Residential Heat Pumps in New Zealand

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ABSTRACT

Sales data shows that the use of air-to-air heat pumps in New Zealand houses is rapidly increasing. This rapid uptake will lead to new energy and peak power demands on the electricity supply system. Recent monitoring work has found solid fuel burners provided 56% of home heating energy while only 24% was electricity. Heat pumps are therefore mainly displacing non-electric heating, and this must ultimately require additional electricity generation, transmission and distribution infrastructure. Patterns of use will be critical to the long-term impact. An August 2007 national survey of 3,407 randomly selected houses obtained data on occupant heating patterns and, if present, the use of heat pumps. It found that 19% of existing houses and 45% of new houses have one or more heat pumps. These results were compared with measurements from the Household Energy End-Use Project (HEEP) which has detailed information on house heating and heating systems. The national survey found that although heat pumps are promoted for winter heating, 60% of households use them for cooling – an almost completely new summer electric load. It was found that heating schedules are longer in heat pump houses – notably over twice as many houses heat in the morning. Heat pump thermostats are also being set to higher temperatures than previously found in New Zealand homes.

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 can also be used to cool.

The market change has been so quick that very little is known about how many heat pumps are installed in New Zealand dwellings or how they are used. HEEP found that solid fuel burners provided most of the heating in New Zealand houses (Isaacs et al 2006). If solid fuel burners are replaced with heat pumps there is potential for an approximate average increase of 60% in the winter peak load demands on the electricity networks. This may be exacerbated if New Zealanders start to use heat pumps for cooling, creating a significant new summer load.

A postal survey has been undertaken to address these issues by providing data relating to heat pump usage in New Zealand. This paper presents analysis of the survey and implications of the rapid uptake of heat pumps in New Zealand for generation and supply.

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. Most heat pumps installed are split single-phase

systems, although multi-split and ducted systems are available and may become more common.

In the external unit, the liquid refrigerant evaporates to become a gas, absorbing energy from the air. This gas is then pumped to the internal coil where 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 pump commonly available on the New Zealand market has a large drop in performance when the air temperature falls below 7°C.

Heat pumps produce the most heat for a given amount of electricity of any commonly available electrical heating system. Heat pumps are required to comply with the Minimum Energy Performance Standards (MEPS) (AS/NZS 3823.2:2005). The MEPS bans the sale of low COP (Coefficient of Performance) heat pumps. 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).

For heat pumps, however, the COP will reduce as the temperature difference between inside and outside increases. Therefore for heating in colder locations they are less efficient than in warmer climates – with the opposite true for cooling. The advertised MEPS COP is determined under test conditions, but in actual use 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). CAENZ suggest heat pumps with a rated COP of 3 will average closer to 2.4 in the colder areas of New Zealand during winter.

Internationally there is evidence that the in-use ducted heat pump performance can be significantly lower than the standardised test results, due to poor installation and operation (Lubiner et al 2005). Anecdotal evidence suggests this is also true in this country. However, no New Zealand work has been undertaken to explore the in-situ performance of heat pumps.

2 INFORMATION ON HEAT PUMPS

A postal survey was sent to two separate samples: 1) a sample of new houses and; 2) a sample of existing houses, giving a total of 3,407 surveys. The existing house sample was a random selection of houses throughout New Zealand. Houses in the new house sample were 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. A total of 791 replies were received from both samples. The results of this work have been published in a detailed report (French 2008).

2.1 Number of heat pumps in New Zealand

From the existing house sample a population weighted average of 19.4% (±3.2% at a 95% confidence interval) of houses had at least one heat pump. A higher percentage of heat pumps were found in the colder areas of New Zealand, compared to the warmer areas.

The quarterly *BRANZ Materials Survey* (see Page 2005 for a descriptive paper on the survey) examines how many new houses have heat pumps. It shows a trend for heat pumps to become more common in new homes. For example in December 2007, 41% of new houses had heat pumps compared to 33% a year earlier in December 2006. The survey has been

undertaken quarterly since September 2005 when 27% of new houses had a heat pump.

Heat pump sales data is collected annually by the Energy Efficiency and Conservation Authority (EECA). Data shows there has been strong growth in the sales of single-phase heat pumps over the last four years. There were 78,549 heat pumps sold in the year ending March 2007, up from 35,469 in 2004 (EECA 2007). The sales of air-conditioners (cooling only) have fluctuated, although the numbers are very small compared to the sales of heat pumps.

3 SURVEY RESULTS

3.1 Reasons for installing heat pumps

The survey asked "Why did you get a heat pump(s)?" and provided 10 choices, with respondents ticking as many boxes as relevant. The two main reasons were 'easy to operate/convenient' and 'energy efficiency', with over 60% for both. 'To get warmer temps' and 'cheap to run' were next. Considering that traditionally houses are not cooled in New Zealand (French et al 2007), it was interesting to note that 29% of respondents reported installing a heat pump to be used for cooling.

3.2 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 (French et al 2007). However, the more recent survey data shows that almost two-thirds (62%) of the heat pump households used heat pumps to cool their homes (French 2008). The percentage of households using cooling varies by climate, with the warmer climate zones having a higher proportion using their heat pump for cooling. Table 1 summarises the thermostat cooling set-points to above, below and within the optimum comfortable 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. The mean cooling set-point is at the lower 18°C, and is the same for the new and existing houses sample.

Table 1. Cooling thermostat set-points

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

It is unclear why occupants set their thermostats so low. This may be due to the system being under-sized and therefore the room temperature is not reduced to 18°C. Alternatively the occupants may be setting the temperature lower than ideal in the belief that they will reach the desired temperature faster i.e. the heat pump will produce more cool air (Kempton 1987).

3.3 Heating use

Heat pumps in New Zealand are primarily installed for heating. Through strong marketing and clean air regulations in parts of the country, the uptake of heat pumps has been rapid and often they replace solid fuel burners. It is important to understand how heat pumps are being used to be able to understand the changes in electricity demand for space heating. Even though heat pumps are more efficient than conventional resistance heaters, electricity savings are not guaranteed. If occupants increase the length of time they are heating and/or heat to higher temperatures, as the heat pump survey results suggest, then electricity consumption could stay about the same or even increase. To explore the first possibility, the reported heating schedules from surveyed houses with heat pumps were compared to the reported heating schedules from HEEP. Houses with heat pumps in the heat pump survey had longer heating hours than the HEEP sample. This was most significant for morning heating,

where the 37% of HEEP houses reported heating and 68% of the heat pump survey. This may be due to the convenience of having quicker heat, the convenience of a remote and/or being able to use a timer to warm the room before the occupants arrive. Evening heating is the most common time of heating in both samples, with 89% of households heating in the HEEP sample and 93% in the heat pump houses.

The survey found the reported mean heating set-point over all houses with a heat pump is 21.1°C with a standard error of 0.2°C, although the range is 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, although user behaviour may also change in subsequent years. A Community Energy Action (CEA) study found occupants tended to increase the set-point and heating hours the longer they had the heat pump (Nimmo and McChesney 2007).

Table 2 gives the achieved temperatures in the HEEP houses by heater type (Isaacs et al 2006). The mean temperatures achieved in HEEP houses are lower than those reported by most heat pump users. This may mean that occupants are heating more with heat pumps, possibly due to occupants installing them because they are energy efficient. It is also possible that the heat pump thermostat set-point temperature may also not be accurately reflecting the room temperature.

Table 2. HEEP temperatures by heater type

Heater type	Temperature (^{o}C)	S.E. (^{o}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/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
Encl. solid fuel	18.9	0.2	138

4 EFFECTS ON NEW ZEALAND'S ELECTRICITY USE

New Zealand has relied on solid fuel energy for heating since pre-colonial times. The recent HEEP monitoring project reported 56% of home heating energy is from solid fuel with only 24% from electricity (Isaacs et al 2006). The heating energy required in New Zealand has the potential to change with the current rate of uptake of electric heat pumps.

The Government Energy Minister Hon. David Parker reports total New Zealand electricity demand is expected to grow by about 20% by 2025, requiring an extra 3500MW of additional generation (Mole 2008). This is a per year growth of approximately 200MW. Last year alone approximately 160MW worth of heat pumps were installed into residential homes. This recent growth in heat pumps has been considered in the scenarios used for the demand forecasts (Electricity Commission 2008). This indicates that new electrical generation plant will be required just for the growth in electrical heating. The increase in electricity use will also place pressure on transmission and distribution and may fast forward the need for upgrades in some areas.

The high number of households with heat pumps reporting evening use suggests pressure will be placed on the peak electricity load demands. Replacing solid fuel burners with heat pumps means there is potential for an approximate average increase of 60% in the winter peak load demands.

One of the drivers of replacing solid fuel burners with heat pumps is the clear air regulations (Ministry for the Environment 2008), which are being enforced by regional and unitary authorities in New Zealand. It is therefore important that the electricity required for powering heat pumps does not produce

harmful emissions if the overall air quality in New Zealand is going to be improved. New Zealand also has a high renewable electric energy target of reaching 90% renewable energy by 2025 (EECA 2007).

In New Zealand the peak electricity demand occurs in the winter, and is driven mainly by electric space heating in houses. This pattern has matched reasonably well with the seasonal availability of renewable hydro power. Currently approximately 55% of all electricity is from hydro (Dang et al 2007). With the introduction of summer cooling, extra electricity generation is required at a time of year when the hydro lakes are traditionally being replenished ready for the winter peak and when there is already a summer peak in some parts of New Zealand caused by commercial building air-conditioning and farm irrigation. Potentially the flow-on effect of increased summer cooling could place extra demands on the electricity network, both for electricity supply and transmission, and in dry years could contribute to electricity shortages.

5 CONCLUSIONS

Sales of heat pumps over the three years 2004–2007 have been strong, with approximately 19% of the current New Zealand housing stock now having at least one heat pump. Occupants report the main reasons for installing heat pumps are 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 will place additional loads on the electricity network. Peak loads and transmission issues due to heat pumps during peak heating times are already causing concern for many electricity supply companies.

Sixty-two percent of survey respondents reported using their heat pumps for cooling as well as heating. Traditionally very little cooling has been possible in New Zealand houses; thus a new summer electricity load is being created by the addition of heat pumps.

The electricity generation required by the number of heat pumps installed is a significant proportion of the expected electricity growth each year for New Zealand as a whole. This suggests that the potentially large increase in electricity demand (from changing New Zealand heating from solid fuel to electric heat pumps) has not been considered when introducing clean air regulations and promoting heat pumps for their energy efficiency.

There is also potential for a large increase in the winter peak load, as the survey has found most heat pump households are heating in the evening when the demand for electricity is the highest.

It is of concern that there have been few measurements of the performance of heat pumps for heating and cooling in New Zealand. There is an opportunity for further work in monitoring the patterns of use of heat pumps in New Zealand homes. Such monitoring would permit investigation into the importance of installation quality, the heat pump room location and the operating regime. It would also provide critical data on their actual performance in use, as compared to the name plate rating.

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