Understanding Houses – A Key Step to Sustainability

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Summary

How do you know your house is sustainable if you have no information on what makes a house unsustainable? The Household Energy End-use Project (HEEP) (completed in 2007), provides baseline information on key measures of sustainability – the use of energy and the temperatures in New Zealand's residential buildings. The results from HEEP now provide the basis for projects such as the Key Energy Uses Study (air-to-air heat pumps and entertainment appliances), Sustainable Water Heating (solar and heat pump), lighting surveys and downlight investigations. HEEP and the Key Energy Uses study are nationally representative monitoring studies collecting energy use, temperatures, and house and social data. Others are case studies or surveys on specific technologies to understand performance and uptake rates.

HEEP found that in order to understand house performance it is necessary to understand occupant behaviour. Further studies of specific technologies have shown the importance of correct installation and use to achieve expected outcomes. HEEP also revealed the fallacies of some long-held beliefs. For example, it was believed that electricity was the most important domestic space heating fuel, as nearly every house had multiple electric heaters. HEEP found electricity was only 32% of space heating energy use, but with the uptake of heat pumps subsequent research has found houses are now warmer, more comfortable and have healthier temperatures, but the fuel switching is leading to higher electricity use. Ideally, electricity use would be reduced, but temperatures and relative humidity kept at a healthy level. This is possible through improving thermal performance of the house, having well-installed and correctly-sized heat pumps and sensible use.

The heating of hot water is another electricity issue, with 88% of homes having electricity hot water systems, whether stand-alone (only electricity) or used in conjunction with solid fuel heaters (such as wet-back water heaters). Electricity provides 75% of the energy used for hot water, but as there is no regularly collected national data, it is not known how this proportion has changed over time or about future changes.

The change in the pattern of demand for a major hot water use has led to changes in the way hot water is used and needs to be supplied. In 1971/1972, 59% of houses with electric hot water systems mainly or solely used the bath. By the time of the HEEP project, which started some 25 years later, only 2% of households mainly or solely used the bath. This societal shift away from batch use of hot water (bath) to continuous flow (shower) has placed new demands on hot water systems that reflect not the modern, but rather the historic, expectation of the designer.

Households have responded to their historic hot water system being unable to meet changing demands by increasing the storage temperature, which while providing more hot water for the continuous demand also creates dangerous tap temperatures, particularly for the very young and the elderly.

The uptake of solar and heat pump hot water systems in New Zealand is low. Very few of these systems were found in the HEEP houses. One government agency – the Energy Efficiency and Conservation Authority (EECA) – is interested in increasing the uptake of these systems and we worked with them to understand their performance. An examination of solar systems showed that overall the installation quality and energy performance was mixed, reflecting the lack of maturity in the industry at that time. A number of follow-up projects have demonstrated that effective solar water heating systems are possible. The examination of heat pump hot water systems found that the systems generally provided a good level of performance except for certain types of systems, as well as households, which only had a low level of hot water use.

The Electricity Commission recognised that very few houses in HEEP were using energy efficient lights. They realised the energy efficiency benefits in increasing the use of these lights in homes, and began by updating HEEP information on the use of different types of bulbs by doing an intensive lighting survey including site examinations of 140 homes in New Zealand. Using the HEEP and Electricity Commission usage information it was then possible to calculate potential savings through increasing the installation of energy efficient lights in homes.

Since 1996 the New Zealand government has had a thermal insulation subsidy scheme. Experience from a similar scheme in Australia showed that there are overheating risks when insulation is installed too close to recessed downlights in ceilings. Laboratory testing was undertaken to determine how to safely install insulation around recessed downlights. The results from the Electricity Commission work supported this analysis by providing real information on the lighting density, type and usage which enabled the subsidy scheme to continue with greater cost effectiveness and reduce overheating risk.

This paper reviews knowledge gained from these studies and how they have been, or are being, used to support the development of national energy efficiency standards: a national insulation scheme; sustainability benchmarks; and energy scenario planning. Together these studies help to identify current and future issues for advancing the sustainability of houses in New Zealand.

Keywords: Energy end-use monitoring, heat pumps, HEEP, sustainable housing.

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This information is being built on by projects such as the Key Energy Uses study (air-to-air heat pumps and entertainment appliances), Sustainable water heating (solar and heat pump), lighting surveys and downlight investigations. HEEP and the Key Energy Uses study are nationally representative monitoring studies collecting energy use, temperatures, house and social data. Others are case studies or surveys on specific technologies to understand their performance and uptake rates.

HEEP found to understand house performance it is necessary to understand occupant behaviour. Further studies of specific technologies has shown how important the correct installation and use of them is to achieve expected outcomes. For example before HEEP it was understood that electricity was the most important domestic space heating source as nearly every house has multiple electric heaters. HEEP found electricity to represent only 32% of space heating energy use. Indoor temperatures were found to be below internationally accepted comfort and health norms. With the uptake of heat pumps, new research is finding that houses are warmer, more comfortable and have healthier temperatures, but the fuel switching is leading to higher electricity use.

This paper reviews knowledge gained from these studies and how they have or are being used to support national energy efficiency standards; a national insulation scheme, the development of sustainability benchmarks and scenario planning. Together these studies help to identify current and future issues for advancing the sustainability of houses in New Zealand.

Keywords: Energy end-use monitoring, heat pumps, HEEP, sustainable housing.

1. Introduction

How do you know a building is sustainable if you have no information on what makes a building unsustainable? If today's buildings are unsustainable, then we need to understand the reasons that they are the way they are, in order to develop sustainable buildings for the future. Many myths have grown up around New Zealand buildings, but the cost and effort of finding factual answers has meant that decisions have too often been made based on the myths rather than on reality.

This paper will explore how a number of research projects – the Household Energy End-use Project (HEEP); the Key Energy Uses Study (examining air-to-air heat pumps and entertainment appliances); Sustainable Water Heating (examining solar and heat pump water heating); lighting surveys; and downlight investigations – contribute to dispelling the myths. HEEP was completed in 2007, with other monitoring and survey projects building on the results. The studies provide baseline information on New Zealand residential energy use and end-uses as part of a measure of sustainability. The research has been designed to support the New Zealand Building Code (Building Code), government policy, building design and construction, and product development as well as being used as an educational tool.

1.1 Housing in New Zealand

A typical house in New Zealand is timber framed with weatherboard cladding, a timber or concrete floor (new house floors are typically concrete) and a long-run steel roof. Houses are typically stand-alone with one or two levels. The construction of houses is influenced by New Zealand being seismically active.

New Zealand has only required thermal insulation in new houses since 1 April 1978. These requirements, modest even for a temperate country, were increased in 2000 and again in 2007. Table 1 sets out thermal resistance requirements for common combinations of roof, wall and floor. The zones are based on climate, from the warmest (1) to the coolest (3).

Table 1 Building Code thermal performance requirements 1978 to current

Year Commenced	Standard	Coverage	R-Values (m^2 °C/W) Ceiling	Wall	Floor	Glazing
1978	NZS 4218P:1978	New Zealand	1.9	1.5	0.9	0.15
2000	NZS 4218:1996	Zones 1 & 2	1.9	1.5	1.3	0.15
		Zone 3	2.5	1.9	1.3	0.15
2007	NZS 4218:2004	Zone 1 & 2	2.9	1.9	1.3	0.26
		Zone 3	3.3	2.0	1.3	0.26

Older houses are not required to upgrade to the current standard, but in some cases roof and floor insulation has been voluntarily installed. Beacon Pathway, a research consortium on sustainable housing, predicts that by 2012 approximately 1.6 million of the 1.7 million houses in New Zealand will have inadequate insulation [1].

Thus far the focus for sustainability requirements in New Zealand has been through the use of thermal insulation to reduce residential energy use. This paper focuses on projects on energy use and indoor environment, but there are other important projects examining opportunities for whole house sustainability e.g. water, materials and passive design. These include HomeStar [2], Level [3] and projects by Beacon Pathways Ltd [1].

1.2 New Zealand climate

New Zealand is long and narrow, approximately 1,600 km in length, with a land area of 270,000 sq km, ranging from Latitude 37°S to 46°S.

The winter season in New Zealand (a southern hemisphere country) is during the months of June, July and August. The summer months are December, January and February. The majority of homes are in a coastal climate, but the central areas of both islands are more continental. The far south is cooler than the far north. For example, the daily mean winter temperature in Invercargill (in the far south) is 6.2°C compared to 11.9°C in Kaikohe (in the far north). The mean summer ambient daily temperature in Kaikohe is 18.8°C, but in Invercargill only 13.3°C. The annual range of monthly mean temperature (difference between the mean temperature of the warmest and coldest months) is relatively small. In the top of the North Island (Northland) and in western districts of both islands it is about 8°C, while for the remainder of the North Island and east coast districts of the South Island it is 9°C to 10°C. Further inland, the annual range can exceed 11°C, reaching a maximum of 14°C in Central Otago [4].

2. Household Energy End-Use Project (HEEP)

HEEP collected energy use and end-use data from 400 randomly selected houses throughout New Zealand. It monitored all fuels (electricity, natural gas, LPG, coal, wood and oil) and end-uses (hot water, space heating, lighting, cooking, refrigeration, entertainment etc). HEEP is a nationally representative study which provides a detailed breakdown of how, why, when and where energy is used [5].

This paper looks at the overall energy use of houses, the types of fuels used for heating as well as the different types of hot water systems, but these only touch on some of the wealth of HEEP information. For more information on HEEP, the final year report [5] covers monitoring methodology, winter and summer temperatures, effect of insulation on energy use and temperatures, appliance ownership, detailed hot water information, standby and baseload, and socio-demographic characteristics of the houses in the sample.

The information gained from HEEP has had many different uses including informing National Energy Efficiency Standards for houses [6], helping to set realistic sustainable benchmarks [7], as well as the examples given in this paper.

2.1 Energy end-uses

HEEP data can be used to provide a national breakdown of residential energy use by fuel type and end-use. Fig. 1 breaks down energy supply by fuel type. Fig. 2 shows that, on average, across all fuel types space heating is the largest single end-use (34%) followed by hot water (29%), appliances (13%), refrigeration (10%), lighting (8%) and cooking (6%). The most important fuel source is electricity, while the most important space heating fuel is solid fuel (wood and coal).

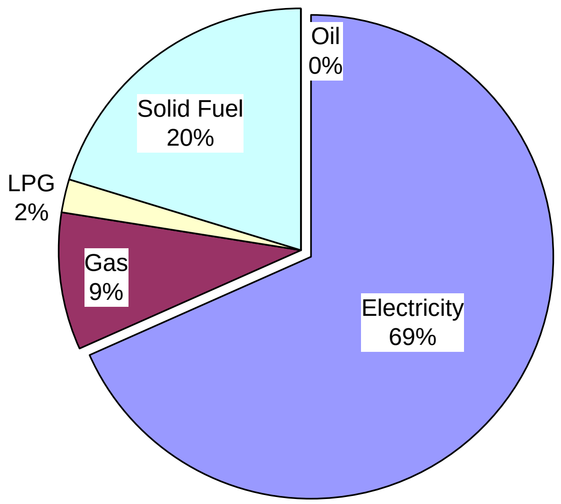


Fig. 1 Total energy use by fuel type

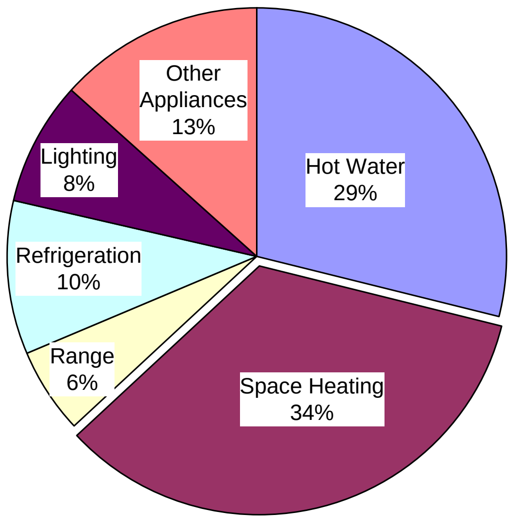


Fig. 2 Total energy use by end-use

Thus the production of low temperature heat is the main (63%) use of household energy. It is used to provide 'space heat' (34%) and 'water heat' (29%). For the first time HEEP identified the actual energy marketplace competitors. This marketplace is not a competition between the two predominant fuels i.e. electricity and natural gas. It is a competition between any fuel that is able to provide low temperature heat e.g. electricity, natural gas, wood, wood pellets etc.

2.2 Space heating

Prior to HEEP, the only national data on the fuels used for space heating in New Zealand homes came from the five-yearly census. Table 2 gives the space heating fuel types reported in the 1996, 2001 and 2006 censuses both as count and proportion [8], and the proportion of the 'main (space) heating fuel' from the HEEP survey.

Table 2 Space heating fuel types – 1996

	Census – Total Responses			**% of Total Dwellings**			**HEEP**
Fuel types	**1996**	**2001**	**2006**	**1996**	**2001**	**2006**	***Main fuel***
Electricity	948,363	937,719	1,051,095	74%	69%	71%	*30%*
Mains gas	142,704	175,419	185,826	11%	13%	13%	*10%*
LPG (bottled gas)	273,927	368,118	388,746	21%	27%	26%	*15%*
Wood	598,605	582,267	574,485	47%	43%	39%	*44%*
Coal	159,537	121,170	98,226	12%	9%	7%	
Solar power	8,913	12,318	15,159	1%	1%	1%	
Other fuel(s)	11,541	14,130	29,304	1%	1%	2%	*1%*
No fuels used in this dwelling	23,343	36,207	33,177	2%	3%	2%	
Not elsewhere included	47,982	57,126	66,189	4%	4%	4%	
Total dwellings	1,276,332	1,359,843	1,471,746	174%	169%	166%	*100%*
Average number of fuel types used per house				1.68	1.63	1.59	*1.74*

As many houses use more than one fuel for space heating, when the responses are summed this results in a value higher than the number of dwellings. If the 'No fuels' and 'Not elsewhere included' categories are removed, this gives the average number of fuels used in New Zealand homes. Table 2 shows that the diversity of fuel use has reduced by 5% over the 10-year period, from an average of 1.68 to 1.59 fuels per home.

Table 2 shows that electricity is the fuel reported in the census to be available to be used for space heating in the largest number of houses, with 71% of private dwellings reporting the use of electricity for space heating in 2006, with wood next (39%) followed by LPG (26%) and mains gas (13%). Other fuels were available in less than 10% of dwellings.

The presence, or ability to use, a fuel is not a measure of its importance. HEEP not only asked occupants what they felt to be the main heating fuel, but also collected monitoring data that permitted the calculation of actual fuel use.

The far right column of Table 2 gives the HEEP 'Main fuel' as stated by the house occupants. The order of importance is different to the census. Solid fuel (wood and/or coal) is the most important (44%), followed by electricity (30%), bottled gas (15%) and mains gas (10%). HEEP found that there were on average 1.74 fuels used per home – 9% higher than the number reported by the 2006 census.

Fig. 3 provides an overview of the relative importance of the major heating fuels based on the monitored gross energy consumption.

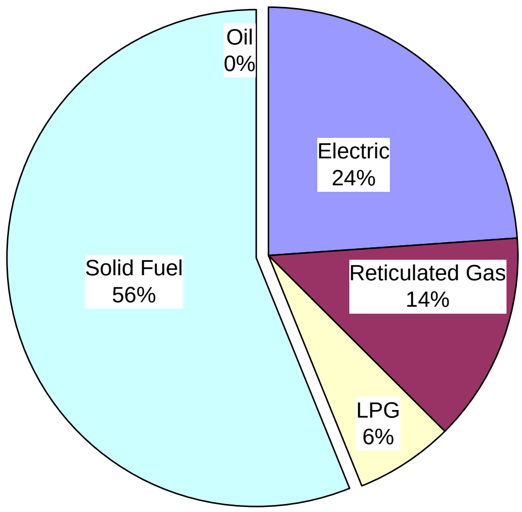


Fig. 3 Space heating gross energy by fuel

Fig. 3 shows that solid fuels are the most important, providing 56% of gross space heating energy, followed by electricity at 24%, reticulated gas at 14%, LPG at 6% and oil under 1%. Heat pumps were found in very few HEEP houses, but their use is fast increasing. The Key Energy Uses Study is currently underway to update information on the use of heat pumps [9].

The results from HEEP significantly changed the national understanding of residential fuel use. Fig. 4 shows the official estimate for wood and coal ('Solid fuel') used in the December 2004 year was 5% of total residential energy use [10]. For this analysis the 'Other' category includes geothermal and solar. For Fig. 5 it has increased to 14% in 2005 [11]. However, this is not due to an increase in the actual residential use of wood or coal, rather an improved understanding of the actual fuel use.

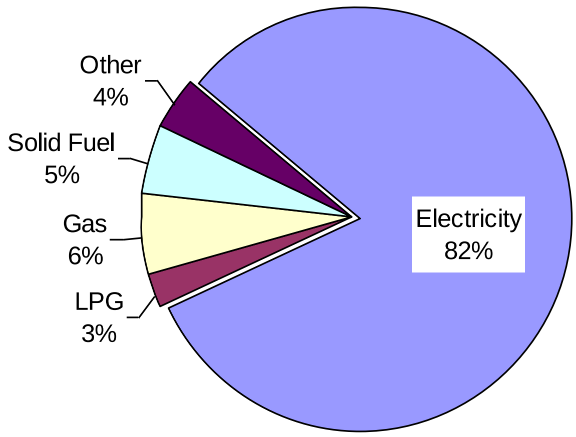


Fig. 4 Fuels all end-uses December year 2004

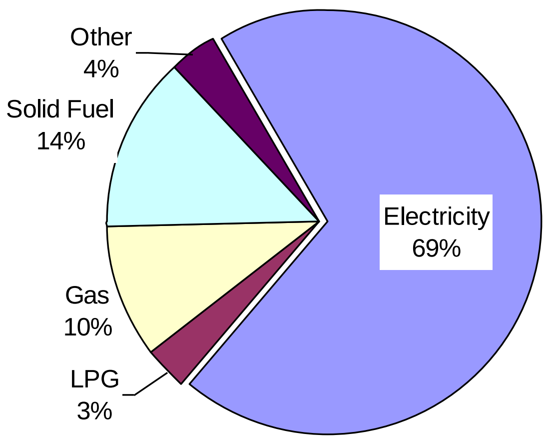


Fig. 5 Fuels all end-uses September year 2005

This result of the HEEP research has led to an apparent national increase in wood use of 5.6 PJ – equal to a 1% increase in total observed consumer energy, or a 9% increase in residential sector consumer energy. If this wood was burnt in solid fuel burners with an efficiency of 50%, it would be equivalent to a 530 MW thermal power station feeding conventional resistance heaters or a 180 MW station feeding heat pumps. In energy terms, meeting this solid fuel heating load would require a 6% increase in residential sector electricity demand if used in conventional resistance heaters, or 2% if used in heat pumps (COP 3 i.e. produce three units of heat for each unit of electricity) [5]. This had implications for the national GHG emissions inventory, but more importantly ensures that planning for GHG reduction is now on a realistic basis.

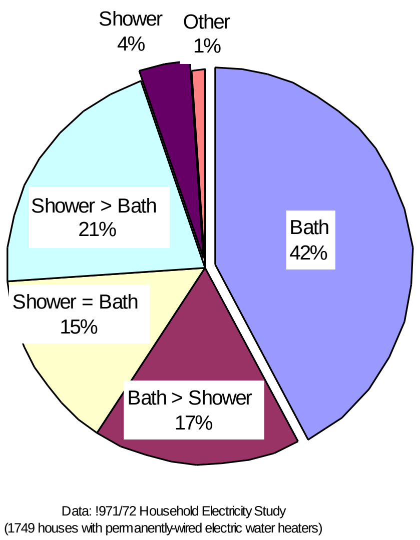
2.3 Domestic hot water

There have been no official statistics on domestic water heating fuels since the 1996 quinquennial census and no data is collected in the more frequent Household Economic Surveys. But why is this lack of knowledge important?

The large majority of New Zealand dwellings have a long life, low-pressure copper electric hot water cylinder. If the cylinder fails, it is likely to be urgently replaced with one of comparable size and type – often for no other reason than to ensure it fits in the existing space. Thus hot water systems, in the main, reflect not the performance that might be expected from a modern installation, but rather the design that was common when the house was built.

But while the hot water system may not change over time, the behaviour of the house occupants does. The 1971/1972 Electricity Study [12] recorded information on the number of baths and showers in the house, and their relative use by house occupants. The results were presented comparing the number of occupants, the number of showers and baths, and their comparative usage. The HEEP Survey asked house occupants for information on their use of hot water.

The following two figures summarise the relative use of baths and showers for the two studies separated by approximately 30 years (Fig. 6 for the 1971/1972 study and Fig. 7 for HEEP). For consistency, the HEEP sample has been limited to houses with one or more electric cylinders i.e. excluding houses with only gas or solid fuel hot water systems.



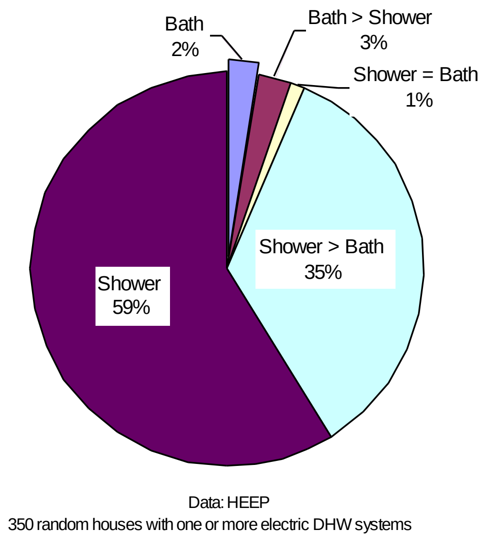


Fig. 6 Use of baths and showers 1971/1972

Fig. 7 Use of baths and showers HEEP

Fig. 6 and Fig. 7 show there have been major changes in bathing habits over the past 30 years. In 1971/1972, 59% of the households ‘mainly’ or ‘solely’ used the bath. Over 30 years later, this has reduced to 5% of the HEEP houses. There has been a sizable growth in the proportion of households using the showers or mainly the shower, growing from 25% in 1971/1972 to 94% in HEEP.

Although uses of hot water have changed, it seems that hot water systems themselves have only altered slightly. Fig. 8 and Fig. 9 compare the total volume of house hot water electric storage cylinders for the 1971/1972 study and the HEEP random houses. The proportion of smaller 135 litre cylinders has reduced from 56% to 40%, while the houses with 180 litre total cylinder volumes have increased from 38% to 45% of the sample. Houses with hot water cylinders over 180 litres have increased from 3% to 12%.

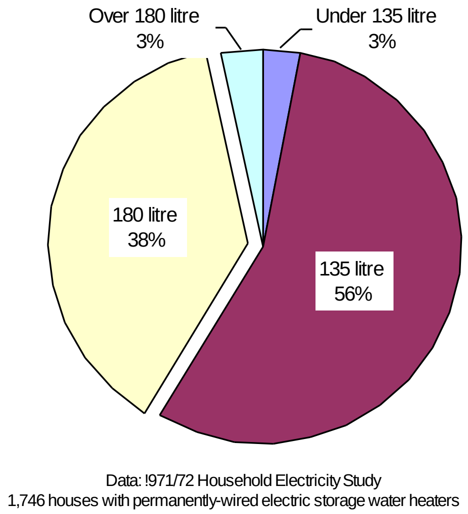


Fig. 8 Household domestic hot water volume 1971/1972

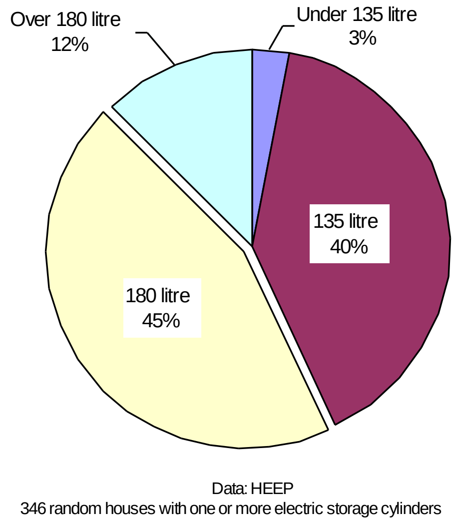


Fig. 9 Household domestic hot water volume HEEP

There has been a 13% increase in the weighted-average size of household hot water systems – from 150 litres per household in 1971/1972 to 170 litres in HEEP. Conversely, the number of people per house has reduced by 15% – from an estimated 3.4 in 1971/1972 to a calculated 2.9 in the 346 HEEP houses with an electric water cylinder and occupant number data.

But has the increase in the size of the hot water system been adequate to meet the changed hot water demands? One measure is the storage temperature – the cylinder temperature will relate to the ability of the cylinder to provide adequate hot water to meet the user needs. If the cylinder does not provide adequate hot water, it is very simple for the occupants to increase the storage temperature by 'turning the thermostat up'.

Table 3 Tap temperatures by system type

	Electric Storage	**Electric + Solid**	**Gas Storage**	**Gas Instant**	**TOTAL**
Count domestic hot water systems	314	63	34	20	441
Count with temp available	292	59	33	12	403
Count >55°C	241	46	26	4	321
%	83%	78%	79%	33%	80%
Count >60°C	186	32	15	3	239
%	64%	54%	45%	25%	59%

Table 3 tabulates for the different types of systems the count in the HEEP sample for which tap temperatures are available, and the number and percent of these with tap temperatures over 55°C and 60°C.

Around 80% of the storage systems (electric or gas) had tap temperatures over 55°C, but only 33% of the instantaneous systems. Sixty-four percent of electric storage, but only 45% of gas storage and 25% of gas instantaneous systems delivered tap water at over 60°C. A t-test comparison of electric storage and gas storage systems suggests these are two different distributions (t = 3.5361, p-value = 0.0009), and similarly an electric and gas fuel-based comparison suggests different distributions (t = 4.8736, p-value = 0).

Since 1993 it has been a requirement under the Building Code Clause G12 to limit tap temperature on the supply to any "sanitary fixture (e.g. by using a 'tempering valve') used for personal hygiene", but to store the water at a high enough temperature to prevent the growth of legionella bacteria. G12/AS1 sets the delivery temperature to a maximum of 55°C in housing but storage at over 60°C. HEEP found only 16% of the cylinders in the sample had a tempering valve fitted.

There is an undesirable safety consequence of users increasing water storage temperatures to ensure an adequate supply of hot water. Hot water is more dangerous to the very young and the elderly, whose skin is less able to withstand higher temperatures. For a child placing their skin into water at 54°C, only 10 seconds is required for a full-depth burn, compared with 30 seconds for an adult [13]. HEEP found no link between the age of the youngest or oldest person in the house and the hot water temperature, suggesting age is no barrier to the provision of dangerous hot water.

3. Research projects building on HEEP

This section covers some of the research projects that have been carried out by BRANZ building on information from HEEP to keep our baseline data up-to-date.

3.1 Key Energy Uses Study

There has been significant growth in residential air-to-air heat pumps in the last few years. HEEP found 4% of houses had heat pumps, whereas preliminary results from the 2011 *BRANZ House Condition Survey* found 28% of houses have one or more heat pumps (not yet published). The Key Energy Uses Study is designed to understand heat pump use in New Zealand houses and the achieved indoor conditions. It is a monitoring project, based on a nationally representative sample of houses with one or more air-to-air heat pumps. Data on energy use, temperatures and relative humidity are being collected for a year from the 170 houses [9]. In addition to data on the heat pump and its installation, the study includes an occupant survey, a house energy audit and the preparation of a detailed house floor plan. Early results have already been used for scenario planning on different electricity networks to help with maintenance and upgrade schedules [14]. A *Good Practice Guide* for heat pump installations has also been prepared based on the knowledge gained from this project [15].

3.1.1 Early results

Monitoring of the heat pumps in the study will not be completed until early 2012. However, some early results can be reported from a sample of 85 houses.

The majority of the householders had the heat pump installed after they purchased their house – only 16% moved into a house with the heat pump, while 8% installed at the time of building. Seventy-four percent of those moving into dwellings after 2005 had heat pumps installed within a year of occupation. Fifty-six percent of householders with a previous heating appliance reported that they substituted that heating appliance with a heat pump. The remaining 44% reported supplementing their previous heating systems with a heat pump.

Thirty-nine percent of the householders that acquired a heat pump got information about heat pumps from family members or friends, and 40% of householders with heat pumps reported that their neighbours had one. Householders consistently refer to seeing other people install heat pumps as a motivation to purchase one.

The types of heaters substituted by heat pumps vary by region. For example in Canterbury, where there are now air quality regulations [16], many householders have substituted heat pumps for non-compliant wood burners. However, nationally the heating and fuel sources most likely to be replaced by heat pumps are reticulated or bottled gas, or electrical appliances.

The householders changing from an electric heater to a heat pump are likely to get a much better service with increased temperatures for possibly less cost (depending on temperature set point and hours of heating). Very few householders reported replacing an enclosed log burner with one or more heat pumps. In general, where log burners were installed already, these householders were using heat pumps as a heating supplement beyond the living room or lounge.

Sixty percent of houses that are replacing an existing heater with a heat pump are changing to electricity. They may get a better service, but they will use more electricity. Table 4 gives the annual space heating use for all energy types and for electricity only per house by region for houses in the HEEP sample [5], and the annual space heating use for heat pumps per house by region for houses in the heat pump study.

Table 4 Average annual space heating use per house (kWh)

	Household Space Heating Energy Use (HEEP) 2000-2005				**Heat Pump Energy Use (incl. Cooling) 2010**	
Region	**All energy types**	**Standard deviation**	**Electricity**	**Standard deviation**	**Electricity**	**Standard deviation**
Nationally (preliminary)	3,820	350	920	190	1,380	190
Auckland	3,190	840	1,630	720	740	100
Wellington	2,630	730	780	600	1,420	310

The average heat pump electricity use per house over the sample is approximately 1,380 kWh, whereas the median is approximately 800 kWh.

In HEEP Auckland was one of only two cities to use more electricity for space heating than any other fuel. This is thought to be because it has a relatively mild climate and therefore few houses have had fixed heating systems installed. Instead they relied on electric resistance heaters. By installing heat pumps in Auckland the electricity use for space heating has decreased due to the heat pump efficiency gains. Table 4 shows that on average Auckland HEEP houses used 1,630 kWh, while the more recent heat pump houses use 740 kWh for electric heating. In Wellington the situation is reversed with the heat pump houses using almost double (1,420 kWh) the amount of electricity for space heating compared to the houses in HEEP (780 kWh). This is due to the Wellington HEEP houses not being as reliant on resistance heaters as Auckland and therefore they do not benefit as much from the efficiency gains.

Although the Key Energy Uses Study has found that more electricity is being used for space heating than in HEEP, the houses are now warmer. HEEP found temperatures in homes were often below what was considered a healthy temperature. When heat pumps are present, an increased proportion of houses are now maintaining comfortable temperatures (see [9] for further analysis).

3.2 Sustainable water heating

HEEP found that the uptake of solar water heating and heat pump water heating was low. The few solar water heating systems encountered within HEEP did not provide sufficient information to analyse the impact this technology is having on residential energy use. Heat pump water heaters are even less common than solar water heaters and no such systems were encountered in HEEP.

To provide data on how these technologies are performing in the New Zealand setting, a series of projects have been undertaken in conjunction with EECA. For the solar water heating systems this assessment included examining the configuration and installation quality of the systems [17], the householders' attitudes and experiences [18], as well as energy savings achieved by the various systems [19].

The systems examined were installed around 2006 when renewed interest in solar water heating was taking place. Overall the installation quality and energy performance was mixed, reflecting the lack of maturity in the industry at that time. A number of follow-up projects have demonstrated that effective solar water heating systems are possible.

A related project involved measuring the energy performance of a number of heat pump water heating systems [20] as part of a larger EECA project. It was found that although heat pump systems generally provided a good level of performance, certain systems did not. These under-performing systems were frequently of a particular type. In addition, heat pump hot water systems did not provide benefits to households which only had a low level of hot water use.

These projects have provided greater certainty as to the benefits of these types of water heaters, with this resulting in both types now being eligible for government support.

3.3 Lighting surveys

The Electricity Commission recognised that very few houses in HEEP were using energy efficient lights. They realised the energy efficiency benefits in increasing the use of energy efficient lights in homes, and began by updating HEEP information on the use of different types of bulbs by doing an intensive lighting survey including site examinations of 140 homes in New Zealand [21].

Using the HEEP usage information it was then possible to calculate potential savings through increasing the installation of energy efficient lights in homes. The Electricity Commission work updated HEEP recommendations regarding the rooms to focus on to get the best return on installing energy efficient lights. For example in most houses the bathroom has more lighting power than any other room (50 W/m²), although the lights are only used an average for 1.1 hr/day. This is so low that it is not normally worthwhile installing an energy efficient light. Occupants can also become frustrated at having a light that is slow to get to full brightness (like some older Compact Fluorescent Lights or CFLs) when it is only used for a short period.

3.4 Recessed downlight investigations

Since 1996 the New Zealand government has had a thermal insulation subsidy scheme. Experience from a similar scheme in Australia [22] showed that there are overheating risks when insulation is installed too close to recessed downlights in ceilings.

Through the information from HEEP and the Electricity Commission lighting survey, it was known that there are enough downlights in New Zealand homes (4.2 million individual downlights in 25% of houses – being an average of 12 downlights per house) for this to be a concern. Laboratory testing was undertaken to determine how to safely install insulation around recessed downlights [23].

Cost benefit analysis of installing insulation in locations of different downlight density could then be undertaken. The results from the Electricity Commission work supported this analysis by providing real information on the lighting density, type and usage which enabled the subsidy scheme to continue with greater cost effectiveness and reduce overheating risk.

4. Discussion

A sustainable future may be built on the past, but unless we understand the present we are faced with unknown problems and opportunities for the future.

This paper has used results from the Household Energy End-use Study (HEEP), which completed data collection in 2007, to explore key aspects of space and water heating in New Zealand homes and to show how these results have provided the basis for more focused investigations.

HEEP revealed the fallacy that electricity was the most important space heating source. Although

71% of homes reported the use of electricity for space heating in the 2006 census, HEEP found that it was the main heating fuel in just 30% of homes, and accounted for only 32% of space heating energy. HEEP also found that solid fuel (wood or coal) was a far more important space heating fuel that previously documented, and resulted in changes to the official energy statistics. These results led to a detailed investigation into household use of heat pumps and preliminary results have been given.

There has been a major increase in the use of heat pumps for space heating since the HEEP work. However, the baseline HEEP data has supported the Key Energy Use Study to understand the impact of this new and rapidly growing electricity use. In many cases, the electricity use of the heat pumps is higher than what was traditionally used for electric heating in New Zealand households. This differs by region, with Auckland using less electricity for space heating than in HEEP. Ideally, electricity use would be reduced but temperatures and relative humidity kept at a healthy level. This is possible through improving thermal performance of the house, having well-installed and correctly-sized heat pumps and sensible use. This project has already shown improvements can be made with the installation quality of heat pumps [24]. Full results from this work will be released in 2012.

The heating of hot water is another electricity issue, with 88% of New Zealand homes having electricity hot water systems, whether stand-alone (only electricity) or used in conjunction with solid fuel heaters (such as wet-back water heaters). HEEP found that electricity provided 75% of hot water heating, but as there is no regularly collected national data, it is not known how this proportion has changed over time, or what future changes are possible. It is known that there have been changes in the pattern of demand for a major hot water use with a societal shift away from batch use of hot water (bath) to continuous flow (shower). This change has placed new demands on hot water systems that were based on the historic expectation of the designer.

Households have responded to their hot water system being unable to meet changing demands by increasing the storage temperature, which while providing more hot water for the continuous demand also creates dangerous tap temperatures, particularly for the very young and the elderly. Improved understanding of energy use has the potential to both better save scarce energy resources but also provide improved safety for the more valuable human resource.

5. Conclusion

Together these research studies have been used to explore selected energy end-uses as measures of the sustainability of the New Zealand residential building stock. They provide essential baseline data and knowledge to support the development of a new generation of sustainable buildings.

The management adage that ‘if you cannot measure it, you cannot manage it’ is true of energy use in buildings. The reality is that lacking any valid measurements, the unsustainable use of energy is likely to continue without change. The research projects discussed have demonstrated that when uses are quantified, errors in assumptions (or myths) can be corrected and opportunities for more sustainable use can be identified.

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