# UNDERSTANDING BUILDINGS – A KEY STEP TO SUSTAINABILITY

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## ABSTRACT

How do you know your building is sustainable if you have no information on what makes a building unsustainable? The Household Energy End-use Project (HEEP) (completed in 2007) and its sibling, the Building Energy End-use Study (BEES) (started 2008), provide baseline information on a key measure of sustainability – the use of energy in New Zealand's residential and non-residential buildings.

HEEP found that the majority of household energy (63%) was for heating – air or water. It uncovered a fallacy, based on results from quinquennial censuses, that electricity was the most important heating source. HEEP found electricity was found to represent only 32% of domestic space heating energy. Hot water is another issue, with 88% of homes having electricity hot water systems but too many with dangerously hot water temperatures suggesting they cannot safely, or sustainably, supply the desired hot water service.

The BEES study is now exploring non-residential buildings. As these buildings are not subject to regular censuses, its first activity has been to establish the distribution of size and use. A phone survey will collect information on some 500 randomly selected buildings, their uses and occupants. Revenue meter data for fuels and water will be obtained and monitoring undertaken in a smaller number of buildings. The results will be used in conjunction with computer thermal simulation models to better understand energy use in this important sector.

Together these two research studies provide essential baseline data and knowledge to support the development of a new generation of sustainable buildings.

**KEYWORDS: energy end-use; residential, non-residential, New Zealand**

## 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 been made based on the myths rather than on reality.

This paper will explore how two major research projects – the Household Energy End-use Project (HEEP) and the Building Energy End-use Study (BEES) – contribute to dispelling the myths. HEEP was completed in 2007, while its younger sibling BEES started in 2008. They provide baseline information on energy use and end-uses in New Zealand residential and non-residential buildings respectively, as one measure of sustainability. BEES is also collecting basic information on water use. The research has been designed to support the building code, government policy, building design and construction and product development as well as being used as an educational tool. The first section of this paper deals with the results from HEEP, while the second deals with BEES.

## HOUSEHOLD ENERGY END-USE PROJECT (HEEP)

HEEP collected energy use and end-use data from 400 randomly selected houses from Invercargill in the south to Kaikohe in the north of New Zealand. It monitored all fuels (electricity, natural gas, LPG, coal, wood, 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 (Isaacs et al 2010).

HEEP received funding from a range of organisations, notably the Building Research Levy, the Foundation for Research, Science and Technology (FRST) from the Public Good Science Fund, and the Energy Efficiency and Conservation Authority (EECA).

### Energy end-uses

HEEP data can be used to provide a national breakdown of residential energy use by fuel type and end-use. Figure 1 breaks down energy supply by fuel type. Figure 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).

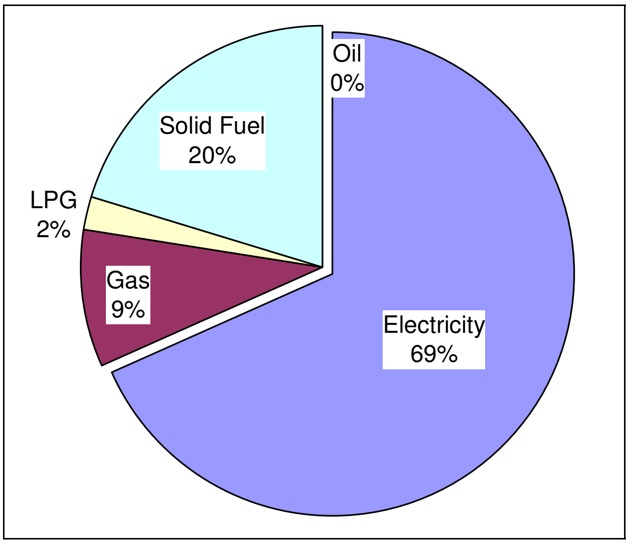



**Figure 1: Total energy use by fuel type**

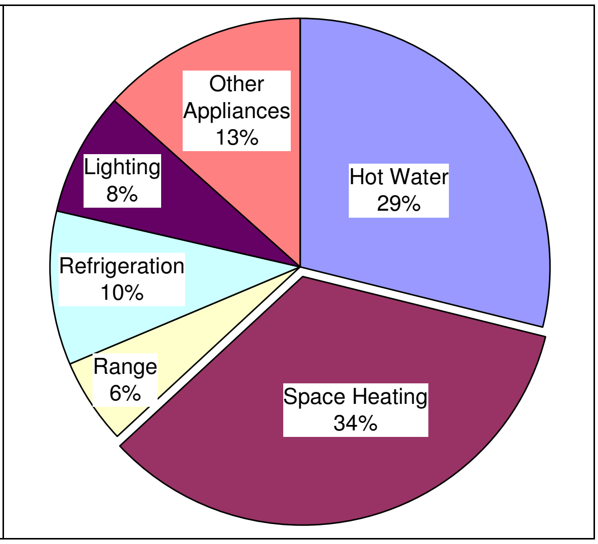



**Figure 2: Total energy use by end-use**

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, 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.

## Space heating

Prior to HEEP, the only national data on the fuels used for space heating in New Zealand homes came from the quinquennial census. Table 1 gives the space heating fuel types reported in the 1996, 2001 and 2006 censuses both as count and proportion (Statistics NZ 2009), and the proportion of the ‘main (space) heating fuel’ from the HEEP survey.

| Fuel types | Census – Total Responses | | | % of Total Dwellings | | | HEEP |
|---|---|---|---|---|---|---|---|
| | **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 (see below) | | | | 1.68 | 1.63 | 1.59 | *1.74* |

**Table 1: Space heating fuel types – 1996**

It is important to recognise that the census data is collected from the occupant completing the ‘House’ form reporting all heating fuel types used in the house. There is no census question about the frequency of use – just if the specific fuel is used. Thus for private occupied dwellings in which more than one fuel type was used, each fuel used is counted. The ‘Not elsewhere included’ category in Table 1 includes households that had a ‘Response unidentifiable’ or ‘Not stated’.

As many houses use more than one fuel for space heating, if 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 1 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.

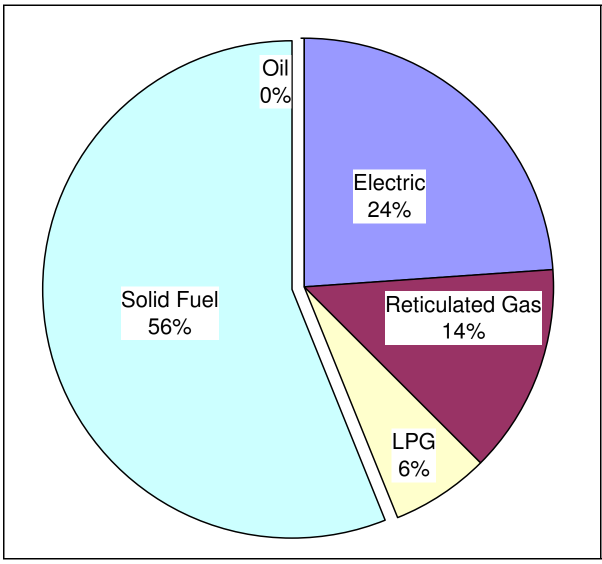
Table 1 shows that electricity is the fuel reported to be available to be used for space heating in the largest number of houses, with 71% of private dwellings reporting the use of electricity for space heating in 2006, with wood next (39%) followed by LPG (26%) and mains gas (13%). Other fuels were 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 1 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.

Table 1 does not provide information on the actual use of these fuels – seasonal variations, hours of use, achieved temperatures etc. This is further investigated in Isaacs et al (2010)

Figure 3 provides an overview of the relative importance of the major heating fuels based on the gross energy consumption taken from the monitored data. Then Figure 4 makes conservative allowances for the efficiencies of different appliances (given in square brackets [ ]). For example, 100% of electricity is converted to heat, but a reasonable quality enclosed solid fuel burner would convert 60% of the energy in the wood to heat.



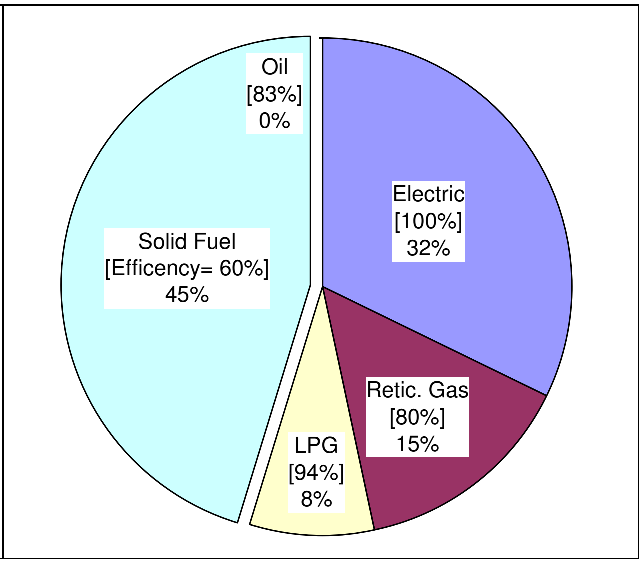




**Figure 3: Space heating gross energy by fuel** **Figure 4: Space heating delivered energy by fuel**

Figure 3 shows that solid fuel is the most important heating providing about 56% of gross[1] space heating energy, followed by electricity at 24%, reticulated gas at 14%, LPG at 6% and oil under 1%. After allowances for conversion efficiency, the proportions change in Figure 4, but solid fuel remains the most important single fuel. Heat pumps were found in very few HEEP houses, although this has changed rapidly in the past few years (French et al 2008).

Thus collection of data to quantify end-uses allows HEEP to correct the misunderstanding based on census data that electricity is the most important heating fuel in New Zealand houses. Although electricity is used, or is available, for heating in nearly three-quarters of New Zealand dwellings, in terms of energy use, solid fuel is more important.

The results from HEEP also significantly changed the national understanding of residential fuels, as reported in the MED Energy Data File. Figure 5 shows the official estimate for wood and coal ('Solid fuel') used in the December 2004 year was 5% of total residential energy use (MED 2005). For this analysis the 'Other' category includes geothermal and solar. For Figure 6 it has increased to 14% in 2005 (MED 2006). However, this is not due to an increase in the actual residential use of wood or coal. The difference is explained in the supporting text (MED 2006):

> *In previous editions of the Energy Data File the figures for residential wood use included in the Energy Balances were based on an average use of 4.3 GJ per household using firewood. This figure had been estimated by an industry analyst in 1996. The 'Household Energy End-use Project' (HEEP) carried out by BRANZ monitored actual firewood use and reported average annual use of 13.7 GJ.*

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[1] Gross energy is the energy content of fuel before it is used in a heating appliance. Solid fuel and gas burners have efficiencies under 100% – some energy is lost during burning and only part is released as heat to the room. Typically gas burner efficiency is about 80%, and solid fuel burners 50-70% e.g. for approval in Christchurch clean air zone 1, over 65% heating efficiency is required (see www.ecan.govt.nz).

*Due to the BRANZ figure having more validity than the earlier figure, values published in this edition have been re-calculated using this new figure.*

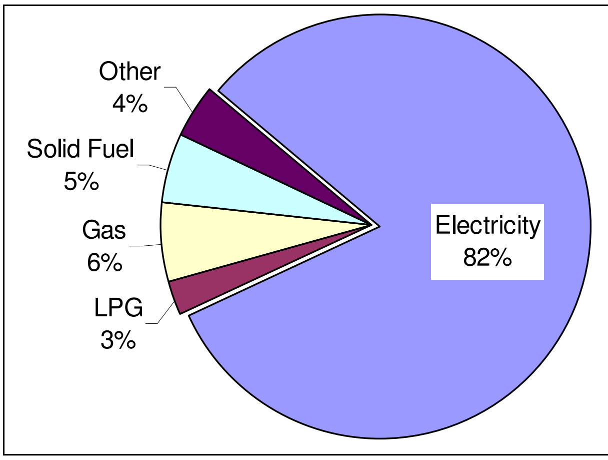


**Figure 5: Fuels all end-uses December year 2004**

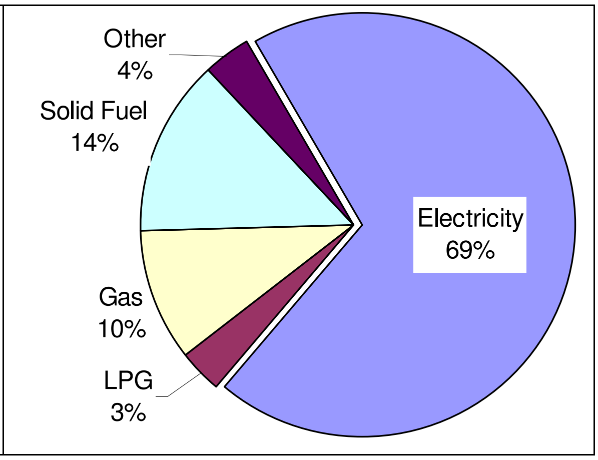


**Figure 6: Fuels all end-uses September year 2005**

This result of the HEEP research has led to a reported 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. For comparison, the Huntly power station is 960 MW. In energy terms, this heating load would be 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) (Isaacs et al 2010).

**Domestic hot water**

HEEP found that electricity provides three-quarters (75%) of energy used for hot water, gas one-fifth (20%), and solid fuel wetback systems almost all of the rest. Outside of HEEP, there is no data available on the fuels or types of hot water systems in New Zealand homes. This question was last asked in the 1996 quinquennial census and is not recorded in the more frequent Household Economic Surveys. But why is this lack of knowledge important?

Historically the provision of domestic hot water (DHW) divides into two categories:

- **batch production**, an early method, often based on carrying cold water to a pan or other holder above a fire; and
- **constant production**, with piped water flowing into a device heated by electricity, gas or solid fuel.

There has been a change over time, with a shift away from batch to constant production. The large majority of hot water cylinders in the HEEP sample were of the continuous production type i.e. as water was drawn off replacement water flowed in to be heated. The few batch heaters, e.g. laundry coppers, were not in regular use. This change is 'common' knowledge, with the old-fashioned copper now being regarded as ideal for growing plants or even holding the fire wood supply. Other changes are not as obvious, but have important impacts on the provision and use of hot water.

Table 2 sets out life expectancies for different cylinder types (Williamson & Clark 2001). The potentially long lifetime of older copper cylinder, low-pressure systems is supported by the HEEP results where, on average, 46% of hot water cylinders are in the same decade as the house, although this proportion varies with house age. Note that the cylinder life expectancy is affected by a range of issues specific to the house and area, notably the water quality.

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.

| Cylinder | Type | Usual Working Head | Life Expectancy |
|---|---|---|---|
| Copper | Low pressure | 2 – 7.6 m | 20 – 50 years |
| Copper | Low pressure | 12.2 m | 20 – 40 years |
| Glass-lined steel | Mains pressure | 35 – 50 m | 12 – 20 years |
| Stainless steel | Mains pressure | 35 – 50 m | 20 – 40 years (estimate) |

**Table 2: Life expectancies of cylinder types**

But while the hot water system may not change over time, the behaviour of the house occupants does. The 1971/72 Electricity Study (NZ Department of Statistics 1973) 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. Data were published only for the 1,749 houses with permanently-wired electric hot water cylinders. Five main divisions were reported: **Bath only**; bath used more than shower (**Bath > Shower**); bath used the same amount as the shower (**Bath = Shower**); shower used more than the bath (**Shower > Bath**); and **Shower only**. A small **Other** category includes houses that lack either a bath or a shower. For the purposes of this analysis, it has been assumed that houses with 'only' a shower or a bath only use only that facility.

The HEEP Survey asked house occupants for information on their use of hot water. For the house, this included the number of baths, showers and shubs (small enclosed bath unit with a shower fitting). For each individual, this included their usual weekday bath or shower usage. The data on bath and shower usage were available for 385 of the HEEP houses.

The following two figures summarise the relative use of baths and showers for the two studies separated by approximately 30 years – Figure 7 for the 1971/72 study and Figure 8 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.

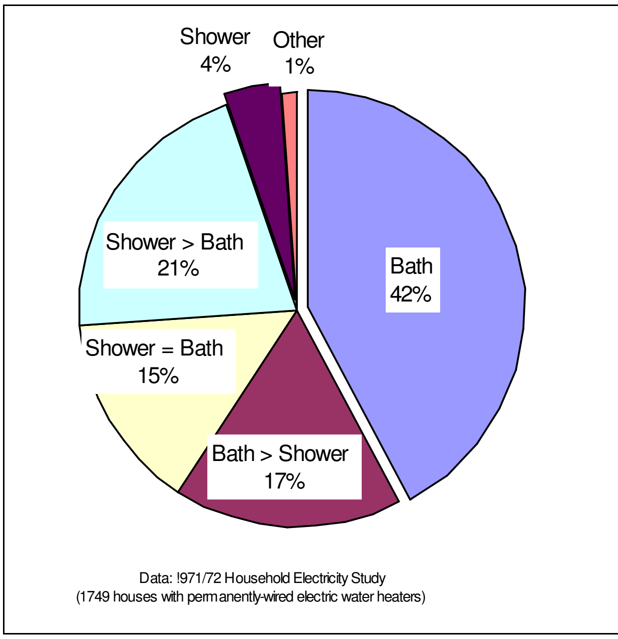


**Figure 7**: **Use of baths and showers 1971/72**

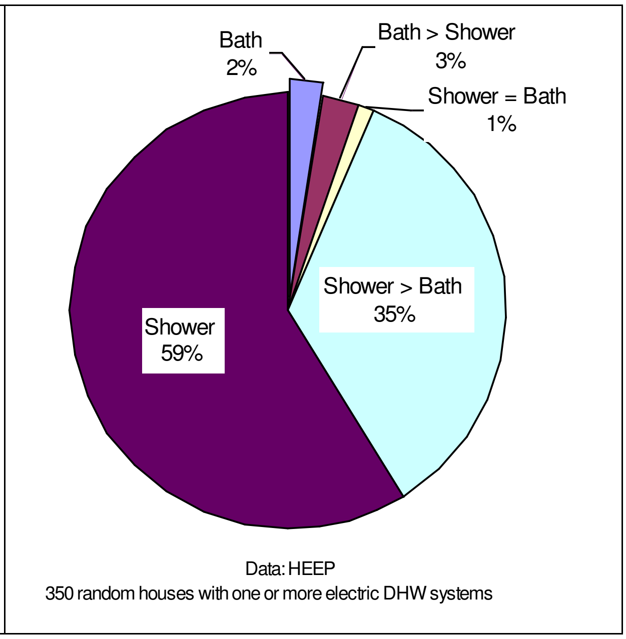


**Figure 8**: **Use of baths and showers HEEP**

Figure 7 and Figure 8 show there have been major changes in bathing habits over the past 30 years. In 1971/72, 59% of the households 'mainly' or 'solely' used the bath. Over 30 years later, this has reduced to 2% 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 1971/72 to 94% in HEEP.

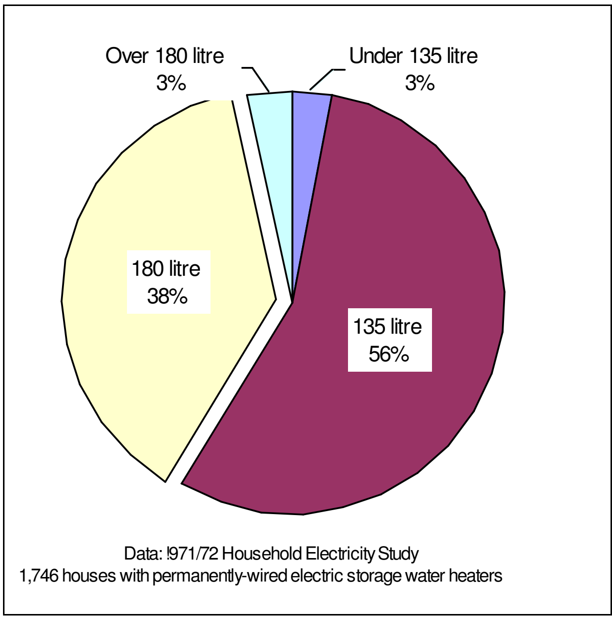


**Figure 9: Household DHW volume 1971/72**

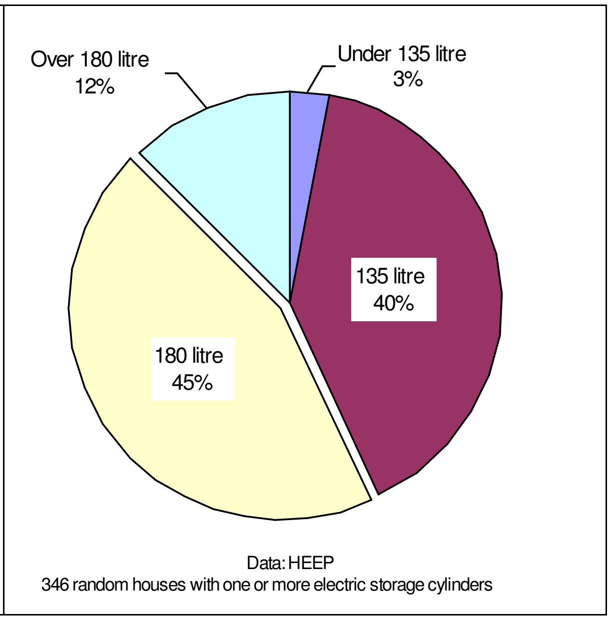


**Figure 10: Household DHW volume HEEP**

Although uses of hot water have changed, it seems that hot water systems themselves have only altered slightly. Figure 9 and Figure 10 compare the total volume of house hot water electric storage cylinders for the 1971/72 study and the HEEP random houses. The houses with 'under 135 litre' total cylinder volume are in the main electric under-sink or point-of use-cylinders, which may not be the main hot water supply for the house. 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%.

There has been a 13% increase in the weighted-average size of household hot water systems – from 150 litres per household in 1971/72 to 170 litres in HEEP. Conversely, the number of people per house has reduced by 15% – from an estimated 3.4 in 1971/72 to a calculated 2.9 in the 346 HEEP houses with an electric water cylinder and for which data was available on the number of occupants.

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'. Even if the thermostat is not designed to be user adjusted, a householder with a screwdriver to remove the protective cover can quickly make an adjustment.

| | Electric Storage | Electric + Solid | Gas Storage | Gas Instant | TOTAL |
|---|---|---|---|---|---|
| COUNT DHW 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: Tap temperatures by system type**

Table 3 tabulates for electric storage, electric storage with solid fuel (wetback), gas storage, gas instant and overall systems the count of each type 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).

Figure 11 shows the temperature distribution for 135 litre (185 systems) and 180 litre (222 systems) electric cylinders. The two cylinder sizes have statistically different temperature distributions ($t = 2.93$, p-value 0.0036), with the mean temperature at 64°C for the 135 litre cylinders and 61°C for the 180 litre cylinders. Extremely high water temperatures were usually found to be due to a faulty thermostat.

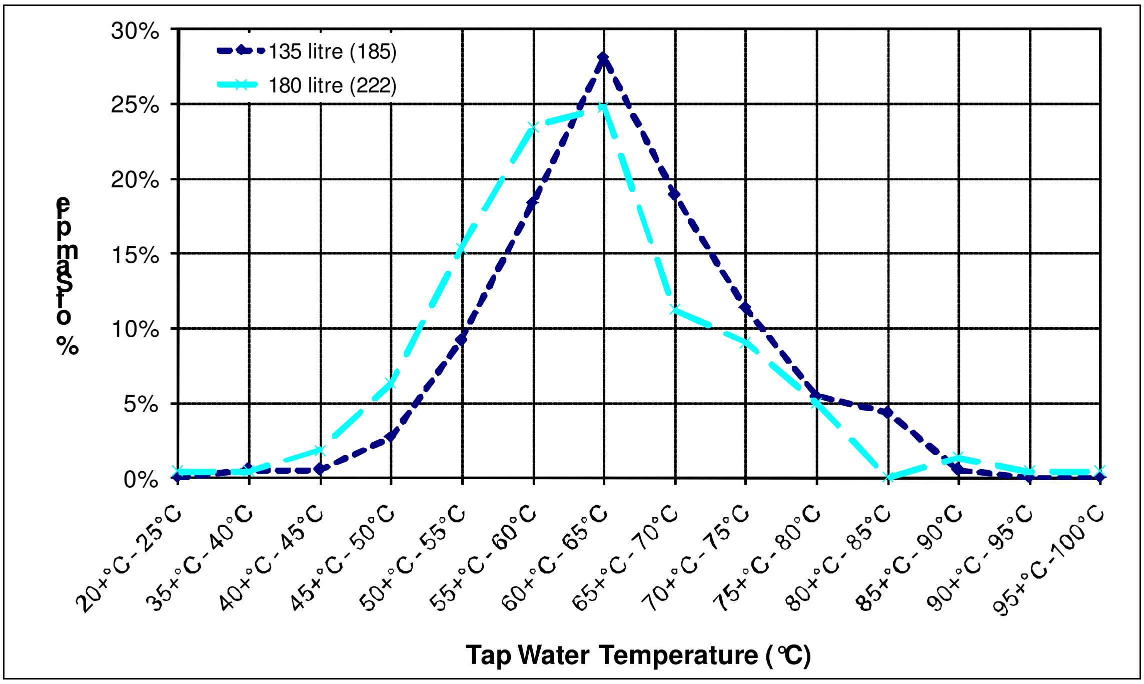


**Figure 11: Distribution of hot water tap temperature by electric cylinder volume**

Since 1993 it has been a requirement under the New Zealand 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 recorded the presence, or absence, of a tempering valve for 462 out of the 530 hot water systems, but only 16% of these had a tempering valve fitted.

Table 3 and Figure 11 show that hot water delivered at a safe temperature (under 55°C) is more likely to be achieved with the larger 180 litre cylinders than the smaller 135 litre cylinders, although higher temperatures are found in too many systems regardless of their volume. As users only adjust the storage temperatures upwards to ensure an adequate supply of hot water at all times, this would suggest that the larger volume cylinders provide a more adequate supply of hot water to meet the modern demands.

From the 1940s through the 1980s, 135 litre cylinders were more popular than 180 litre cylinders, but during the 1990s this popularity had shifted to the 180 litre cylinder being used in more homes. Interestingly while 14% of the HEEP houses did not have electric water heating, in 1971/72 when neither natural gas nor LPG was available but town gas was in many locations, only 12% of houses did not have electric water heating.

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 (Jaye et al 2001). 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.

## BUILDING ENERGY END-USE STUDY (BEES)

BEES is currently starting to explore fuel and energy end-uses in non-residential buildings, and is expected to be completed in 2013. The work is supported by the Department of Building and Housing (DBH), the Building Research Levy, the Foundation for Research, Science and Technology (FRST) from the Public Good Science Fund, and the Energy Efficiency and Conservation Authority (EECA).

It is tempting to liken BEES to a non-residential version of HEEP. However, upon analysis, the programme structure and method of BEES must be significantly different to that implemented in HEEP. Not only is BEES concerned with both energy and water, but the non-residential sector's buildings and use patterns are significantly more diverse than those found in the residential sector.

Eight key research questions have been identified as being critical to achieving the BEES goals and objectives and ensuring their alignment with improving policy setting, building performance and building management. These are set out in Table 4.

The first major research question is simple: What is a 'building'? There is no 'list' of all the non-residential buildings in New Zealand. The best available is the PropertyIQ[2] 'Valuation Roll' which is principally used for the purposes of local government rating based on 'valuation records'. However, each valuation record refers to the value placed on a rating unit, and a rating unit may, or may not, be a single building. For example in a multi-storey building each floor can be strata-titled, and hence each is a 'rating unit'. As BEES is concerned with physical buildings, and not legal descriptions, it was necessary to first combine the 'valuation records' into 'Building Records'. Once inspection has been completed on a Building Record, it can be determined whether or not this is a 'building'.

| Key Research Questions | Contribution to Policy |
|---|---|
| 1. What is the aggregate energy/water consumption of non-residential sector buildings?<br>2. What is the average kWh/$m^2$/annum used?<br>3. What categories of non-residential buildings appear to contribute most to the aggregate energy/water consumption of the commercial sector buildings? | ▪ Highlight importance of commercial buildings in context of NZ energy/water use.<br>▪ Allow policy sector to consider potential of intervention in relation to quantum of resource use.<br>▪ Provide crude indication of possible intervention targets. |
| 4. What is the average kWh/$m^2$/annum used by each selected non-residential building category?<br>5. What are the uses to which energy/water are directed?<br>6. What are the determinants of those patterns of use:<br>a. Building structure and form<br>b. Function<br>c. Other attributes e.g.:<br>▪ Climate; Ownership; Multi-use<br>▪ Occupancy; City/town position; Building age | ▪ Allow policy sector to consider potential of intervention in relation to quantum of resource use.<br>▪ Indicate possible intervention targets and the variables important in developing interventions.<br>▪ Establish extent of variation in resource use and determinants.<br>▪ Provide crude indicator of the types of intervention that might be critical ranging from education, incentives and disincentives, regulation. |
| 7. What are the critical intervention points to improve non-residential building resource efficiency:<br>▪ Building envelope and amenities<br>▪ Building management<br>▪ Occupant behaviour | ▪ Establish the range of interventions, programmes and regulatory requirements for building stock efficiency improvements. |
| 8. What is the likely change in energy and resource demand from the non-residential sector buildings into the future as stock type and distribution changes? | ▪ Provide forecasts of resource efficiency as building stock changes in quantum and type.<br>▪ Identify risks and opportunities for managing resource consumption in the commercial sector. |

**Table 4: Alignment of BEES objectives and contributions**

Extensive use has been made of the internet to obtain information on the Building Records and the occupants. Tools provided through the internet include Google Maps, Google StreetView, Yellow Pages and internet searching for physical addresses. These together identified a proportion of the premises in each building, but it was necessary to undertake physical inspections to ensure high quality coverage. The existence of online photographs for many of the buildings permitted a visual model to be created, which will ultimately provide the input to EnergyPlus thermal simulation software.

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[2] See www.propertyiq.co.nz

The sample frame has been divided into 50 strata based on the PropertyIQ categories:

- **5 size groups** (quintiles), based on estimated total floor area by Building Record
- **5 use groups**, 'office', 'retail', 'mixed', 'IS' and 'IW', based on the use category of the PropertyIQ parent record
- **2 geographic groups** ('Auckland' and 'rest of New Zealand') – the Auckland group is defined by the area covered by the Auckland Regional Council.

The stratification by floor area is necessary to vary the sampling rates for different size groups. The grouping has been done to give approximately equal total floor areas, as shown in Table 5.

The stratification by use groups is to increase the statistical precision of the survey. In particular, the 'Industrial Service' (IS) and 'Industrial Warehouse' (IW) categories (as defined by PropertyIQ) are expected to contain relatively few buildings with office or retail uses, the 'Office' and 'Retail' categories to contain few buildings without such uses, with the 'Mixed' being somewhere in between.

The two geographic groups were defined to help deal with what is expected to be a relatively low response rate in Auckland. It is desirable to replace non-responding Auckland buildings by Auckland buildings. The same consideration also applies to the other grouping variables.

| **Floor Area Group** | **1** | **2** | **3** | **4** | **5** | **Total** |
|---|---|---|---|---|---|---|
| Minimum floor area | 5 $m^2$ | 650 $m^2$ | 1,500 $m^2$ | 3,500 $m^2$ | 9,000 $m^2$ | |
| Approx. no. of 'buildings' | 33,781 | 10,081 | 4,288 | 1,825 | 564 | **50,539** |
| % of buildings | 67% | 20% | 8% | 4% | 1% | **100%** |
| Total floor area (million $m^2$) | 9.9 | 9.6 | 9.5 | 9.6 | 9.8 | **48.3** |
| % total floor area | 20% | 20% | 20% | 20% | 20% | **100%** |

**Table 5: Non-residential size strata**

The 'Aggregate Survey' is using a phone survey to collect information on about 500 randomly selected buildings, their uses and occupants. Revenue meter data for fuels and water will also be obtained and upon analysis will provide reliable new knowledge on energy and water use in this sector. The 'Targeted Monitoring' and 'Case Study' activities will be undertaken in a smaller number of buildings, and this will be used in conjunction with computer thermal simulation models to better understand energy use in this important sector. The monitoring will be selected from the following list, depending on whether it is a Targeted or Case Study building:

- temperature and relative humidity
- light level
- $CO_2$ levels
- fuels (primarily electricity and natural gas, but all fuels will be monitored).

BEES is a comparatively new research project looking at energy and water use in non-residential buildings, but it builds on the experience of HEEP in residential buildings to develop a methodology that will meet the needs of a wide range of stakeholders and funders. When BEES is completed, it will provide a new level of knowledge about energy and water use in the non-residential buildings sector. Together HEEP and BEES will provide high quality data on buildings where the building itself can significantly affect the energy use.

## 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 discussed parts of 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. It 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.

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 heater (wet-back water heater). 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 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 1971/2, 59% of houses with electric hot water systems mainly or solely used the bath. By HEEP, some 30 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 lessons learnt from understanding energy use in the residential sector are now being applied to non-residential buildings. While the Building Energy End-use Study (BEES) is also interested in understanding how, where, why and when energy and water are used in non-residential buildings, it faces a number of issues not experienced with residential buildings.

As there is no comprehensive list of non-residential buildings, it has been necessary to first create a list based on the valuation used for local body rates (land tax). As the energy and water is used either by the building occupants or the building central services, it has then been necessary to create a comprehensive list for a random sample of buildings of the occupants and building management. This work has been completed in order to allow the first nationally representative survey to be started. It will be based around a telephone survey, with energy and water use data obtained (with the respondent's permission) from their supplier(s).

Secondly the energy uses that occur in non-residential buildings are far from homogeneous, unlike in houses. The variation in energy use for a space (for example used as a small bakery) is likely to be different from the same space used as a shoe shop. To minimise the variation, BEES is focusing on energy used in buildings with a predominance of office or retail uses. However, as for HEEP, once the building has been selected to be included in the sample all fuels and their uses will be documented regardless of the actual use of the space

## CONCLUSION

Together these two research studies are used to describe energy and water end-uses, as measures of the sustainability of the majority of the New Zealand residential and non-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 and water use in buildings. The reality is that lacking any valid measurements, the unsustainable use of energy and water is likely to continue without change. The completed project (HEEP) has demonstrated that when uses are quantified, errors in assumptions (or myths) can be corrected and opportunities for more sustainable use can be identified. The project that has recently started (BEES) holds similar promise.

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