16%	16%	8%	8%
No heating	7%	8%	50%	52%	67%	69%

Table 4: Percentage of houses reporting heating at that time. Source HEEP

In summary, New Zealand houses are subject to zone heating, with the living room being heated during the winter evening. Other rooms, perhaps most importantly from a health point of view, bedrooms, seldom have formal heating appliances in use overnight (see Table 4). Instead the heat comes from the human occupants and equipment such as televisions which generate heat as an unintended consequence of their operation.

Households, Temperature and Energy Consumption

Under heating of HEEP dwellings is associated with low winter indoor temperatures and zone heating is related to the low penetration of central heating systems. While these are common characteristics of the dwellings in HEEP it is clear that even so, some households are colder than others.

The Luxemburg method (Atkinson et al. 1995) has been used to calculate equivalised household income, in order to control for household size effects. The equivalised income is calculated by dividing the total household income (before tax) by the square root of the number of occupants.

Table 5 shows that dwellings with mean winter evening living room temperatures below 16ºC are over-represented in those dwellings occupied by households in the two lowest income quintiles.

HEP Equivalised Income Quintiles	**Mean Evening Living Room Temperature < 16°C**		**Mean Evening Living Room Temperature ≥ 16°C**	
	Count	**%**	**Count**	**%**
Quintile 1: <= $15,653	24	32.4	49	18.1
Quintile 2: $15,654-$24,749	19	25.7	62	22.9
Quintile 3: $24,750-$35,000	7	9.5	53	19.6
Quintile 4: $35,001-$49,498	13	17.6	62	22.9
Quintile 5: $49,499 +	11	14.9	45	16.6
Total	*74*	*100*	*271*	*100.1*

Table 5: Equivalised Income Quintiles by At Risk Mean Temperatures. Source HEEP

There was also a significant statistical association between these low average winter living room evening temperatures and household size and household tenure respectively. One person household were over-represented in low temperature dwellings, as were tenanted households. Although for total energy use, DHW and residual energy use, life stage has a statistically significant correlation, no such statistically significant relationship was found for heating energy use.

This raises the issue of whether low indoor temperatures are simply generated out of under-heating and low heating energy inputs or because of affordability problems.

HEEP is unique in that it allows expenditure by households to be matched with data relating to actual energy consumption and data to achieved indoor temperatures. That data revealed two critical dynamics.

Table 6 shows over a quarter (28 percent) of low income households spend more than 10 percent on their monthly income on energy (which is the recognized definition of fuel poverty). This demonstrates that fuel poverty is an issue for a substantial proportion of households in New Zealand.

Equivalised Income Quintiles	**Winter Energy Expenditure <10% of Monthly Income**		**Winter Energy Expenditure ≥10% of Monthly Income**	
	Count	**%**	**Count**	**%**
Quintile 1: <= $15,653	46	72	18	28
Quintile 2: $15,654-$24,749	65	97	2	3
Quintile 3: $24,750-$35,000	52	100	0	0
Quintile 4: $35,001-$49,498	60	100	0	0
Quintile 5: $49,499 +	48	100	0	0

Table 6: Equivalised Income Quintiles by Winter Energy Expenditure Proportion. Source HEEP

Perhaps even more importantly, HEEP found that households in dwellings with very cold indoor temperatures during winter (under 16ºC) spend a greater proportion of their income on energy than the HEEP households overall.

The households with very cold living rooms on average expend 5.6 percent of income in winter on energy compared to an average 4.3 percent of income for the total set of HEEP households. There is statistically significant relationship between equivalised income and self-reported winter energy expenditure (Pearson test, r = -0.621, p<001).

Policy and Programme Shifts

What the HEEP data suggests is that New Zealanders do have a desire for warmer homes. They do attempt within the constraints of affordability to heat their dwellings but are unable to achieve acceptable indoor temperatures during winter. The data suggests that while fuel poverty is an issue, the problem does not simply reside in low incomes and will not, consequently, be remedied through income support interventions.

The fundamental problem for NZ households is that their dwellings have not performed well; the heating appliances they use encourage zone heating; and they fail to achieve healthy temperatures. Those factors prevail for both low and higher income households, but lower income households have the problem of being exposed to low indoor temperatures compounded by problems of fuel poverty.

HEEP findings emerged in the last five years and have contributed to some critical policy shifts in NZ. Firstly, improved knowledge of heating patterns and temperatures has been used to revise the mandatory insulation levels in dwellings. Second, there has been a shift in the focus of residential energy efficiency policy. Previously, the outcomes sought by retrofitting existing stock were directed at reducing energy consumption at the household and national levels. The HEEP data on low indoor temperatures has contributed to recognition that benefits of retrofitting existing stock are likely to be improved indoor conditions rather than energy savings.

There have also been some critical shifts in the interface between energy, environmental and health policy. Prior to the HEEP study, residential energy policy was focused on energy reduction, while environmental and health policy was focused on the issue of outdoor air quality. Associated with the latter was a series of local authority initiatives to replace both open fires and enclosed wood burners with, predominantly, electricity-based heating. HEEP data showing the association between wood burners and healthier indoor winter temperatures coupled with the prevalence of wood burners prompted a rethinking of that approach and was associated with the establishment of a Ministerial Advisory Committee on Warm Homes.

Two policy responses have now emerged. Firstly, the interface between energy, environment and health has been recognised and is subject to active inter-sectoral policy and programme development. Second, there has been a diversification of heating appliances subsidised through grants or loans to include wood burners as well as electrical and gas heating appliances, The market has responded strongly to the latter with a new generation of wood burners with higher efficiency and lower emissions performance.

It is notable that current programmes still encourage zone heating. Subsidies for retrofitting more efficient heating appliances are limited to appliances for living spaces. These both reflect the current patterns and reinforce them by encouraging zone heating by only funding heating devices to be placed in the ‘main living room’ and sized to heat that space only (e.g. Environment Canterbury 2010).

There is little governmental, industry or consumer focus on central heating opportunities, such as the use of enclosed wood burners to heat bedrooms through hydronic-radiators, although there is a developing use of roof space mounted flexible ducting to move heated air. If anything, the requirement under the National Environmental Standards for Air Quality for the wood burner thermal efficiency to be based solely on the heat delivered to the room with no allowance for any heat used elsewhere in the house (Ministry for the Environment 2005, 2010) is a disincentive to the greater use of solid fuel for whole house (or water) heating. New Zealand homes, consequently, will continue to have low bedroom temperatures.

The other shift in policy has been around support for improving the thermal performance of the housing stock. HEEP and subsequent work by Beacon Pathway Limited (www.beaconpathway.co.nz) has contributed to the recent change for insulation retrofit subsidies to be:

- extended into newer housing stock, and
- targeted to both low and higher income households by extending subsidies beyond low income household grants to higher income household lending programmes.

These are relatively limited responses to pervasive problems of poor stock performance and underheating.

Conclusion

HEEP is unique because it empirically matches energy use and the actual achieved temperatures, as well as using household income data and energy expenditure to explore the actual heating (and other energy using) behaviours. It provides a more comprehensive view about issues of energy use and fuel poverty than the internationally more widespread use of income data, surveyed energy expenditure and limited actual temperature data.

Overall, understanding how, why, when and where house occupants use energy and the services they receive from that energy has great promise. The results of such knowledge has been and can be used in the future for a wide range of purposes, including energy policy, greenhouse gas emissions reduction policies, building codes and the identification of commercial business opportunities

In an environmental and resource constrained world, the future is not in just increasing energy supply. The future must have knowledge as to how that supply can be most effectively (and efficiently) used to meet the many demands of building occupants. HEEP, through understanding the behaviour of occupants and their energy uses provides an example for other countries and regions interested in opportunities for the future.

Acknowledgements

This work was supported by long term funding from the NZ Government's Foundation for Research Science and Technology's 'Public Good Science Fund' and Building Research Levy. The support of other funders, researchers and the many house occupants involved in the research is also gratefully acknowledged.

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