STUDY REPORT

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Active Cooling and Heat Pump Use in New Zealand – Survey Results

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The work reported here was funded by the Building Research Levy

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Preface

This is the first report from a Building Research Levy funded project on active cooling in New Zealand. This report covers key findings from a national survey to increase the current knowledge about heat pumps in New Zealand. The second and final report due in March 2009 will cover electricity use from active cooling using modelling for several different scenarios.

Acknowledgments

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- Alastair Childs, Energy Efficiency and Conservation Authority (EECA), for supplying heat pump sales data
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- James Griffin and Ian Page, Economics Department (BRANZ Ltd), for conducting the postal survey
- Numerous family, friends and colleagues for pilot testing the postal survey
- Finally, the respondents to the postal survey.

Active Cooling and Heat Pump Use in New Zealand – Survey Results

BRANZ Study Report SR 186

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Reference

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Abstract

New Zealand is experiencing rapid uptake of heat pumps (or reverse-cycle air conditioners). Approximately 80,000 units were sold last year, over double the number sold three years ago. Heat pumps are relatively new to New Zealand and little is known about how they are being used, their electricity consumption or performance. This work has conducted a postal survey to begin to answer some of the unknowns. Primarily, the survey has been designed to look at heating and cooling. However, questions about the installation and heat pump choice have provided some interesting results. The survey was sent to 3,407 randomly selected houses throughout New Zealand. Nineteen percent of houses were found to have a heat pump. All respondents used their heat pump for heating, with 60% cooling with them – a new electricity load for New Zealand. Twenty-nine percent of respondents indicated they purchased a heat pump with the intention of cooling. Forty percent installed a heat pump to replace another heating source, often a solid fuel or gas burner. The survey found that 28% of heat pumps are NOT being sized by a heat pump specialist suggesting that they are possibly the wrong size and have also NOT been installed by a specialist. Overseas studies have shown that installation quality, heat pump size and operation can reduce efficiency by up to 50%. The results of this work show that there is room for improvement in all three of these areas.

Keywords:

Heat pump, reverse-cycle air conditioner, cooling, heating, survey.

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1. INTRODUCTION

New Zealand has been experiencing rapid growth in the sales of heat pumps in the last few years. Heat pumps are seen by many as an energy efficient way to heat and cool.

Very little is known at present about how many heat pumps are installed in New Zealand dwellings or how they are used. The Household Energy End-use Project (HEEP) found that solid fuel burners provided most of the heating in New Zealand houses (Isaacs 2006). If solid fuel burners are replaced with heat pumps there is potential for about an average increase of 60% in the peak load demands on the electricity networks. This may be exacerbated if New Zealanders start to use heat pumps for cooling.

This report addresses those issues through an analysis of data related to heat pump usage in New Zealand generated by a postal survey sent to 3,407 houses throughout the country. The report begins with a brief background to heat pumps and heat pump research in New Zealand, and then presents the survey data related to: the number of heat pumps in New Zealand; cooling with a heat pump; over-heating in houses; heating with a heat pump; and heat pump statistics. The report also comments on the educational needs of heat pump users and the potential for regulations to improve the efficiency of heat pump use.

1.1 How heat pumps work

The most common type of heat pump in New Zealand is the air source heat pump – also known as a *reverse-cycle air conditioner*. These heat pumps work like a refrigerator, pulling heat out of the air and moving it inside.

In the external unit, the liquid refrigerant evaporates to become a gas, absorbing energy from the air. This gas is then pushed to the inside coil. In the internal unit, the gas condenses to a liquid, giving up the heat. The opposite occurs when cooling – heat is extracted from the inside and moved to the outside air. Heat pumps work best when the temperature difference between inside and outside is small – the colder the temperature outside, the less efficient the transfer process. The type of heat pumps commonly on the New Zealand market work best in climates with temperatures over 7°C, although technology is improving.

Heat pumps produce the most heat for a given amount of electricity of any electrical heating available at present. Not all heat pumps are equally efficient, however, although they are required to comply with the Minimum Energy Performance Standards (MEPS). The MEPS requirement removes heat pumps with the lower efficiencies from the market. New Zealand uses the same standard testing of heat pumps as Australia although the MEPS requirement differs. This test method covers both cooling (Energy Efficiency Ratio - EER) and heating efficiency (Coefficient of Performance - COP).

The EER and COP's are a unit-less measure of efficiency giving the ratio of supplied coolth/heat to the energy taken for producing the heat – the higher the EER/COP, the more efficient the heat pump. For example, a heat pump with a COP of three will produce 3 kW of heat for every 1 kW of electricity used. For a heat pump with an EER of 3, when used in cooling mode, 3 kW of heat will be removed from the room for every 1 kW of electricity used.

A resistance heater has a COP of one and is not affected by climate or other factors that change between houses. For heat pumps, however, the COP will reduce as the temperature difference between inside and outside increases. Therefore in colder locations (e.g. Southland) heat pumps are less efficient than in warmer climates (e.g. Auckland) for heating – with the opposite true for cooling. The advertised COP used for regulation of heat pumps is

determined under test conditions. The COP of an installed heat pump will change as the temperature difference between inside and outside changes. The Centre for Advanced Engineering NZ (CAENZ) has developed a simple model, based on outdoor temperatures, to evaluate the maximum annual effective mean COP for heat pumps in four locations (Duncan et al 2007).

To get the best performance from a heat pump it needs to be designed for the climate in which it operates. It must also be correctly sized for the space it is being used to heat and it must be correctly maintained. Heat pumps are best installed by a Heating, Ventilation and Air conditioning (HVAC) engineer and the occupants need to be educated on how to maintain their heat pump. Overseas, there is evidence that the performance of heat pumps can be significantly lower due to poor installation and operation compared to a heat pump's performance in standardised tests (Lubiner et al 2005). Anecdotal evidence suggests this is also true in New Zealand. However, no work has been done looking at in-situ performance of heat pumps.

Usually heat pump specialists will specify a heat pump according to its output kW rating. The heat pump will have one output rating for heating and another for cooling. A heat pump needs to have sufficient output for both functions. The output is dependent on the COP of the heat pump. Consequently the output reduces in colder climates. A heat pump specialist should know how the climate and site will affect performance and be able to specify an appropriately sized heater.

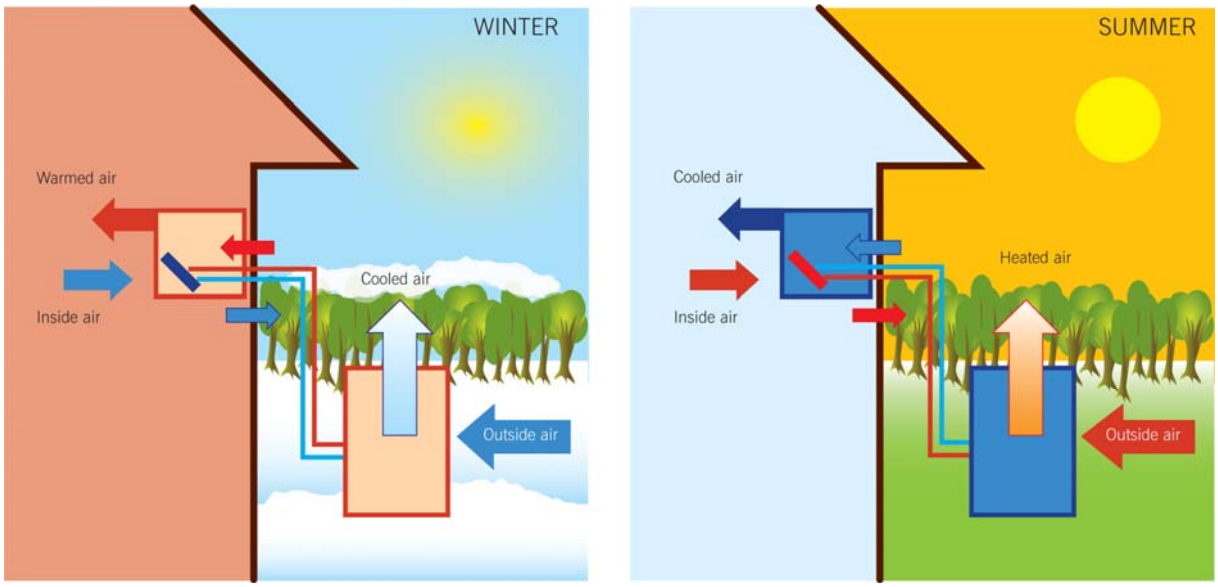

Figure 1: How air source heat pumps work

1.2 Current knowledge about heat pumps

There have been several recent projects examining heat pump use and occupants' opinions on heat pumps. Research in New Zealand has focused on the use of heat pumps for heating rather than cooling. This section provides an overview of other heat pump research in New Zealand.

The Community Energy Action (CEA) group have been tracking 23 houses with heat pumps since 2003. They have recently released their third report outlining findings from how occupants use their heat pumps that were installed in 2002/2003 (Nimmo and McChesney 2007). Although there are now only eight of the original participants left in the study, the results show that occupant opinions and use of heat pumps change the longer they have the

heat pump. Occupants are still satisfied with the heat pumps, but appear to have higher expectations. Overall, they are setting the thermostat to a higher temperature than when they first started using the heat pump.

In early 2007 BRANZ undertook a literature review on the national uptake and impacts expected from heat pumps (Buckett 2007). This report showed rapid uptake of heat pumps in New Zealand. It highlighted trends of increasing peak electricity loads and suggested that heat pumps could cause generation and transmission issues for electricity.

Lettink (2007) looked at heat pump and wood burner usage in Timaru where occupants have had a heat pump installed but kept the wood burner. In most other studies the heat pump has replaced a non-clean air complying appliance. The majority of the occupants were found to continue using their wood burners, but to a lesser amount than previously. Occupants often used the wood burner when temperatures were particularly cold. Elderly and single-person households tended not to use the wood burner at all.

The CAENZ has modelled heat pumps to determine the maximum effective mean COP for heating in Auckland, Wellington, Christchurch and Dunedin (Duncan et al 2007). The work was commissioned by the New Zealand Gas Association and allows realistic comparisons of efficiencies between heat pumps and other heating appliances.

The Otago Regional Council (2006) completed a postal survey of residents in Central Otago examining current heating practices in preparation for the introduction of clean heat regulations. Thirty-two percent of respondents indicated they have a heat pump, with 68% of the respondents' heat pumps being less than three years old. This demonstrates the strong growth in heat pump use. It is particularly notable given the HEEP study.

The HEEP project monitored energy use and temperatures in 400 randomly selected houses throughout New Zealand from 1999 to 2005 (Isaacs 2006). The HEEP database gives valuable information about heating and cooling in New Zealand during this time. The selection procedure of the HEEP houses means they are considered representative of the New Zealand housing stock at that time. In the sample just 4% of houses were found to have a heat pump.

2. GATHERING INFORMATION ON HEAT PUMPS – SURVEY

The survey was carried out by the Economics Department at BRANZ which undertakes a quarterly *BRANZ Materials Survey* (Page 2005). The survey was conducted as a postal survey in August 2007. Responses to this survey provide the data for analysis on which the following sections in this report are based. An example of the survey form can be seen in Appendix A. The survey asked questions on heating, over-heating as well as heat pumps and their usage.

2.1 Survey approach

The postal survey was sent to a sample of new houses and a sample of existing houses, giving a total of 3,407 surveys. The existing house sample is a random selection of houses. Houses in the new house sample are all known to have heat pumps. The existing house sample has been used to determine the number of heat pumps in houses in New Zealand and usage. The new house sample provides information on heat pump usage.

The existing house sample was selected from the HEEP Quotable Value New Zealand (QVNZ) sample provided to BRANZ. Randomly selected houses from the regions shown in Table 1 were sent the survey, and the number of surveys sent to each region was population weighted. Table 1 also shows the number of replies received from each region. A total of 3,000 surveys were sent, with an expectation to receive approximately 1,000 responses. Occupants were given the option of an incentive for the completion of the survey. Choices were a Lotto ticket, a $5 book voucher or a discounted copy of the BRANZ book *Maintaining Your Home*.

Region	**Existing sample**		**New**
	Without rentals	With rentals	
Northland	28	33	1
Auckland	121	141	5
Waikato	56	64	9
BOP	38	41	8
Gisborne	10	12	1
Hawkes Bay	22	23	3
Taranaki	0	0	3
Manawatu/Wanganui	35	38	9
Wellington	83	95	13
Tasman	31	36	1
Nelson	0	0	8
Canterbury	86	101	36
Otago	46	53	23
Southland	24	32	2
Total	**580**	**669**	**122**

Table 1: Number of replies from each region in the existing and new house sample

The new housing sample was selected from respondents to the quarterly *BRANZ Materials Survey* from September 2005 to December 2006 who indicated that a heat pump was installed. 407 were sent to these houses. Approximately 150 responses were expected from this survey from all regions shown in Table 1. As with the existing house survey, a choice of incentives was offered for its completion. Incentive choices were a Lotto ticket, a $10 petrol voucher or a discounted copy of *Maintaining Your Home*.

2.2 Sample representation

The response rate of 24% for the existing homes was lower than hoped (669 responses). 153 surveys were returned due to an incorrect address (not included in the response rate). A response rate of 35% of new homes was higher than expected, and 59 were returned from incorrect addresses resulting in 122 responses.

Postal surveys have been received from throughout New Zealand; all major cities have been sampled and randomly selected rural areas. There are some regions that have not been sampled in the existing house sample including Central Otago and the West Coast of the South Island. Due to the relatively low population in these areas, it is not thought these omissions will skew the results.

As Table 2 shows, the total surveyed sample under-represents rental properties. The national average of occupants renting their home is 33%, and in the existing house sample 13% of occupants rent. The low representation of renters in the sample is likely to have been caused by the sample design. The database used recorded the names and the addresses of the house owner rather than the house occupants. This resulted in less rental properties receiving the postal survey. The impact of the sampling approach emerged during analysis of the data. Due to the low representation of renters it was decided to remove all rental properties from the analysis after consultation with CRESA.[1] The sample is only representative of owner-occupied houses rather than all dwellings in New Zealand. Due to the method of sampling, this should not have a regional impact on the results. Rental properties may use heat pumps in a different way to owner-occupied houses, but this is not able to be proved or disproved from the results of this work.

	Renting	Own house
Existing houses	13%	87%
Census data[2]	33%	67%

Table 2: Renting or owning

Table 3 shows the number of usual residents in a house from the New Zealand census 2006 data, the existing house sample, the new house sample and the previous two samples combined. Ideally the surveyed samples will be similar to the census data, but there are differences, mainly in the one and two-person households. The one-person households are under-represented and the two-person households over-represented in the surveyed sample.

Usual number of residents	NZ average[3]	Existing houses	New houses	Combined sample
1	23%	15%	7%	14%
2	34%	42%	37%	42%
3	17%	16%	18%	16%
4	15%	16%	23%	17%
5	7%	8%	10%	9%
6	3%	1%	3%	2%
7+	2%	1%	1%	1%

Table 3: Number of occupants

[1] Personal communication with Kay Saville-Smith, CRESA, Wellington, New Zealand on 27/11/07.
[2] Statistics New Zealand www.statistics.govt.nz accessed August 2007, 2006 census data.
[3] Statistics New Zealand www.statistics.govt.nz accessed August 2007, 2006 census data.

Figure 2 is a bar graph showing the percentage of houses in each decade from 1900 to 2000 for both the surveyed sample and the QVNZ database. The house ages of the surveyed sample are very similar to the QVNZ database for houses from the 1930s to the 1990s. There is more variation with houses from the 1900s to 1920s and houses built in the last seven years. The house ages of the existing surveyed sample was taken from the QVNZ website[4] rather than asking the occupants. The lack of new houses is due to the sample population used being generated early in 2000. However, the new house sample contains recently built houses.

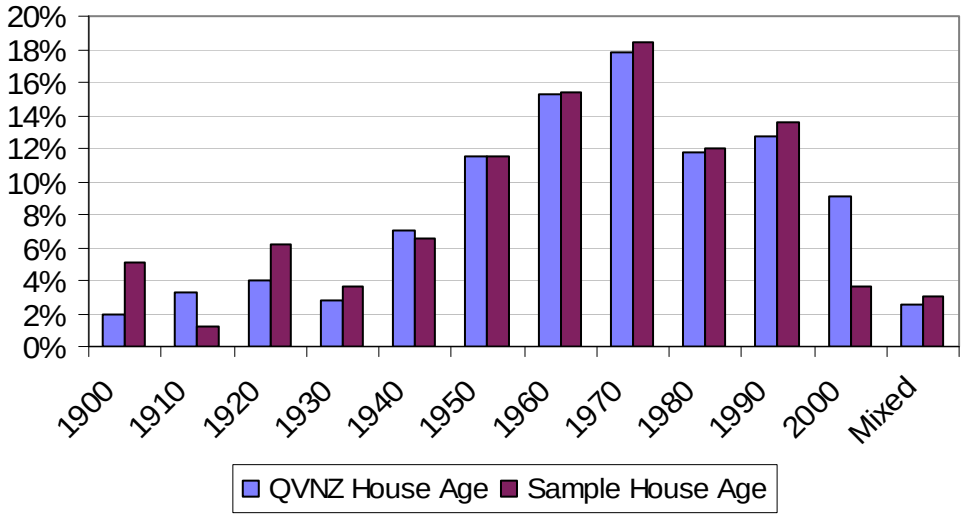

Figure 2: New Zealand house ages and sample house ages

[4] www.qv.co.nz accessed August, September and October 2007.

3. NUMBER OF HEAT PUMPS IN NEW ZEALAND

From the existing house sample 19.4% (±3.2% at a 95% confidence interval) of the replies to the postal survey had at least one heat pump (Table 4). A population weighted average has been given due to the different number of houses in each location. The confidence of the results for each region does vary as some regions have a small sample and/or a low number of heat pumps in the region. For example, analyses from the existing house sample in Auckland found an average of 10% of houses have a heat pump. However, given the 95% confidence interval is ±5%, the percentage of houses with heat pumps could be between 5% and 15%.

Region	% of responses with heat pump	95% Confidence Interval Margin of Error
Northland	14%	±13%
Auckland	10%	±5%
Waikato	29%	±12%
BOP	16%	±12%
Gisborne	0%	-----*
Hawke's Bay	23%	±18%
Manawatu/Wanganui	14%	±12%
Wellington	15%	±8%
Tasman	3%	±6%
Canterbury	39%	±10%
Otago	35%	±14%
Southland	50%	±20%
Population weighted average	**19.4%**	**±3.2%**

Table 4: Percentage of houses with a heat pump by region (north to south)

* Only 10 responses were received from houses in Gisborne, with none reporting a heat pump. Statistical tests indicate the proportion of houses in Gisborne to have heat pumps to be between 0% and 28%.

A higher percentage of heat pumps were found in the colder areas (e.g. Southland, Otago and Canterbury) of New Zealand, compared to the warmer northern areas (e.g. Auckland and Tasman).

3.1 New houses

Since September 2005 the quarterly *BRANZ Materials Survey* has asked if there is a heat pump installed in the house. The survey is sent to randomly selected houses that have had a building consent issued. This question will continue to be asked until at least March 2009. Results so far can be seen in Table 5. Although there is variation between quarters, there is a trend of heat pumps becoming more common in homes when they are built. The June 2007 quarter has a lower number of surveys returned. This is because two types of surveys were sent that quarter, with only one having the question on heat pumps.

	Sep05	Dec05	Mar06	Jun06	Sep06	Dec06	Mar07	Jun07	Sep07	Dec07
Number of houses reporting a heat pump	61	60	67	73	112	98	109	17	112	124
Number of surveys returned	227	211	274	270	340	295	301	38	303	305
Percentage of houses with a heat pump	27%	28%	26%	27%	33%	33%	36%	45%	37%	41%

Table 5: Heat pumps in new houses (*BRANZ Materials Survey*)[5]

Please note: numbers are subject to change

3.2 Heat pump sales

Heat pump sales data is collected annually by the Energy Efficiency and Conservation Authority (EECA), and is shown in Table 1 and Figure 1. As this data is for total sales, it does not provide information about whether heat pumps will be used in residential or commercial applications. The data can distinguish between single and three-phase models. The majority of the smaller single-phase systems are installed in residential houses and most of the three-phase systems into commercial buildings [6]. Therefore, only the single-phase systems are reported here. EECA has separated sales by heat pump size, according to the bands used for MEPS (Figure 1).

Table 1 shows there has been strong growth in the sales of single phase heat pumps over the last four years. Heat pump sales in 2006 are more than double that in 2004, with a further increase in sales in 2007. The sales of air conditioners (cooling only) have fluctuated, although the numbers are very small compared to the sales of heat pumps.

Year ending 31 March	2004	2005	2006	2007
Sales – Heat pumps and air conditioners (cooling only)*	**35,469**	**54,076**	**72,002**	**78,549**

Table 6: Single-phase sales for heat pumps and air conditioners 2004-2007

Data collected by EECA
* Air conditioners are less than 2% of the total sales between 2004 and 2007

Heat pumps in the 4 kW to 7.5 kW range have had the highest sales in the last two years (Figure 1). They will usually be individual units (single split) designed to heat one moderately sized living room and possibly adjoining areas. The smaller heat pumps are also very popular, but growth has slowed. These will also be mostly single-split heat pumps generally heating one space.

The larger capacity heat pumps, above 10 kW, will likely be ducted systems that would heat the majority if not all of a house. The larger systems are likely to be installed into new houses, houses that have had extensive renovations done, or commercial premises.

[5] Analysis from Joe Fung and James Griffin, BRANZ Economists.
[6] Communication with EECA.

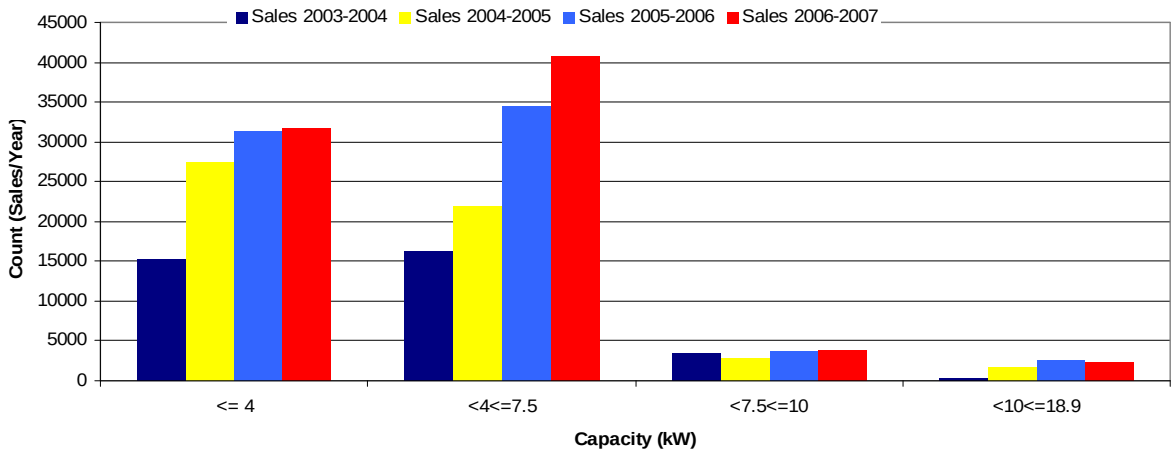

Figure 3: Single-phase sales by size 2004-2007

Data collected for MEPS by EECA

It is difficult to directly compare the number of sales to the number of heat pumps found in the existing house sample. The reasons for this include:

- the existing house sample does not include rental dwellings
- sales data records show the number of heat pumps rather than the number of houses with heat pumps – there may be multiple heat pumps in a dwelling
- sales data does not split heat pumps used in commercial and residential buildings
- sales data provided by EECA is from the year ending 31 March 2004.

However, some simple scenarios can be looked at. If all of the heat pumps sold between 2004 and 2007 were installed into owner-occupied houses, assuming one heat pump per house, 24% of houses in New Zealand would have a heat pump. If all heat pumps sold between 2003 and 2007 were installed into houses, including rental houses (again assuming one heat pump per house), 16% of the houses in New Zealand would have a heat pump. We do know, however, that approximately 20% of houses with heat pumps have more than one heat pump (see Section 7.2). We also know that there are heat pumps in New Zealand older than 2003 (see Section 7.3).

4. COOLING WITH A HEAT PUMP

The use of heat pumps for cooling is explored by analysing the existing and the new house sample – 221 of those houses had heat pumps. All reported information on cooling excludes houses built in 2007 and heat pumps reported to be installed in 2007 (reducing the sample to 149). This removes the houses in the sample that are unlikely too have experienced a summer with their heat pump. Where appropriate, the data has been divided by climate zones as used for the H1 insulation requirements in New Zealand (Standards NZ 2003).

4.1 Cooling use

Cooling in New Zealand houses is a relatively new electricity load. Cooling in the HEEP houses was basically non-existent, with only 4% of houses having the ability to cool (Isaacs 2006). However, this more recent data shows that almost two-thirds (62%) of the heat pump households used heat pumps to cool their homes. The percentage of households using cooling varies by climate (Table 7), with the warmer climate zones having a higher proportion using their heat pump for cooling.

	Zone 1	Zone 2	Zone 3	Total
Number of heat pumps (pre-2007)	16	53	80	149
Number used for cooling	13	35	45	93
Percentage of sample cooling	81%	66%	56%	62%

Table 7: Cooling by climate zone

It should also be noted that there are larger climate variations within the three climate zones in summer than in winter. Climate zone 3 covers the South Island and the centre of the North Island as these are the coldest areas in winter. However, there is far more variation in summer.

Figure 4 shows 17% of respondents use their heat pump to cool when the weather is hot. Another 30% of respondents will cool on some days during hot weather, with 53% of respondents rarely cooling. This question was only answered by respondents who had already indicated that they use cooling.

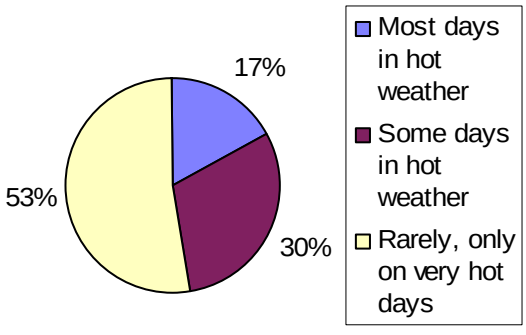

Figure 4: When respondents use heat pumps for cooling

The survey asked the occupants their reasons for active cooling with several options given (see Figure 5). Respondents were able to indicate more than one option. The 'speed' that a

heat pump was able to cool the space was the most popular answer and the next ‘too humid’. ‘Too much sun’ and ‘not enough air movement’ were replies that were common. A small number said they use the heat pump as opening windows was a ‘security risk’ and the least common answer was they did not want to open windows due to ‘external noise’. Only a small number of respondents indicated security and noise was an issue. A large number of respondents indicated that a reason for using a heat pump for cooling was ‘not enough air movement’. This could be solved with a ceiling or room fan.

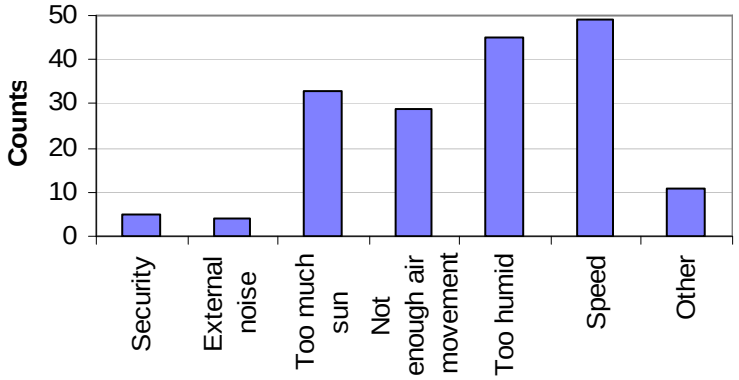

Figure 5: Why occupants cool with a heat pump

4.2 Months

The survey asked which months they used their heat pump for cooling. There were seven months where houses were reported being cooled, with January and February being the most common periods.

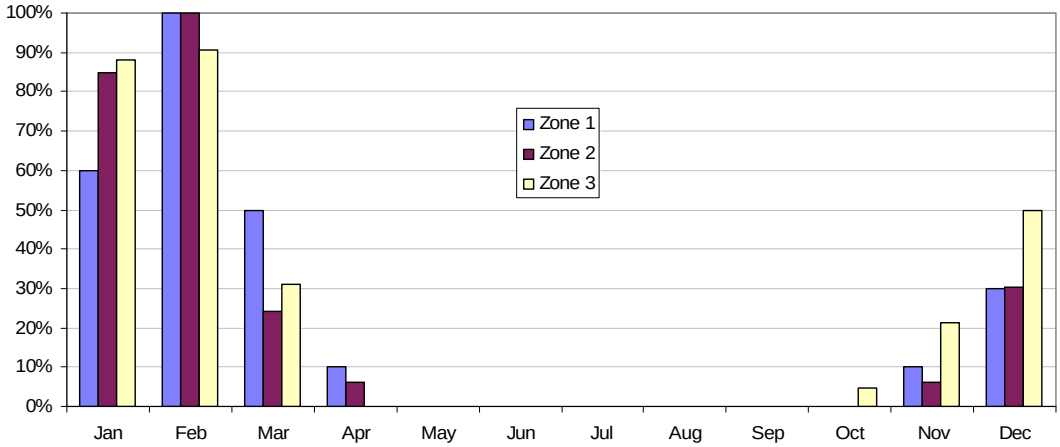

Figure 6: Months of cooling by climate zone

Figure 7 and Figure 8 give the average number of cooling days per month as reported by survey participants. Over one-third (42%) reported cooling for less than seven days per month, which suggests for most cooling is not done regularly. With 30% of respondents choosing to cool for over half of the month, there are likely to be higher cooling loads in the summer months.

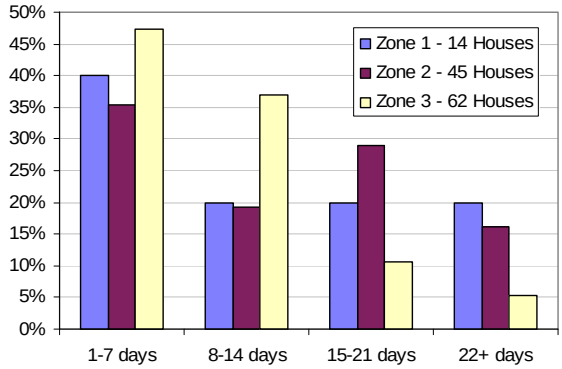

Figure 7: Cooling days per month by climate zone

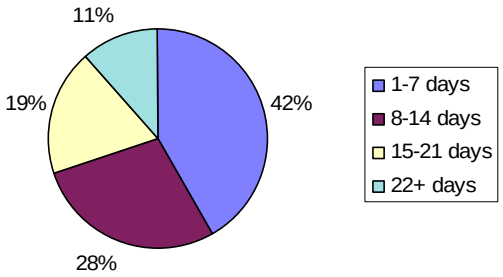

Figure 8: Cooling days averaged over zones

Table 8 gives the statistics on the number of cooling days per month showing the median at nine days and the mean at 11.5 days.

	Days cooling per month
Minimum	1
Maximum	30
Median	9
Mean	11.5

Table 8: Cooling days per month

4.3 Time of day cooling

Respondents were asked what time of day they cooled. They were given the following options and asked to tick all that apply:

- Morning 7 am to 9 am
- Day 9 am to 5 pm
- Evening 5 pm to 11 pm
- Night 11 pm to 7 am

If all boxes were ticked it was recorded as 24 hours.

The most common time for cooling is during the day and the evening. Very little cooling is done overnight and during the morning (Figure 9).

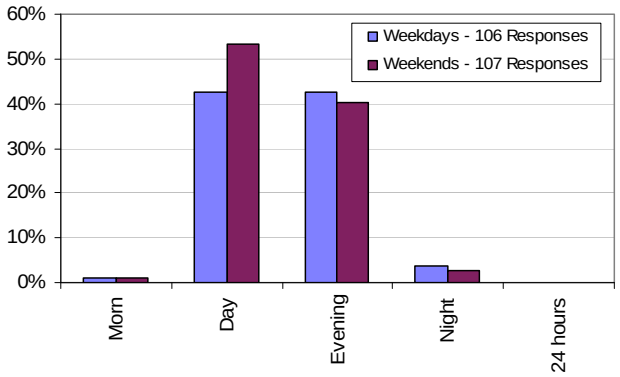

Figure 9: Cooling by weekends and weekdays

The HEEP work found the average time the indoor temperature was the warmest during summer was 5.40 pm (Isaacs 2006). There was regional variation from approximately 5 pm to 6.40 pm, with the southern locations reaching the peak temperature later. From HEEP results, we would expect most cooling to be done in the afternoon and evening when the temperatures are warmest.

4.4 Cooling the whole house or rooms

Occupants were asked if they used their heat pump(s) to cool part or all of their house, and if part, which rooms. Whole house cooling was done in 17–20% of houses (Table 9), with the remaining cooling part of their house. The difference between the two samples is not statistically significant. It is, however, clear that households are more likely to cool just part of their house.

Heat pump heat whole or part-house	New houses sample	Existing houses sample
Whole	20%	17%
Part	80%	83%
Total responses	**54**	**64**

Table 9: Whole house or part-house cooling

The most common room cooled is the family room or lounge (Table 10). Due to the low numbers, this data cannot be considered representative of the population as a whole. However, it is clear that households are more likely to cool their family room/lounge or dining room than other rooms in the house.

Part-house rooms	New houses sample	Existing houses sample
Family room/lounge	84%	89%
Dining room	74%	57%
Bedrooms	28%	24%
Other	16%	11%
Total responses	**43**	**54**

Table 10: Rooms that are cooled

4.5 Thermostat set-point for cooling

Respondents were asked to record their average thermostat set-point for cooling in the postal survey (see Figure 10). Seventy-seven households answered this question.

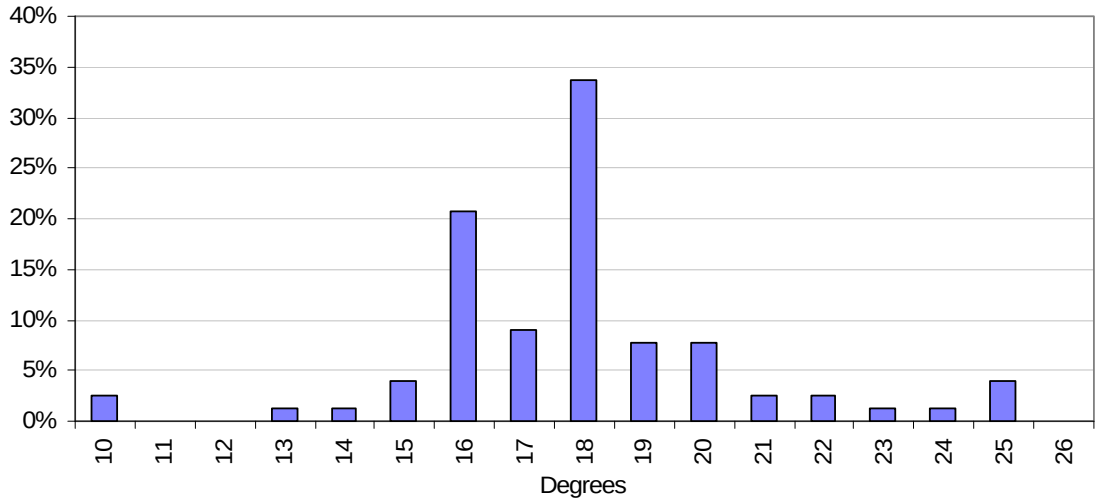

Figure 10: Thermostat setting for cooling

Table 11 summarises the thermostat cooling set-points to above, below and within the optimum temperature range (18–25°C) recommended by the World Health Organisation (WHO 2003). The majority of respondents (61%) indicate they have the thermostat set from 18–25°C, while 39% of respondents indicate they set the thermostat below 18°C. The mean cooling set-point is 18°C; this is the same for the new house sample and the sample of existing houses.

Set-point	Percentage	Count
Below 18°C	39%	30
18–25°C	61%	47
Above 25°C	0%	0
Total	100%	77

Table 11: Cooling set-points by the WHO optimum temperature range

It is unclear why occupants set their thermostats below 18°C. This may be due to the system being under-sized and therefore the room temperature never reaches 18°C. The occupants may be setting the temperature lower than what they would like with the belief that they will reach the temperature faster (i.e. the heat pump will try harder and produce more cool air). This is discussed further in Section 6.4. Technology has advanced since the literature cited in Section 6.4 was completed with the availability of more advanced inverter models. However, inverter models do not help a room to cool or heat quicker, but rather have different levels of output for once the room is close to the desired temperature. This means the heat pump will run on a lower output rather than constantly switching on and off at the full output when the desired temperature is reached. One area where more education could be given to heat pump owners is how to use heat pumps more effectively and efficiently.

If occupants are setting the thermostat temperature lower than the occupants want there is the risk they will use more energy than if they had it set to the actual temperature they would like. Heat pumps will use more energy if occupants do not turn the heat pump off or adjust the thermostat when the temperature reached is comfortable.

4.6 Opening windows when cooling

The majority (67%) of the respondents indicate they do not have the windows open in the room they are cooling. Heat pump operating manuals suggests the heat pump is most effective with the windows and doors closed (Airwell, LUXAIRE and Mitsubishi Operating manuals). One-third of respondents indicated they sometimes or often have the window open when cooling. This is another area where more education will increase the efficiency and effectiveness of heat pump use.

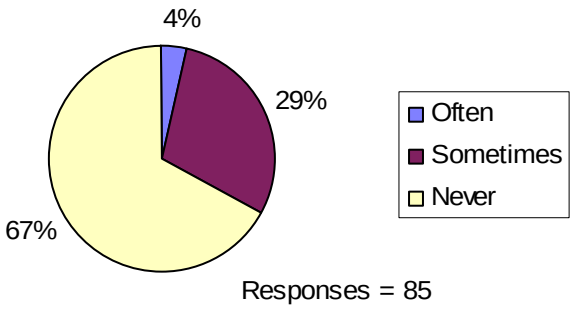

Figure 11: Windows open while cooling

5. OVER-HEATING IN HOUSES DURING SUMMER

All respondents to the postal survey (with and without a heat pump) were asked about over-heating. This question was asked to investigate if there is a market for cooling in New Zealand houses. Table 12 gives the results from the two samples separately and combined about whether their house gets too hot. About one-third of the respondents do not have a problem with over-heating, leaving two-thirds who do find their house too hot at times during summer (although only a small number of respondents are finding their house too hot often, with a large number too hot sometimes).

Too hot?	New houses	Existing houses	Combined
Never	34%	33%	33%
Often	7%	8%	8%
Sometimes	59%	59%	59%
Total replies	110	570	680

Table 12: Over-heating in summer

The HEEP work found that indoor temperatures are influenced strongly by outdoor temperatures (French 2007). The warmer the outside temperature the higher the inside temperature is likely to be. The outside temperature explains around 70% of the inside temperature, thus having the most influence on the indoor temperatures in the HEEP houses. Through climate change the temperature is expected to increase throughout New Zealand,[7] and this will directly affect the inside temperatures in houses. If houses are over-heating now they are likely to be over-heating more in the future. Many of the remaining one-third of houses that are comfortable at the moment may become too hot for the occupants.

Designing and building to lessen the number of houses that are becoming too hot is important for the future. Good design may not prevent the house from over-heating entirely, but it will help decrease the number of days where the house is uncomfortable. Analysis from HEEP suggests preventing a house from over-heating requires consideration of the amount of glazing, ventilation and shading.

5.1 Occupant response to over-heating

All occupants were asked how they deal with the heat if their house becomes too hot. Figure 12 gives the answers to this for all houses (with and without a heat pump). The most common option is opening windows, and then using a fan. Occupants' answers to 'other' include: moving to another area of the house, closing curtains and using the home ventilation system (e.g. DVS or HRV).

There does look to be potential for greater use of both ceiling fans and room fans within the house in combination with opening windows to increase air movement. Often using different methods in combination can greatly increase the effectiveness.

[7] www.mfe.govt.nz/issues/climate/resourses/impact-map.index.html accessed 11/12/07.

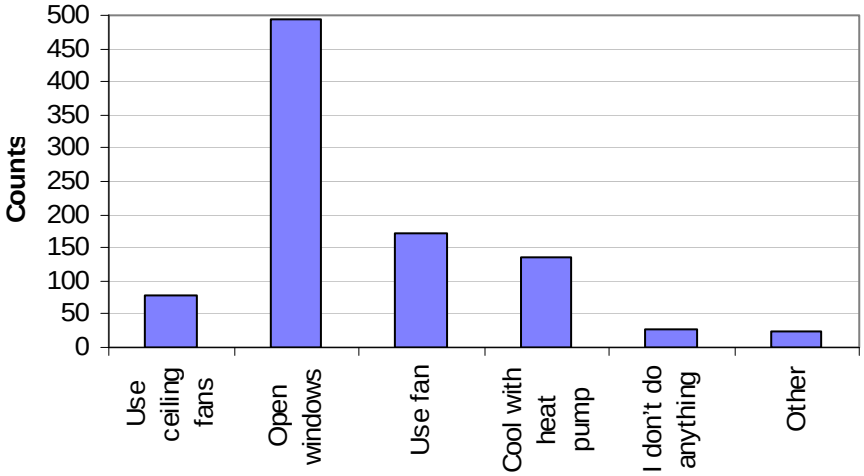

Figure 12: How occupants deal with over-heating – all houses

Note: occupants answered as many options as applicable.

6. HEATING WITH A HEAT PUMP

The following data on heat pump use for heating is taken from both the existing and the new house sample of 221 houses with heat pumps. Where appropriate, the data has been divided by climate zone.

6.1 Months of heating

Heat pump users show a variety of patterns of use which are associated with climate zones (Figure 14). Climate zone 3 has a greater proportion of households using their heat pump for more of the year. During the colder months of the year (June, July and August) the use of heat pumps in zone 3 is proportionally lower than in some other zones. This may be because occupants in the colder areas of New Zealand do not always prefer to use the heat pump in the colder months, instead preferring to use their wood burner. Wood burners can have a greater heat output in colder weather compared to heat pumps, due to the efficiency of heat pumps decreasing the larger the temperature difference between inside and outside.

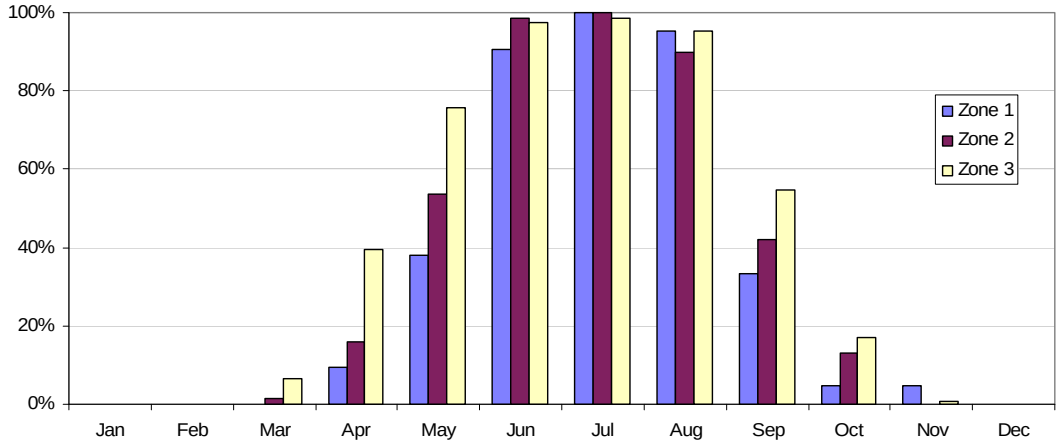

Figure 13: Months of heating by climate zone

6.2 Times of days

The reported heating schedules from the houses with heat pumps are able to be compared to the reported heating schedules from HEEP (Table 13). Houses with heat pumps in the study report extended heating relative to the HEEP sample. This is most significant in the morning where the proportion of houses reporting heating is 37% among HEEP houses and 68% among heat pump houses.

Percentage of sample heating	Heat pump dwellings survey	HEEP – all fuels
Morning	68%	37%
Day	34%	26%
Evening	93%	89%
Night	24%	18%
24 hours	15%	11%

Table 13: Heat pump and HEEP heating schedules – weekdays

Propensity to heat during the morning, day, night and over 24 hours is higher in climate zone 3 (Figure 14). Heat pump heating is at its peak during the evening, in climate zone 1. Overall, heating in the evening is the most common time for heat pump households as well as non-heat pump users in the HEEP sample. The morning heating is higher than what is traditionally done with other forms of heating. This is thought to be due to the convenience of having quick heat (controllable by a remote) and being able to use a timer to warm the room before the occupants are awake (convenience was the reported key reason for installing a heat pump – see Figure 16).

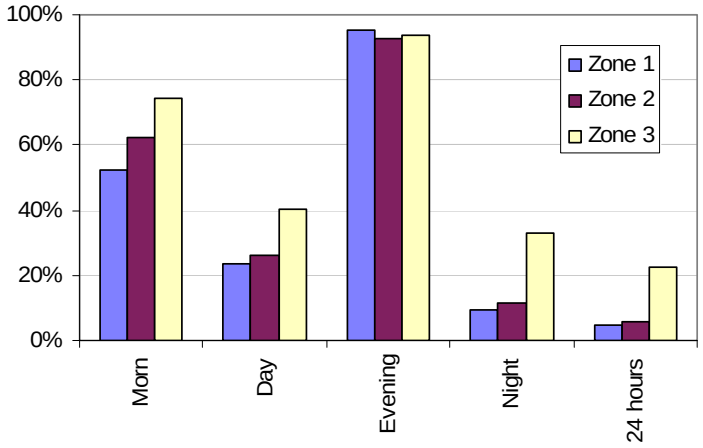

Figure 14: Weekday heating by climate zone

6.3 Whole house or part

Occupants were asked if they were heating their whole house or just part of their house with a heat pump, but a question about the temperature to which the house was heated was not asked. It is possible that some parts of the house reported to be heated, are only heated to a low temperature.

Most of the heat pump users reported heating just part of their house (76–78%), with the remaining reporting heating their whole house with a heat pump(s) (Table 15).

Heat pump heating – whole or part house	New houses	Existing houses
Whole	24%	22%
Part	76%	78%
Total responses	**96**	**122**

Table 14: Heating the whole house or part with a heat pump

When occupants reported heating just part of their house with a heat pump, over 90% heated their family room or lounge (Table 15). Eight-one percent of new houses and 73% of existing houses reported heating their dining room. The differences between the two samples are small in most cases and there is unlikely to be a statically significant difference. It is clear, however, that households are more likely to heat their family room/lounge and/or dining room than other areas of their house.

Part-house rooms	New houses	Existing houses
Family room/lounge	92%	90%
Dining room	81%	73%
Bedrooms	26%	19%
Other	27%	23%
Total responses	**74**	**96**

Table 15: Rooms that are heated with a heat pump

6.4 Thermostat set-point

Kempton (1987) suggests there are two ways thermostats are set by occupants in their homes. First, the way the thermostat is designed to be operated – by setting the thermostat to the temperature the occupants would like to feel and let the heater do the rest. Secondly, Kempton suggests from monitoring and interviewing occupants that 25–50% treat the thermostat like a valve under the theory that – the higher the temperature the more warm air should be produced, therefore this warms the space faster. This second method requires more occupant interaction with the thermostat and would explain the higher set-points reported by some occupants (Figure 15).

Many of the set-points above 22°C could be operated according to Kempton's valve theory. Unless the occupants are actively monitoring and adjusting the thermostat they are likely to heat to a higher temperature than desired resulting in higher energy use. Kempton also found in his work that often there was conflict between different occupants of the same house, with some believing one theory and others the second theory. Kempton found they were often very committed to their way of believing, despite often reporting they knew little technically about how the thermostat worked. This study does not pick up the differences between occupants, with the operating method of the person filling in the survey likely to be the method reported. Although Kempton refers to thermostats in relation to heating, it is likely the same thinking is applied to cooling.

Users of heat pumps were asked to report their average set-point for heating. The results are shown in Figure 15.

The CEA study found occupants tended to increase the set-point and heating hours the longer they had the heat pump (Nimmo and McChesney 2007). Changes in set-points were not looked at in this BRANZ survey, but a large number of the respondents have had their heat pump for more than a year so should be fairly stable with their set-points and heating schedules.

The mean heating set-point over all houses with a heat pump is 21.1°C with a standard error of 0.2°C. There is a range from 15–30°C. This shows a variation in the way occupants use their heat pumps as well as the temperatures they want to achieve. Temperatures achieved in the rooms were not measured. It is not known if the temperature that the thermostat is set is the temperature in the room. If the heat pump is under-sized, the average temperature is likely to be lower than the thermostat set-point. Similarly, if the operation of the heat pump is intermittent, it may not be on long enough to reach the thermostat temperature.

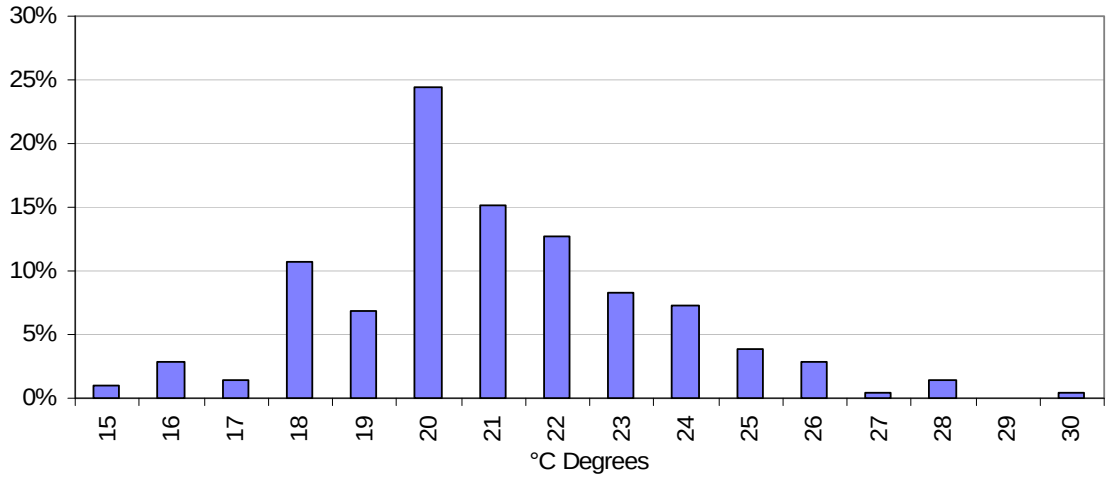

Figure 15: Thermostat set-point for heating

Almost one-quarter of the houses (24%) set the thermostat to 20°C for heating, making it the most common choice. Table 16 gives the percentage of the sample who set their thermostat to either the optimum temperature range (18–25°C) according to WHO (2003) or below or above the optimum range. Eighty-nine percent of occupants set their heat pump within the WHO optimum range, with 6% above and 5% below that range. The occupants may prefer to be either warmer or cooler than the optimum range, or it is possible that the heat pump is not achieving the temperature of the set-point and therefore has to be set higher to achieve a comfortable temperature. For the houses that are setting their heat pump below 18°C this may be due to the cost of heating, using the heat pump to heat bedrooms to a lower temperature overnight or possibly personal preference. Information on these variables was not collected in the survey, thus limiting further investigation.

Set-point	Percentage	Count
Below 18°C	5%	11
18-25°C	89%	183
Above 25°C	6%	12
Total	100%	206

Table 16: Heating set-points by the WHO optimum temperature ranges

The climate zone has found to affect the thermostat set-point that occupants have chosen. With a p-value of 0.001, linear modelling indicates that differences between the mean set-points between the climate zones are statistically significant. The mean set-points decrease the colder the climate zone (Table 17). The sample size in climate 3 is large (124) and some houses are still setting their set-point as high as 30°C.

Climate zone	Mean set-point (°C)	S.E. (°C)	Count
1	23.0	0.7	19
2	21.6	0.3	63
3	20.5	0.2	124

Table 17: Mean heating set-points by climate zone

The higher set-points indicated that houses are likely to be heating to higher temperatures than previously. Table 19 gives the achieved temperatures in the HEEP houses by fuel type (Isaacs 2006). Fuel type was found to be a strong driver of the temperature achieved. It should be noted that there is a very small sample size for heat pump heated houses of just four. The mean temperatures achieved are much lower than what most heat pump users are

setting their thermostats. This may mean that occupants are heating more with heat pumps, possibly due to occupants installing them because they are energy efficient (Figure 16).

HEEP heater type	Temperature (°C)	S.E. (°C)	Count
Open solid fuel	16.0	0.5	12
Electric	16.9	0.3	83
LPG	17.1	0.2	54
Fixed electric	17.8	0.3	19
Solid or liquid fuel central	17.9	0.2	2
Gas	18.0	0.5	26
Heat pump	18.0	0.4	4
Gas central	18.3	0.7	7
Enclosed solid fuel	18.9	0.2	138

Table 18: Winter living room evening temperatures by heater type (Isaacs 2006)

The thermostat set-point has also been compared with region, heating months, heating times, additional or replacement heaters. There is a relationship between heating months and set-point. The houses that reported the longer heating season often have higher set-points. No other relationships were found.

7. HEAT PUMP STATISTICS

The survey asked several questions about the installed heat pump(s), and choices leading up to the installation. This section summarises some of the findings. When a house had more than one heat pump the respondents were requested to supply information for the most commonly used heat pump.

7.1 Reasons for installation of heat pumps

Figure 16 gives the responses from both the new and existing houses to the question "Why did you get a heat pump(s)?" Respondents were able to tick as many boxes as were relevant. The two key reasons were 'easy to operate/convenient' and 'energy efficiency' with over 60% for both. Twenty-nine percent of respondents installed a heat pump for cooling. Traditionally houses are not cooled in New Zealand (Isaacs 2006).

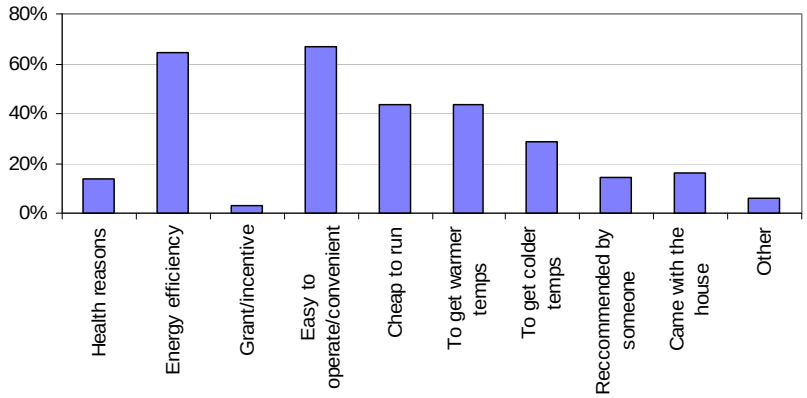

Figure 16: Reasons occupants installed heat pumps

One issue that was not asked specifically is whether or not occupants were installing heat pumps to help with damp issues. It is possible that occupants may have placed this under health reasons, but it is unlikely to have picked up all respondents. It is interesting to note 18% of existing houses reported installing a heat pump for health reasons compared to 8% of the new houses. From the survey data it is not possible to know what health issues were concerns for the occupants. But health issues could cover both damp issues and low temperatures, both of which heat pumps are able to help with.

7.2 Number of heat pumps per house

In both the existing and the new house sample the number of heat pumps installed in the house was asked. This was an open-ended question rather than ticking a box. A number of respondents also indicated that they have a ducted system, although this was not asked specifically. Figure 17 shows the percentage of houses with one, two, three and four heat pumps for both samples. In both existing and new houses most have one heat pump (82% and 67%). The new houses are more likely to have more than one heat pump compared to the existing houses. Twenty-seven percent of new houses had two heat pumps, 5% had three and 1% had four.

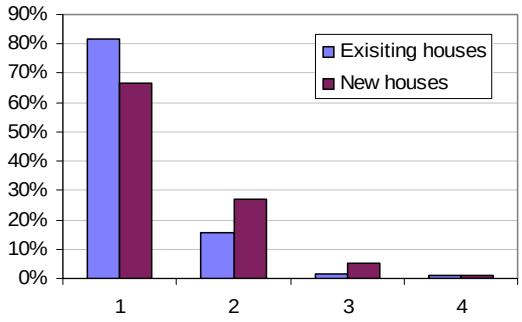

Figure 17: Number of heat pumps installed in each house

7.3 Age of heat pumps

Over three-quarters of the existing house sample (78%) had their heat pump installed within the last three years (Figure 18). This matches the huge growth of heat pumps in the last few years. The number of heat pump installations more than tripled from two to three years ago (8% to 27%). Figure 18 looks at the existing house sample (not including new builds of which almost half are likely to install heat pumps as shown in Table 5).

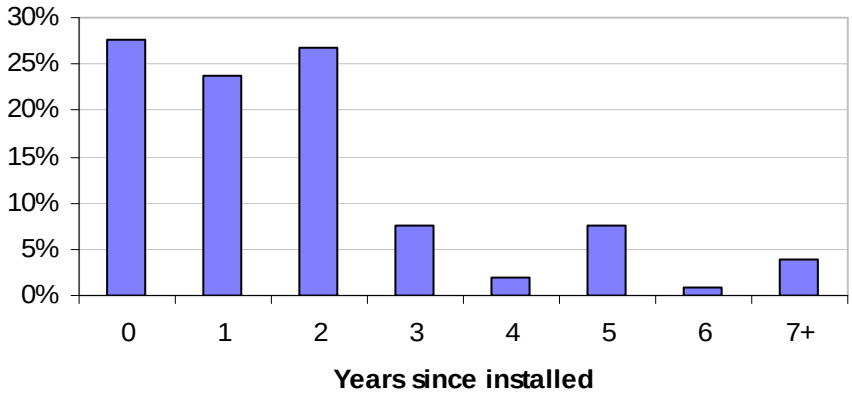

Figure 18: Number of years since the heat pump installed in existing house sample

7.4 Heat pump brand, size choice and installation

Figure 19 shows how respondents choose their heat pumps. There were a number of respondents who moved into a house with a heat pump. This could explain the 'other' category. The bulk of respondents chose a brand that was either recommended or well known to them. Often the recommendations came from family or friends or some occupants indicated advertising recommended the brand. It was mostly the new houses (19% of the sample) that had the builder/architect choose the brand. It is noted that most respondents are not just purchasing the cheapest heat pump.

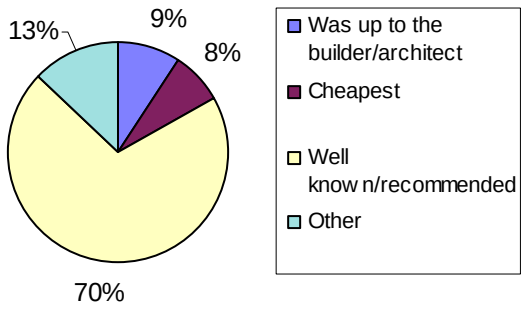

Figure 19: Choice of heat pump brand

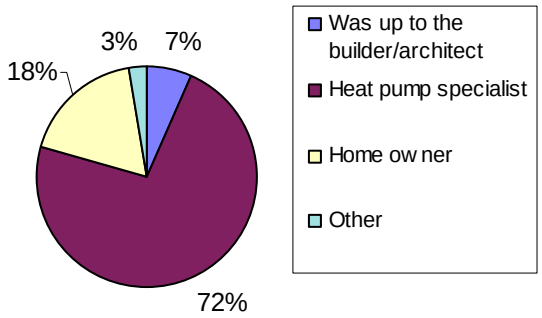

Figure 20: Choice of heat pump size

Figure 20 shows the results when the occupants were asked who chose the size of the heat pump for installation. The majority (72%) had a heat pump specialist size the heat pump appropriately. Eighteen percent of occupants reported they chose the heat pump size themselves, which is not recommended. Seven percent of occupants reported the builder or architect sized the heat pump. Sixteen percent of new houses left the decision to the builder/architect, again hopefully in conjunction with a heat pump specialist, although many may use the electrician they have on-site.

The sizable proportion of home-owners not having their heat pump sized by a specialist raises questions around installation quality. In New Zealand only a basic electrical certificate is required to install a heat pump (Buckett 2007), unless the system plugs into an existing power point. New Zealand is one of the only countries where heat pumps can be brought off the shelf and installed without a specialist retailer or installer. Installers should use specialist equipment required for refrigerant handling, unless it is a simple back-to-back system. However, no qualifications are required. The quality of the installation affects the performance of the heat pump, and a loss in the refrigerant charge will dramatically reduce performance. The Consumer Institute has suggested that the quality of the installation is more important than the heat pump brand, in terms of effectiveness, which in turn affects the energy efficiency (Wilson 2007). In the USA it has been found that poor installation, along with poor operating, can reduce efficiency by up to 50% (Lubiner et al 2005).

7.5 Heat pump capacity

Figure 21 gives the reported kW ratings for the main heat pump (if more than one) from the occupant survey. To answer this question the respondents were asked to look at the label on the inside unit of their heat pump. New houses with heat pumps installed have a greater proportion of larger heat pumps (10 kW plus). Thirteen percent of new houses have 10 kW plus heat pumps compared to 1% of the existing houses sample. Newer houses are more likely to have ducted systems which transfer heat around or cool the house.

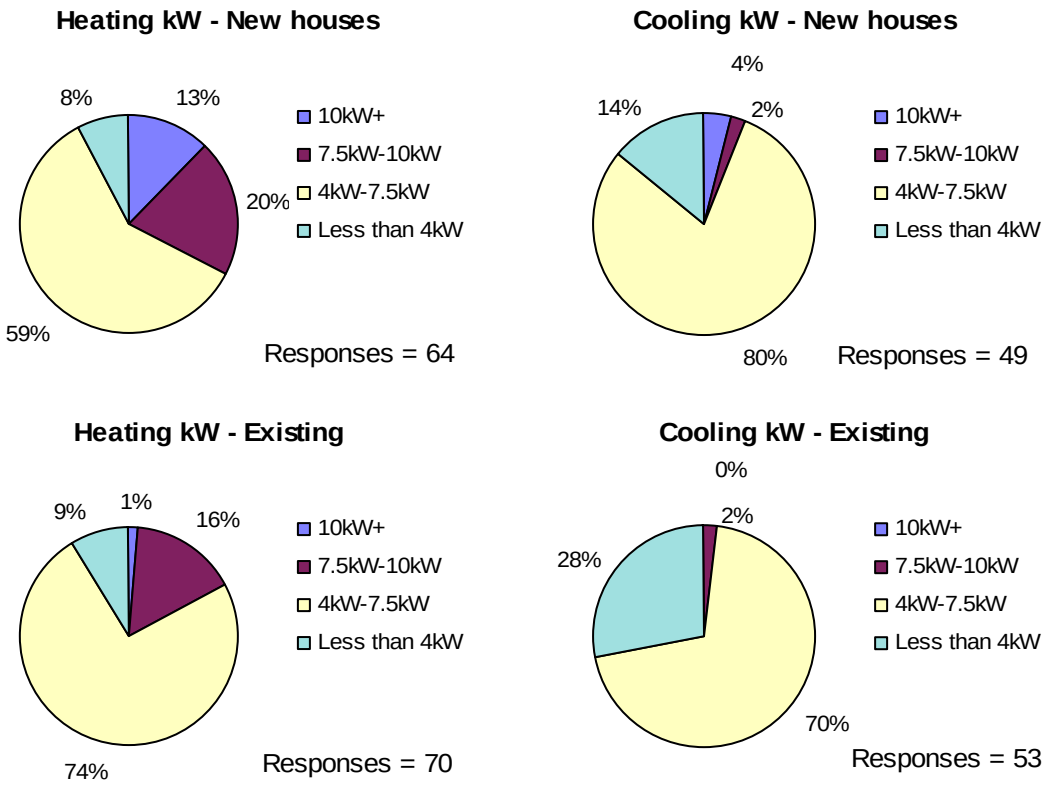

Figure 21: Heating and cooling kW rating for the main heat pump

7.6 Location of heat pump in the house

The majority of heat pumps in the survey were installed in the living area/room, lounge, sitting or family room (82%), for both samples (Figure 22). Heat pumps were found to be installed close to the ceiling in 81% of houses. Nineteen percent were installed close to the floor (Figure 23).

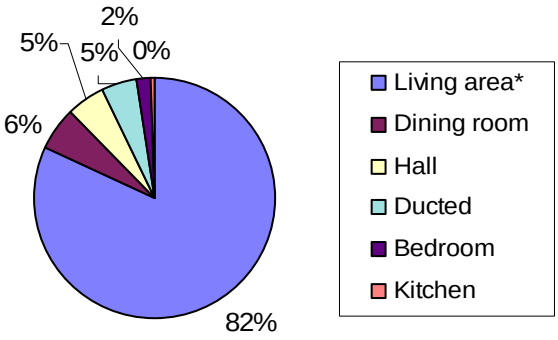

Figure 22: Location of heat pumps in the house

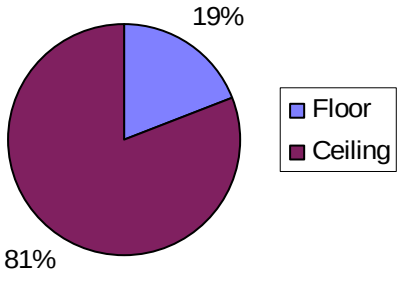

Figure 23: Installed close to the floor or ceiling

**The living area includes responses of sitting room, lounge and family room.*

This placement is different to New Zealand's traditional placement of heating appliances. Traditionally heaters in New Zealand are located at floor level. This allows the heat generated from the heater to rise and heat the room. The majority of heat pumps in New Zealand are not installed at floor level, but instead close to the ceiling. To evenly distribute the heat the fan forces air movement in the space. Because heat pumps have strong fans, this should work well in most cases, although getting heat right to the floor could be an issue at times, and the heat pump may have to be running for some length of time before air close to the floor feels warm. In some spaces having the heat pump located close to the floor may not be ideal as due to the arrangement of furniture it may mean that the warm (or cool) air is not distributed evenly around the room.

There may be several reasons that most heat pumps are installed close to the ceiling, and this is an area that could be investigated further. Occupants may not realise there is a choice – advertising is typically done with heat pumps installed near the ceiling, and anecdotal evidence indicate installers suggest the heat pump being located in this position. Or it is possible that most occupants value having more floor space and are not as concerned about wall space.

When the heat pump is used in cooling mode the heat pump should be very effective at cooling the room quickly, if close to the ceiling. The cold air should quickly drop, cooling the occupants.

7.7 Replacement of heaters with heat pumps

The existing houses were asked if their heat pump was installed as an additional heater or to replace an existing heater (Table 19). There were 104 responses to this question.

Heat pump installed for:	
Additional heating	60%
To replace an existing heater	40%

Table 19: Heat pump as an additional or replacement heater

It was also asked what type of heater the heat pump was replacing. There were 59 responses to this question and the results can be seen in Figure 24. There are a large proportion of respondents replacing their wood burner or gas heater with a heat pump. Replacing electric heaters is ideal, as they are installing a more efficient heater using the same fuel. In many cases the houses that are replacing electric heaters are likely to use the heat pump more and not always use less electricity, but occupants will be more comfortable and are likely to have healthier temperatures. Recent work (Isaacs 2006) shows New Zealand houses that heat by standard electric heaters are on average achieving a temperature of 16°C during the evenings in winter in their living rooms. This is below the WHO optimum temperature range of 18–25°C (WHO 2003).

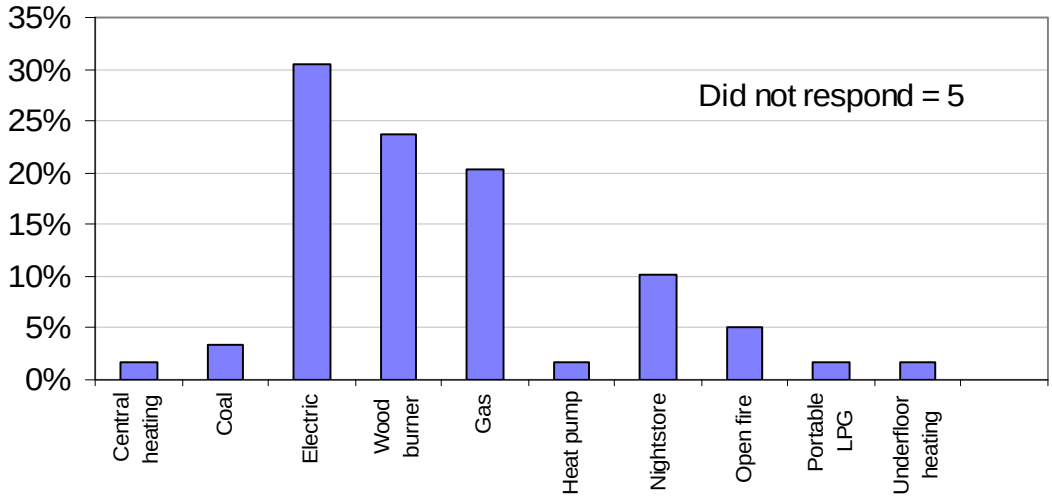

Figure 24: Heaters replaced by heat pumps

It was expected most houses in the new house sample would have had their heat pump installed when the house was built. However, two new houses installed their heat pumps to replace other heaters. One new house replaced electric plug-in heaters and one replaced a fireplace.

8. SUMMARY AND IMPLICATIONS

Sales of heat pumps over the last three years have been strong, resulting in approximately 19% of the current New Zealand housing stock with heat pumps. Occupants report the main reasons for installing heat pumps as convenience and energy efficiency. This may indicate a trend to increasing standards of heating and cooling in homes. The shift from other energy forms to electricity places extra loads on the electricity network. Peak loads and transmission issues caused by heat pumps during peak heating times are causing concern for many electricity supply companies already.

All occupants in the sample (both with and without heat pumps) were asked if their house became too hot. Two-thirds of the sample reported their house was often or sometimes too hot. Results therefore suggest that most houses in New Zealand are likely to be cooled if they have the capability to do so. Good design of houses could reduce this demand for cooling and complement current practices for energy efficient heating. Key considerations include not over-glazing, shading, opening windows and passive vents and/or fans to allow good ventilation in the house. With the strong influence of climate on the interior temperature (French 2007), the expected increases in outdoor temperatures due to climate change are likely to increase over-heating in houses and strengthen the demand for cooling.

In the survey 62% of occupants use their heat pumps for cooling as well as heating. Traditionally very little cooling has been possible in New Zealand houses; thus a new energy load is being created by the addition of heat pumps. Only 27% of heat pump users reported cooling as a reason for buying one. This suggests once occupants have a heat pump they will use it for cooling, even if this was not the original intention. Further work is required to understand whether occupant intentions change over time.

A high number of occupants reported sizing their heat pump themselves. A trained HVAC engineer is the best person to size one to ensure the capacity of the heat is adequate, but not excessively so, for the requirements of the occupants. The occupants reporting sizing heat pumps themselves are also not likely to be using a heat pump specialist for the installation. This may also be true in many new builds when the builder is organising the installation – they may use the electrician on-site. In New Zealand and overseas, the installation has found to affect the COP of the system. Ideally only trained HVAC engineers would sell, install and size heat pumps to ensure they are installed to operate as efficiently as possible.

Within the industry there have been reports of installations of heat pumps being done without specialist equipment. This results in heat pumps with poor refrigerant charge that are not performing well. There has also been a case of a cheap brand heat pump that plugs into an electrical socket being sold with incorrect instructions. This has resulted in many home-owners attempting the installation themselves and often losing all the refrigerants. A loss in refrigerants reduces efficiency of the heat pump. This is one area where a change in legislation would help improve the efficiency of the heat pumps.

There are also areas where information is lacking for both the installer and the home-owner. There is an opportunity for further work in determining if heat pumps are best installed close to the ceiling or the floor, to ensure maximum effectiveness and efficiency for heating in our climate.

Ideally, this would involve monitoring of energy use and temperatures, recording use and set-points and comfort levels of the occupants. This work would help guide the installation of heat pumps to maximise efficiency and effectiveness. It was not possible to find

recommendations on the best location for a heat pump in the installation or operating manuals for heat pumps looked at. A number of heat pump websites did follow a theme of advertising the high wall models first and often saying “most popular residential choice” (or similar).

There are some areas where information is found to be lacking for the home-owner. Heat pumps need to be well maintained and operated effectively for optimum energy efficiency. The thermostat settings suggest occupants are not using their heat pumps as efficiently as possible.

There is an opportunity for further work in monitoring installed heat pumps. At present, there have been few measurements of the performance of heat pumps for heating and cooling in New Zealand. Monitoring would show the effect of the quality of the installation, the location of the heat pump in the room and the operating regime.

This Building Research Levy funded project will continue with the development of a cooling design tool and guidelines to design climate suitable houses that require minimal or no cooling. Modelling work will also be undertaken to understand electricity use for both heating and cooling using heat pumps. This project will be completed in March 2009, and a final Study Report will be published.

REFERENCES

Airwell from EMAILAIR. *Air Conditioner Split Wall Mounted – Programming and Operating Manual – Installation Instructions.* Accessed on 6/12/07 www.airwell.com.au.

Buckett NR. (2007). 'National Impacts of the Widespread Adoption of Heat Pumps in New Zealand'. BRANZ *Study Report 169*. BRANZ Ltd, Judgeford, New Zealand.

Duncan J, Hamm A, Jordan R and Hooper G. (2007). *Understanding the Contribution of Direct Use of Gas to New Zealand's Future Energy Efficiency Objectives*. A report produced for the Gas Association of New Zealand by the New Zealand Centre for Advanced Engineering (CAENZ), Christchurch, New Zealand.

French LJ, Camilleri MJ, Isaacs NP and Pollard AR. (2007). 'Temperatures and Heating Energy in New Zealand Houses from a Nationally Representative Study – HEEP'. *Energy and Buildings* 39: 770–782.

Isaacs NP, Camilleri M, French L, Pollard A, Saville-Smith K, Fraser R, Rossouw P and Jowett J. (2006). 'Energy Use in New Zealand Households: Report on the Year 10 Analysis for the Household Energy End-use Project (HEEP)'. BRANZ *Study Report 155*. BRANZ Ltd, Judgeford, New Zealand.

Kempton W. (1987). 'Two Theories of Home Heat Control'. In *Cultural Models in Language and Thought.* (Eds) Dorothy Holland and Naomi Quinn. Cambridge University Press, Cambridge, UK.

Lettink W. (2007). *Wood Burner Usage Study Report*. Prepared for Environment Canterbury by Energy Mad Limited, Christchurch, New Zealand.

Lubiner M, Andrews J and Baylon D. (2005). 'Heating with Residential Heat Pumps'. *ASHRAE* 47(10): 36–43. Accessed on 8/7/07 www.proquest.com.

LUXAIRE Mini-split High Wall Air Conditioner – Installation and Owner's Manual Models LJHA07-24 MEPS.
Accessed on 6/12/07 www.thewarehouse.co.nz/Content.aspx?id=100022631

Mitsubishi Electric Indoor Unit MSZ-GA22VA, MSZ-GA24VA, MSZ-GA35VA, MSZ-GB50VA. Accessed on 6/12/07 www.bdt.co.nz/comfortmaster/data/manuals/r410a/OM_MSZ-GA22-50VA_SG79Y404H03.pdf

Nimmo K and McChesney I. (2007). *Heat Pump Survey – Report 3: Winters 2005 and 2006*. Community Energy Action, Christchurch, New Zealand. Accessed October 2007 www.cea.co.nz/news-research/.

Otago Regional Council (prepared by Advanced Business Research Ltd). (2006). *Central Otago Home Heating and Air Pollution – 2006 Survey Findings*. Dunedin New Zealand. Accessed July 2007
www.orc.govt.nz/Documents/ContentDocuments/publications/air/homeheating%20survey%20full%20web.pdf.

Page I. (2005). 'BRANZ Building Materials Survey'. *BUILD* 90: 65 (October/November).

Standards New Zealand (SNZ). (2003). *SNZ PAS 4244:2003 – Insulation of Lightweight-Framed and Solid-Timber Houses*. SNZ, Wellington, New Zealand.

World Health Organisation (WHO). (2003). *Heat-waves: Impacts and Responses*. WHO Briefing Note for the Fifty-third Session of the WHO Regional Committee for Europe, Vienna, Austria (8–11 September 2003).

Wilson H. (2007) Radio interview on Radio New Zealand's Nine to Noon programme, 27 July 2007 (file ntn-20070727-0912-Heat_Pumps-064.mp3 downloaded from www.radionz.co.nz).

APPENDIX A

20th July 2007

The household occupants
Address 1
Address 2
Address 3

Dear Sir/Madam

How do you heat and cool your home?

BRANZ is currently undertaking a study of heating and cooling in houses, this project is funded by the Building Research Association. To make this study relevant to New Zealand we need information on how people heat and cool. Your house was randomly selected to be part of this study. We would therefore appreciate it if you were able to complete the attached survey.

All answers and comments given will remain completely confidential and will not be used for any purpose beyond this research.

Without your support research like this would not be possible. To show our appreciation we would like to offer you the option of either a Lotto ticket, $10.00 petrol voucher or a discounted copy of 'Maintaining your home' (see enclosed brochure & order form) for each completed form returned in the envelope supplied.

If you would like to know more about BRANZ please see our website www.branz.co.nz or if you have any questions please contact me at lisafrench@branz.co.nz or 04 237 1176.

Please tick [✓] the following preferred option and advise a contact name:

Contact name: _____

[ ] Lotto ticket

[ ] Whitcoulls voucher

[ ] Maintaining your home publication for the discounted price of $39.95 + $4 P&P

Retail price $59.95. Please fill out enclosed brochure and return with survey.

Yours faithfully

Lisa French
Building Energy Scientist

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Heating and cooling in homes

1. **Do you rent or own this house?**
   - ☐ Rent
   - ☐ Own (with or without a mortgage)
2. **Household occupant information**

   Number of people living in house: _____

   On average, how many people are home during these times of the day:

   Mon-Fri during the day _____ **Mon-Fri during the evening** _____
3. **Size of house**
   - ☐ Small (0-100m²)
   - ☐ Medium (101m²-200m²)
   - ☐ Large (200m²+)
4. **House information** *(tick all that applies if known)*

Ground floor	**Windows**	**Glazing**	**Wall construction (structural)**
☐ Concrete	☐ Aluminium	☐ Single glazing	☐ Timber frame
☐ Timber	☐ Timber	☐ Double glazing	☐ Concrete (including concrete blocks)
			☐ Solid timber (e.g. - Lockwood)

5. **Is your ceiling insulated?** *(please tick)*
   - ☐ Yes ☐ No ☐ Don't know
6. **Do you have and use the following?**
   - ☐ Thermal/heavy curtains ☐ Ceiling fans ☐ Heat transfer units (room to room)
   - ☐ Air vents in window frames ☐ Fans ☐ Mechanical ventilation (e.g. - DVS)
7. **What heating devices do you use in your house?** *(tick all that apply)*
   - ☐ Heat pump ☐ Electric (plug in)
   - ☐ Portable LPG ☐ Gas heater
   - ☐ Enclosed fire ☐ Gas (central heating)
   - ☐ Open fire ☐ Other, *please specify* _____
8. **Of these heating devices above, which one is the main form of heating in your house?**

   _____
9. **Why is this heating device the main form of heating in your house?**
   - ☐ Health reasons ☐ Energy efficiency
   - ☐ Cheap to run ☐ Easy to operate/convenient
   - ☐ Cheap to buy ☐ Free wood/coal
   - ☐ Other, *please specify* _____
10. **If the main form of heating in your house broke down, what form of heating would you replace it with?**

    _____
11. **What is your reason for choosing this form of heating you specified in question 10 above?**

    _____
12. **Is the temperature you heat to limited by any of the following** *(tick all that apply)*
    - ☐ Cost of fuel ☐ House design/construction (e.g. - Draughty, size, lack of insulation)
    - ☐ Power of heater(s) ☐ I'm not limited by anything
    - ☐ Availability of fuel ☐ Other, *please specify* _____
13. **Do you find your house can be too hot in summer?**
    - ☐ Often ☐ Sometimes ☐ Never
14. **If your house does get too hot in summer, how do you deal with it?**
    - ☐ Use ceiling fan ☐ Use fan ☐ I don't do anything
    - ☐ Open windows ☐ Cool with heap pump ☐ Other, *please specify* _____
15. **Do you leave windows open when you are out during the day in summer?**
    - ☐ Most windows ☐ Some windows ☐ No windows

If you have a heat pump installed please continue, if not please go to the end of the survey

If you have a heat pump installed please continue, if not please go to the end of the survey

16. How many heat pumps do you have in your house? ☐

17. For your most commonly used heat pump, please indicate the following information about your heat pump: *(if known, usually information will be on heat pump label)*

Make:_____

Year heat pump installed (approx): _____

Heating capacity (size kW): _____

Cooling capacity (size kW): _____

Location of heat pump (e.g. Hall): _____

Is your heat pump *(please tick one)* : ☐ Close to the floor
☐ Close to the ceiling

18. What temperature settings do you have your main heat pump on? *(heating and cooling)*

Average thermostat set point: Cooling _____ºC
Heating _____ºC

19. Why did you get a heat pump(s)? *(tick all that apply)*

☐ Health reasons
☐ Energy efficiency
☐ Grant/incentive
☐ Easy to operate/convenient
☐ Cheap to run
☐ To get warmer temperatures
☐ To get cooler temperatures
☐ Recommended by: _____
☐ Came with house → Go to question 23
☐ Other, *please specify* _____

20 Did you install a heat pump(s) to replace a heater, or to use as an additional heater?

☐ Replaced heater, *please state the heater it replaced:* _____
☐ Additional heating source

21 Why did you choose this supplier/brand?

☐ Was up to the builder/architect
☐ Cheapest
☐ Well known/recommended
☐ Other, *please specify* _____

22 Who chose the size of the heat pump(s) (power output)?

☐ Was up to the builder/architect
☐ Heat pump specialist
☐ Home owner
☐ Other, *please specify* _____

23. What are the main months of the year you HEAT with a heat pump(s)? *(please circle the appropriate months)*

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

24. On average, what time of the day do you heat with your heat pump(s) (for weekdays and weekends)?
Please tick all that apply

Time of day	Weekdays	Weekends
Morning (7am-9am)	☐	☐
Day (9am-5pm)	☐	☐
Evening (5pm-11pm)	☐	☐
Night (11pm-7am)	☐	☐

25. Do you find your heat pump(s) adequate for heating?

☐ Very Adequate
☐ Adequate
☐ Poor

26. Do you open any windows in the rooms you heat while heating with a heat pump(s)?

☐ Often ☐ Sometimes ☐ Never

27. Do you use your heat pump(s) to heat the whole house or part of the house?

☐ Whole house → Go to question 29
☐ Part of the house → Go to next question

If you use your heat pump(s) to cool, please continue, if not please go to the end of the survey

If you use your heat pump(s) to cool, please continue, if not please go to the end of the survey

28. If you use your heat pump(s) to heat part of the house, please indicate which rooms are heated:

- ☐ Family room/lounge
- ☐ Dining room
- ☐ Bedroom(s)
- ☐ Other, *please specify* _____

29. What are the main months of the year you COOL with a heat pump(s)? *(please circle the appropriate months)*

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

30. Please estimate the average number of days per week (or per month) you cooled using a heat pump(s) last summer

_____ **Days per week, OR** _____ **Days per month**

31. On average, what time of the day do you cool with your heat pump(s) in summer (for weekdays and weekends)?
Please tick all that apply

Time of day	Weekdays	Weekends
Morning (7am-9am)	☐	☐
Day (9am-5pm)	☐	☐
Evening (5pm-11pm)	☐	☐
Night (11pm-7am)	☐	☐

32. Do you find your heat pump(s) adequate for cooling in summer?

- ☐ Very Adequate
- ☐ Adequate
- ☐ Poor

33. Do you open any windows in the rooms you cool while cooling with a heat pump(s)?

☐ Often ☐ Sometimes ☐ Never

34. Do you use your heat pump(s) to cool the whole house or part of the house?

- ☐ Whole house → Go to question 36
- ☐ Part of the house → Go to next question

35. If you use your heat pump(s) to cool part of the house, please indicate which rooms are cooled:

- ☐ Family room/lounge
- ☐ Dining room
- ☐ Bedroom(s)
- ☐ Other, *please specify* _____

36. When do you use your heat pump(s) to cool? *(please tick one only)*

- ☐ Most days during hot weather
- ☐ Some days during hot weather
- ☐ Rarely, only on very hot days

37. Why do you use a heat pump(s) to cool your house? *(please tick as many that apply)*

- ☐ Security (don't want to open windows)
- ☐ External noise (don't want to open windows)
- ☐ Too much sun
- ☐ Other, *please specify* _____
- ☐ Not enough air movement
- ☐ Too humid
- ☐ Speed (quick at cooling)

Thank you for spending time completing the survey.

Remember to tick your preferred option (Lotto ticket, petrol voucher or maintaining your home book) on the front page.

Please fold and return in the pre-paid envelope supplied to BRANZ by the:

31st August 2007