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Supply Requires Demand – Where Does all of New Zealand's Energy Go?

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Supply requires demand – where does all of New Zealand's energy go?

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Executive Summary
Although the media and energy supply industry focus is on issues of supply, most of our energy problems result from the need for ever-increasing demand to be matched by ever-increasing supply. This paper uses research results from the Household Energy End-Use Project (HEEP) to illustrate how improved energy supply system planning can come from improved understanding of energy demand.

Although the energy use per household has increased by only 6% over the past 30 years, the total residential sector energy use has increased by 70%. During this time there has been a 61% increase in the number of households and a 34% increase in population. The preliminary HEEP results show that the patterns of energy use have changed markedly.

While the household electricity use is similar (8,400 kWh/yr in 1971/72 NZ average compared with 7,900 kWh/yr for the Auckland HEEP houses), the main three end-uses of electricity have shifted considerably from the pattern found in 1971/72:

- appliances (including lights) have increased from 28% to 49%
- home heating remains about the same at 15% in 1971/72 and 17% in HEEP
- water heating has reduced from 44% to 28% of electricity use
- range (oven and hobs) has reduced from 13% to 7% of electricity use.

A closer examination of the HEEP data finds that lighting (about 15%) and refrigeration (about 10%) each account for a sizable portion of the electricity use. The relative importance of these uses has not previously been recognised.

However, understanding electricity use alone is not adequate. Electricity is about three-quarters (74%) of household fuels, solid fuels (coal and wood) about 13%, and gas (natural gas and LPG) about 13%.

When the energy sourced from electricity, natural gas, LPG and solid fuels is considered, a preliminary estimate (based on Auckland, Wellington, Christchurch and regional locations) found appliances account for about 35%, home heating about 30%, water heating about 29% and cooking about 6%. Heating (water and space) is the major use of energy in NZ homes.

The preliminary HEEP results are already changing the understanding of residential sector energy use. In some cases the research results come within the initial research goals, while in others they are a serendipitous discovery. Some examples of opportunities identified include:

- possibilities of time-of-use profiles for different consumer groups
- different importance of standing losses for different types of hot water cylinders
- impact on energy and water costs of low-flow shower heads
- patterns of heating and actual winter temperatures in NZ houses
- impact of thermal insulation on living room and bedroom temperatures
- importance of lighting on peak power demand
- appliance 'stand-by' power
- importance of faulty refrigeration appliances.

Our energy statistics and scientific research funding are weighted towards energy supply, resulting in a critical lack of knowledge about energy demand. If unchanged, productive opportunities will be stifled by ever-increasing investment in energy supply.

Supply requires demand – where does all of New Zealand's energy go?

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Abstract

The Micawber Principle (expenditure should not be greater than income) applies equally to energy (ever-increasing demand must be matched by ever-increasing supply) as it does to finances. Today's research and planning is largely focused on new sources of energy supply, their conversion and transmission to the end user. The focus is on ever-increasing supply to meet an apparently ever-increasing demand, rather than understanding the underlying causes of demand. The paper examines New Zealand society's energy demand, and through historical review looks at the widely diverse drivers for increasing demand. The latest research results from the Household Energy End-Use Project (HEEP) will be used to illustrate opportunities for improved energy supply system planning through improved understanding of energy demand.

Introduction

> *Another piece of advice, Copperfield," said Mr. Micawber, "you know. Annual income twenty pounds, annual expenditure nineteen nineteen six, result happiness.*
> *Annual income twenty pounds, annual expenditure twenty pounds ought, and six, result misery.*
> *The blossom is blighted, the leaf is withered, the God of the Day goes down upon the dreary scene, and – and in short you are forever floored.*
> *As I am!* (Dickens, 1850)

Where would Mr Micawber be today? After visiting his local Citizen's Advice Bureau, he would be guided to a Budget Advice Service, where the first question would be to ask him to set out details of his income and expenditure.[1]

The problems that result from the need for ever-increasing demand (expenditure) to be matched by ever-increasing supply (income) can be seen in the energy sector as well as a household. For example, the past year has seen activity due to:

- a short-term crisis, as rain did not refill the hydro-lakes
- uncertainty that the Maui natural gas field may be reaching the end of its theoretical economic life
- increased international oil prices as demand growth does not appear to be matched by comparable short or long-term growth in oil supplies.

Now is an appropriate time to review the supply and demand of energy in New Zealand, starting with a budget review – what are the details of energy supply and demand?[2]

[1] www.cab.org.nz is an excellent first step.
[2] Note: In this paper percentages in tables or on charts may not add to 100 due to rounding.

New Zealand energy supply

The Ministry of Economic Development publishes twice a year the Energy Data File which provides official statistics on energy supply and consumption in New Zealand (MED 2004a). It is based on analysis of energy imports and production, plus mandatory reporting by energy supply companies of deliveries by sector. The following analysis is based on this publication.

Figure 1 illustrates the proportions of New Zealand's main fuel sources – including the use of oil and natural gas for 'non-energy' purposes (e.g. fertiliser, roading, etc). 'Other renewables' includes electricity generation from wind, biogas, industrial waste and wood.

Figure 1 shows that New Zealand's single most important fuel source is the fossil fuel, oil. Over the past 30 years oil has decreased from just under half (48% in 1975) of the total primary energy supply, to over one-quarter (around 28% in the 1980s), but since then has steadily increased to the current 38% (2003 provisional data). In the same time, total annual primary oil use has increased from 185 PJ to 278 PJ – an increase of 50%.

New Zealand energy demand

But where does all this fuel go? Figure 2 re-evaluates the national energy data from a consumer demand perspective. Not surprisingly, the largest fuel supply (oil) feeds into the largest consumer demand (domestic transport). The importance of oil is at variance with the reports in our general and business news media, which are largely focused on electricity.

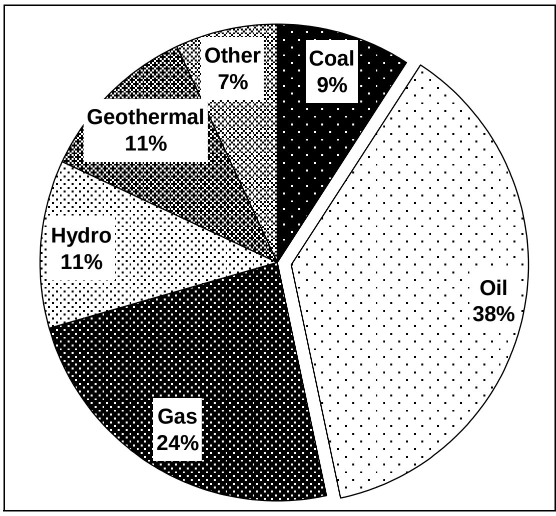

Figure 1: NZ 2003 primary energy by fuel

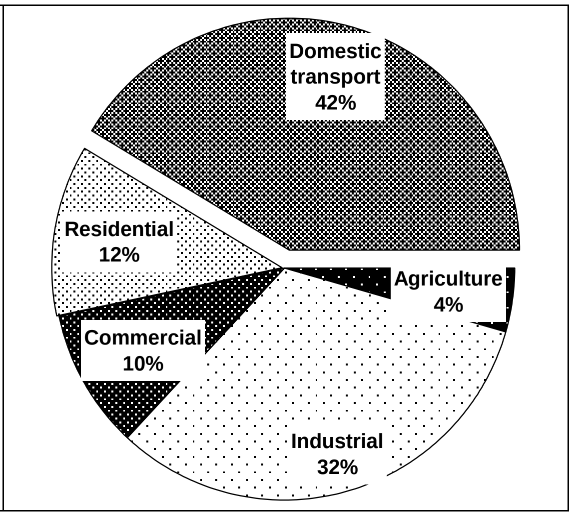

Figure 2: NZ 2003 consumer energy by sector

Figure 3 compares the fuel types used in the different sectors of the New Zealand economy, with the total demand by sector provided at the top of the graph.

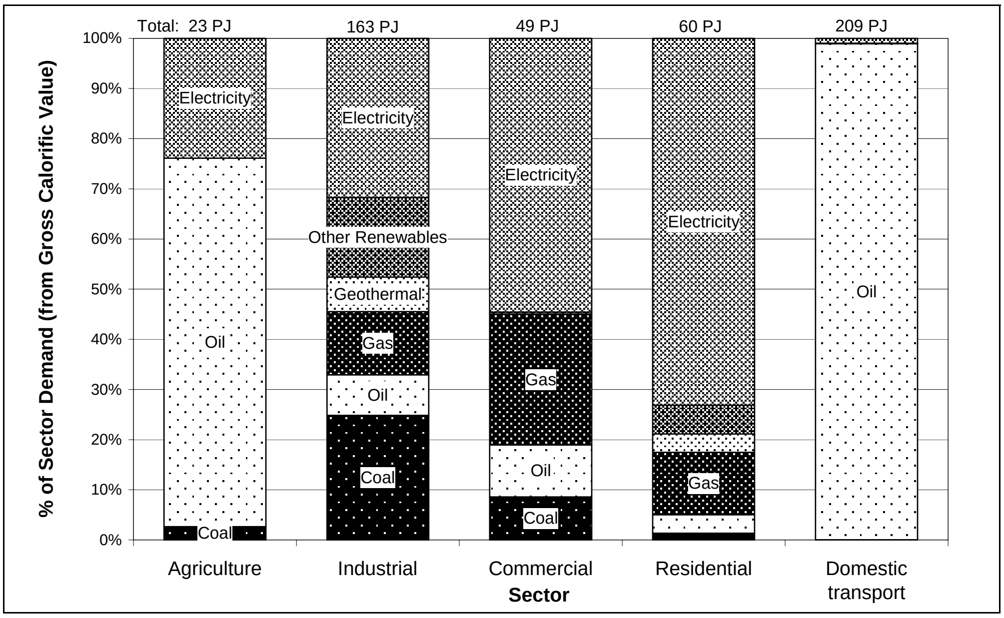

Figure 3: NZ consumer energy demand (2003) by sector and fuel

Agriculture and domestic transport are the most oil intensive sectors, but it is worth noting that all sectors of the economy make use of the ‘transport’ sector – in the main, apart from a relatively small fuel use for motor sports, transport is a service sector. It should also be noted that the ‘commercial’ sector includes public lighting, rail and urban traction.

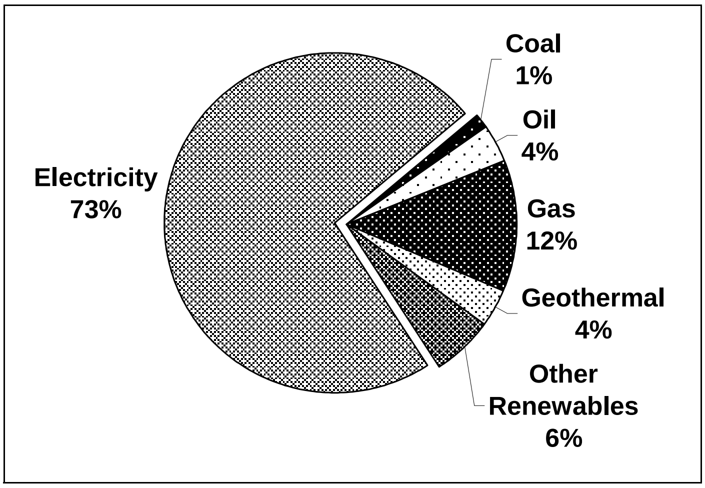

Figure 4: Residential sector energy use by fuel 2003

Examining only residential sector fuel, Figure 4 shows that electricity is just less than three-quarters (73%) of the energy used in the residential sector, with natural gas following second at 12%.

‘Other renewables’ at 6% is followed in order of importance by oil and geothermal at 4% and coal at 1%.

Currently the residential sector consumes about one-third (34%) of consumer electricity, but just under 30 years ago this was close to one-half (48% in 1976). Thus, although electricity is so critical to the residential sector, other sectors now play a more significant demand role.

Have there been any changes in residential energy demand?

> *The relative energy intensity of an average household today is not much different from what it was 30 years ago – and yet we are using far more convenience devices and appliances today.* (Doug Heffernan, CEO Mighty River Power – quoted in Schäffler, 2004)

There are two parts of this statement to be considered – whether energy intensity has changed, and the importance of the convenience devices and appliances.

The first part of this statement does not seem unreasonable. Based on the number of *occupied permanent private dwellings* recorded in quinquennial censuses and the Energy Data File (MED, 2004a), residential energy use per household has increased by only 6% over the period 1971 to 2001. In the same time, the population has increased by 34% and the number of households by 61%, so there are less people per house. The result – total residential sector energy use has increased by 70%, and energy use per person has increased by 27%.

The most recent decade shows a slightly different picture. Figure 5 (data from MED, 2004a and Statistics NZ, 2004) plots total residential energy consumption (PJ), consumption per household (GJ/household)[3] and per person (GJ/person) from 1990 to 2004. Figure 5 shows increases over the period 1993 to 2004:

- total residential sector energy use by 8%
- the number of households by 17%
- the number of people by 15%.

The consequence of these changes is that the average energy use per household has fallen by 8% and the residential energy use per person by 6%.

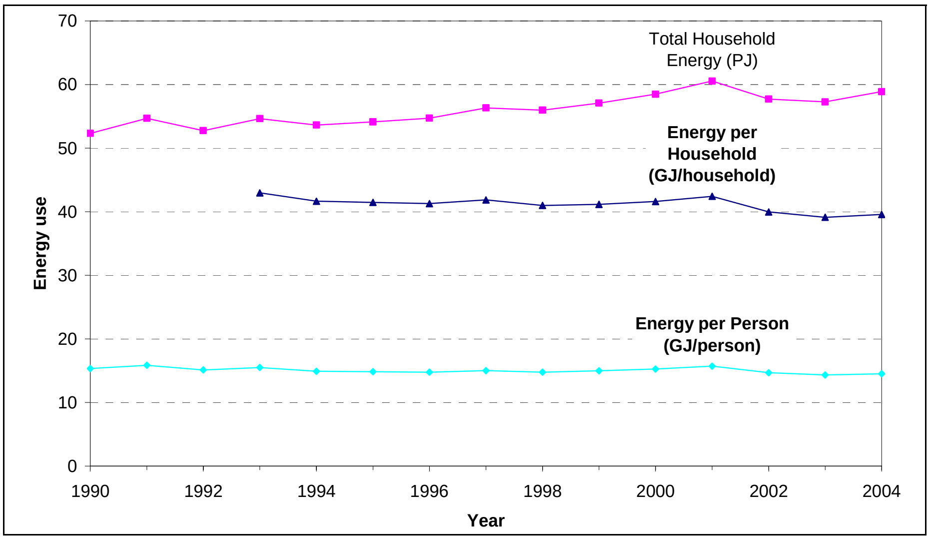

Figure 5: Residential energy consumption 1990–2004

The patterns shown in Figure 5 are related to more than just energy use. For example, New Zealand households show a long-term trend of falling occupancy rates – reducing from 2.8 people per household in 1991 to 2.7 people in 2001 (Statistics NZ, 2002). Structural changes in households (e.g. number of people per household) need to be considered as much as structural change in technology.

But what about the last part of the statement – *yet we are using far more convenience devices and appliances today.* Where does energy use go in New Zealand homes? Are convenience devices and appliances so important in their energy use, or do other uses drive the residential sector energy use? This information is not available from the supply data used to prepare the Energy Data File, so it is necessary to find other sources.

Investing in energy demand knowledge?

Before committing any funds, the wise investor looks carefully at all possible investments – noting the different risks and opportunities. The first step is careful research to obtain the

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[3] Note: The 'Permanent dwelling' series previously used are no longer available, so the results presented here are based on 'estimated households' and thus differ from the HEEP Year 6 Report.

necessary data for analysis. Data are not collected without funding support, so who is funding the search for such data in New Zealand?

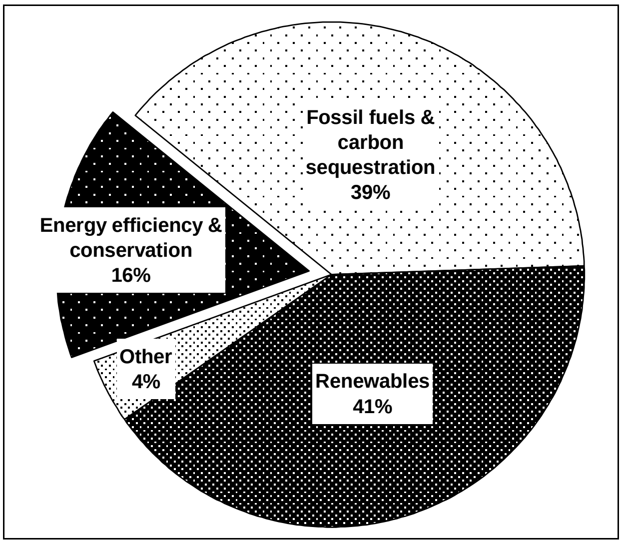

Figure 6: FRST Energy research budget 2003/4

Figure 6 summarises the Foundation for Research Science and Technology 2003/04 budget for energy research (MED, 2004b). The total budget was $12.2 million, of which $2 million was invested in ‘energy efficiency and conservation’. No comparable data is available for private sector investment.

It shows that the majority of Government ‘energy’ research is concerned with supply. Apart from the HEEP, it is clear that there is only limited new work being carried out into understanding energy end-uses in other sectors of the economy. It is thus necessary to first look to historical data.

What uses household energy?

For the past 30 years, almost all knowledge of household energy use has been based on the 1971/72 Household Electricity Study, conducted by the then New Zealand Electricity Department and the Department of Statistics (Statistics NZ, 1973). As the title would suggest, it was concerned solely with electricity use – the use of other fuels (e.g. for water heating, cooking or heating) was recorded, but no estimate made of that fuel use.

Figure 7 illustrates electricity breakdown by end-use from the 1971/72 study – the three largest uses of electricity being water heating (44%), other appliances including lighting (28%) and home heating (15%) (Statistics, 1976). The data used in Figure 7 is subject to a number of caveats in the original report:

- the winter of 1971 was exceptionally mild, suggesting less heating was used than for a more normal (i.e. colder) winter
- the majority of houses used ‘electricity and other fuels’ as their main means of home heating (74% of the insulated houses, 68% of the uninsulated houses) but no estimate was made of the non-electricity heating fuel use.

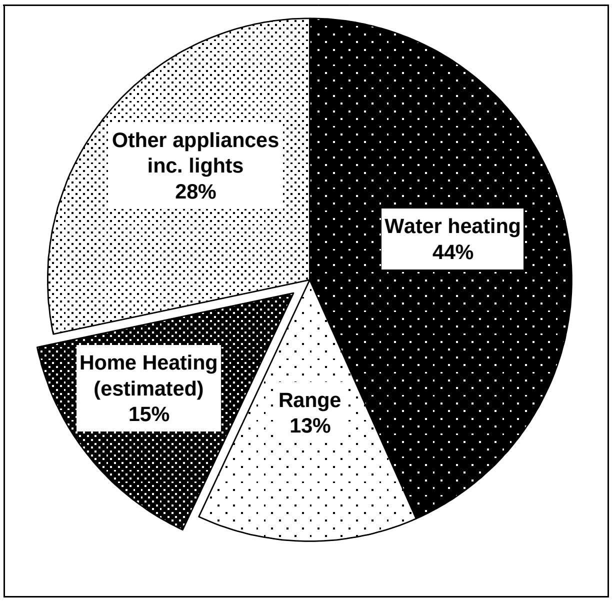

Figure 7: 1971/72 NZ electricity end-uses

- 19% of the houses used electricity and some other fuel for the provision of hot water, but again no estimate was made of the non-electricity fuel use
- the sample included 315 ‘insulated’ (19%) and 1,336 ‘uninsulated’ (81%) houses, but the presence of insulation was associated more with higher income groups and a more widespread use of electric heaters
- the insulated houses in the matched sample were not only warmer, but also consumed 40% more heating electricity (1,632 kWh vs 1,158 kWh).

By the end of the 1970s, natural gas was becoming available in major locations throughout the North Island, an oil crisis had shifted residential interest away from oil as a form of space heating and improved solid fuel burners were replacing the open fire.

There were also changes in both technical and social aspects of the way houses were built and used, with largely unknown energy consequences. There have, for instance, been significant changes in:

- **materials** (e.g. large sheet particleboard for flooring has replaced strip flooring)
- **the NZ Building Code** (e.g. thermal insulation has been required since 1978)
- **appliances** (e.g. microwave ovens widely available from the late 1970s)
- **electronic controls** (e.g. remote controls require ‘standby’ electricity)
- **work practices** (e.g. retailing is now a seven-day-a-week operation)
- **house layout** (e.g. greater use of open plan living spaces)
- **home energy consumption** such as home offices (e.g. home computers)
- **household characteristics** including household ethnicity, size and age composition.

Although the need to understand these changes has been publicly discussed since the early 1980s (e.g. N.Z. Parliament, 1984), it was not until late 1995 that the Building Research Association of New Zealand, Inc (BRANZ) started the Household Energy End-use Project (HEEP) with a pilot study of 10 houses in Wanganui (Stoecklein et l., 1997).

HEEP is a multi-year, multi-discipline, New Zealand study that is monitoring all fuel types (electricity, natural gas, LPG, solid fuel, oil and solar used for water heating) and the services they provide (space temperature, hot water, cooking, lighting, appliances etc). The monitoring of 400 randomly selected houses will be finished in early 2005, with a national residential sector energy model to be completed in 2007. Preliminary results from the HEEP work have been published annually since 1997.[4] It should be noted that the results reported in this paper are subject to change as data processing proceeds.

Figure 8 provides preliminary HEEP estimates of electricity end-uses for Auckland houses.

[4] For latest results, see the BRANZ website: www.branz.co.nz/main.php?page=HEEP

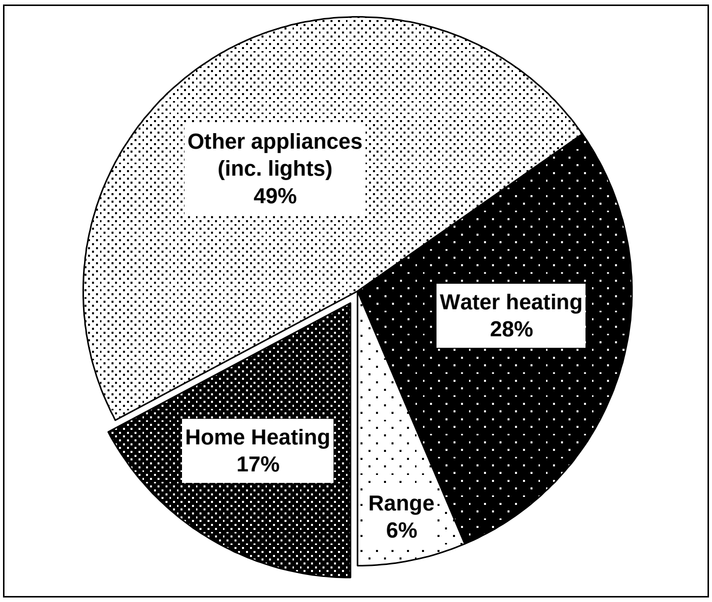

Figure 8: HEEP estimate of Auckland electricity end-uses

Whilst the household electricity use is similar (8,400 kWh/yr in 1971/72 New Zealand average compared with 7,900 kWh/yr for the Auckland HEEP houses), the main three end-uses of electricity have shifted considerably from the pattern found in 1971/72 (see Figure 7):

- appliances (including lights) have increased from 28% to 49%
- home heating remains about the same at 15% in 1971/72 and 17% in HEEP
- water heating has reduced from 44% to 28% of electricity use
- range (oven and hobs) has reduced from 13% to 7% of electricity use.

A closer examination of the HEEP data finds that lighting (about 15%) and refrigeration (about 10%) each account for a sizable portion of the electricity use. The importance of these uses have not previously been recognised, possibly due to a lack of end-use data or perhaps because each is only a small power load. However, a small load turned on and used for a long time (e.g. a heated towel rail operating all day, all year) uses as much energy as a large load turned on for a comparatively short time (e.g. electric clothes dryer used 90 minutes daily).

Understanding electricity use does not provide an adequate understanding of household energy use. Although it is possible to use electricity for all household uses, very few houses use only electricity. In particular, most households use more than one fuel for space heating.

The results of the most recent HEEP energy analysis are reported in Figure 9 and Figure 10. They provide preliminary energy estimates based on the 300 randomly selected houses in the HEEP sample in Auckland, Wellington, Christchurch, Dunedin, Invercargill, Whangarei and Tauranga, and in locations on the Kapiti Coast, Otago, Northland and Waikato. The estimates will be subject to change as wet-back water heating and solar water heating are included. The completed results of this work will be reported in the next available HEEP report.

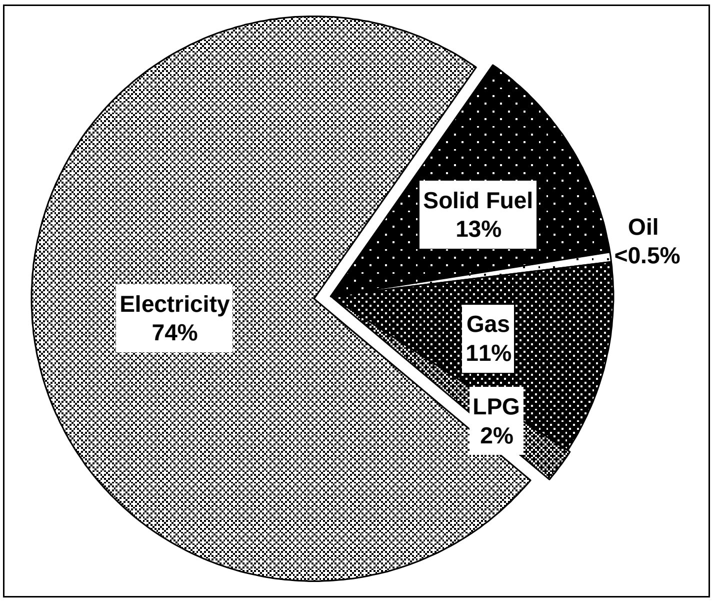

Figure 9: Residential fuel use – preliminary HEEP estimate

Figure 9 shows a preliminary estimate of the relative importance of the main residential fuels. Comparing the HEEP analysis in Figure 9 with the residential sector fuel use from the Energy Data File (Figure 4) shows a similar importance of electricity, but differences in that:

- no household geothermal energy use has been measured by HEEP (although this may relate to the specific sampling areas)
- HEEP monitored use of oil is lower than that suggested in the Energy Data File
- solid fuel (coal and wood) and LPG are a higher proportion in the HEEP fuel use than in the Energy Data File (assuming 'Other renewables' includes wood).

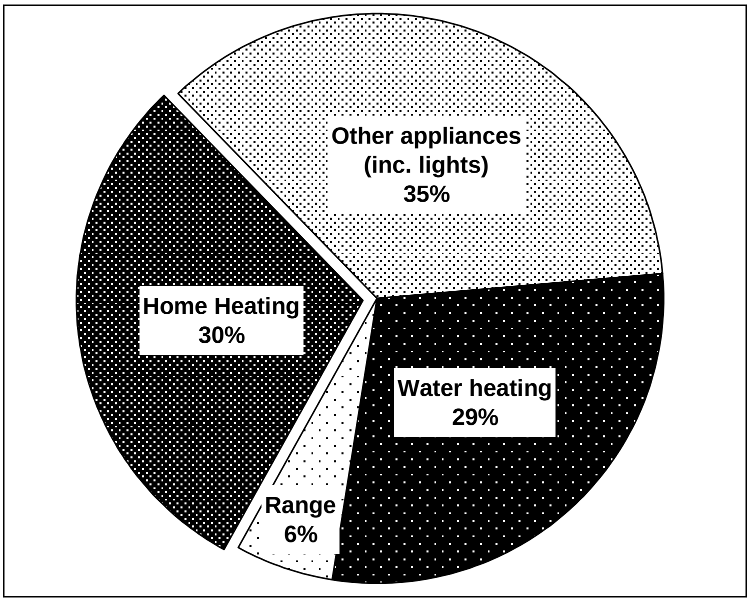

Figure 10: Residential end-uses – preliminary HEEP estimate

Figure 10 provides a preliminary estimate of residential energy use by end-use for the fuels in Figure 9. The proportion differences from electricity end-uses in Figure 8 reflect the role of LPG, reticulated gas and solid fuels in providing space heating and domestic hot water.

Although it is possible to use different fuels for water and space heating, the shift is likely to occur over a long time period and be associated with consequential structural change. For example, 'portable kerosene heaters' were found in 11% of households in 1984, but over the following 17 years have all but disappeared – only 0.6% of households had one in 2001. Similarly, 'portable electric heaters' were found in 89% of houses in 1984, but by 2001 were only in 71% of households (Statistics NZ, 2001). In most cases (as evidenced by the HEEP house appliance inspections), these heaters are no longer available for use. This would suggest that there are long-term energy supply planning implications of such shifts in energy end-uses.

These four figures illustrate how household energy end-use has changed over 30 years:

- Figure 7 (1971/72 Household Electricity Study) demonstrated for the first time that hot water heating, appliances and space heating were the major uses of electricity
- Figure 8 (HEEP 2004 estimate based on the electricity use in 100 Auckland houses), illustrates how electricity use has changed over the past 30 years, particularly the increased importance of appliances
- Figure 9 (HEEP 2004 estimate – based on 300 mainly urban and suburban houses) illustrate the important role played by solid fuel (wood and coal) and LPG
- Figure 10 (HEEP 2004) – provides for the first time a preliminary understanding of all the energy end-uses in New Zealand houses.

The common theme in all of the end-use analyses is that heating fuels (space and water heating) are the drivers of household energy use, not the suggested 'convenience appliances'.

Opportunities from understanding household energy demand

The exploration of the HEEP research into previously uncharted energy use has already given some important insights. The following examples are early results, and as the analysis progresses with the completion of the monitoring portion of the project, further insights can be expected. These examples illustrate the type of opportunities that result from improved understanding of energy end-uses. Most importantly, understanding of demand can be used to identify specific opportunities to deal with specific energy supply issues, rather than taking the simplistic option of reverting to investment in new supply.

- **Time-of-use profiles**
  Although the New Zealand electricity market has been based on half hour time-of-use profiles since April 1999, there is little evidence that tariff profiles are anything more than based on the shape of all the electricity consumed at the local grid exit point, minus the electricity consumed by commercial and industrial consumers. HEEP monitors all household fuels on at least a 10 minute basis, and can therefore generate time-of-use profiles for specific groups.

- **Domestic hot water – standing losses**
  The New Zealand Standard for the energy performance of domestic water heaters is based on laboratory testing, but the energy performance of hot water systems in actual homes is more complex and difficult to measure.

  The energy used to provide household hot water relates to two issues: social (the amount of water used by people for different tasks) and technical (the energy used to heat water and maintain it at temperature). HEEP has quantified, for the first time in New Zealand, these two components:
  - 'Delivered hot water' represents the social portion of the energy use – the average use is between 4.2 kWh/day for electric night storage systems and 12.5 kWh/day for natural gas instanteous systems. This energy includes that used to heat the water that remains in the pipes after 'use'.

- ‘Standing losses’ represent the technical portion of the energy use, and range on average from nothing for natural gas instantaneous systems (with electronic ignition) to an average of 4.1 kWh/day (27% of total gas use) for natural gas storage to an average of 2.6 kWh/day (34% of total electricity use) for electric storage systems.

Both the delivered hot water and standing losses vary from house to house, and from cylinder to cylinder, depending on a range of factors. These will include the cylinder size, age, insulation, thermostat type and water pressure, and the pipe material, insulation and length. HEEP is now exploring these differences, and those between fuel types.

- **Water conservation**
  There is an interesting inter-relationship between water and energy use. At the regional level, the provision of mains water involves a sizeable energy investment, principally in the form of pumping water from storage to the point of use. In the home, energy is used to raise the temperature of the water, so any action that leads to a change in hot water use will result in an increase in energy.

  Traditionally New Zealand homes have been provided with ‘low pressure’ hot water systems – often a copper hot water cylinder with a ceiling mounted ‘header’ tank. Seventy eight percent of the HEEP hot water systems are ‘low’ pressure, with the remainder ‘mains’ pressure. A major use of hot water is for showers, where the ‘length of shower’ is measured not in water consumption, but by time. On average, ‘mains’ pressure water systems have a higher flow rate than ‘low’ pressure systems – averaging 10.6 litres per minute compared to an average of 7.2 litres per minute.

  HEEP has been able to quantify the impact of a low-flow shower head on water and energy use based on actual measurements. In Auckland (where there are charges for both potable water supply and waste water removal), the savings from fitting a low-flow shower head would be of the order of $90 per year for one shower per day – or $360 for a four person household. About half of the financial savings are from water and half from energy savings.

- **Winter temperatures**
  New Zealand has a relatively mild climate – ‘temperate with sharp regional contrasts’ according to the *CIA World Factbook* (CIA, 2003) – leading to the expectation that indoor temperatures are also temperate. The measured facts differ from this assumption.

  HEEP has provided the first nation-wide data on the temperature patterns found in New Zealand homes. Current HEEP work suggest that the winter heating season includes the period between June and August (inclusive), and during this season the living room is heated in the evening between 17:00 and 22:50. In the remainder of the house, and during the day, only minimal heating is used in most New Zealand houses.

  The average winter evening temperature in the current 300 house sample follows a normal distribution, with an average temperature of 17.3°C and a standard deviation of 0.2°C. Importantly, about 28% of these average temperatures are below the healthy minimum of 16°C (WHO, 1987). Further work is being undertaken to explore the reasons behind these heating patterns and resultant temperatures. These results will also be used to improve design guidance and thermal modelling tools.

- **Impact of thermal insulation**
  Houses built since 1 April 1978 are required to have minimum component levels of thermal performance, generally achieved by the addition of thermal insulation, but in some cases provided as an intrinsic part of the construction technology.

HEEP monitors the living room and bedroom temperatures. HEEP analysis has found that there is a relationship between the age of the house and the winter evening average temperatures. Based on the 400 house sample, we can conclude that living rooms in post-1978 houses are on average 1.0°C warmer (18.6°C compared to 17.6°C).

HEEP research has also found that households seldom heat bedrooms overnight, but post-1978 bedrooms are still 1.3°C warmer (14.5°C compared to 13.2°C), so this is achieved at no purchased energy cost – it is a benefit from the body heat of occupants and any energy using appliances e.g. clock radio, lights, etc. It is possible other issues are also important (e.g. different occupancy groups, house construction, etc) and this is being investigated.

- **Lighting and peak power**
  May 2004 saw the spectre of winter power outages in the top of the South Island due to potential peak demand electricity transmission capacity constraints. HEEP has identified lighting as a noticeable, but not major, use of household electricity. More importantly, HEEP has found that lighting is a significant component of peak electric power demand.

  Peak lighting electricity use closely coincides with peak system power demand. Analysis of the HEEP database suggested that the peak lighting load was about 200 W per house. For the 230,000 houses in the area of the South Island expected to be subject to peak power constraints, this is a peak load of 47 MW.

  The HEEP surveys showed that on average there are 20 incandescent lamps, one compact fluorescent lamp (CFL) and one halogen lamp in houses. Halogen lamps can not be simply replaced by CFL, as the fittings are not suitable. Of the 20 incandescent lamps, some will be in fittings that are not suitable for CFL, not all are high use, and some are not going to be used at peak times. A comparison of the average lighting power to the peak power load suggested that, on average, two incandescent lamps per house could be usefully replaced by CFL. This would reduce the peak power demand by 35 MW (i.e. from 47 MW to 12 MW) without reducing the service provided to house occupants.

  The replacement of a 100 W incandescent lamp that is used all evening, with a 25 W CFL at an assumed cost of $10 (including GST and installation), will save the householder $16.38 per year. It will also have the effect of reducing peak electricity demand at a cost equivalent to $130 per peak kW. The capital cost of the incandescent lamps, assuming a service life of 1,000 hours, is actually 50 cents higher than the capital cost of the CFL, also giving the householder a capital benefit.

  In some houses more lamps could be expected to be ‘on’ at peak times – kitchen, living room, hallway, study, dining room – and these may provide additional peak power reductions, but would need to be considered on a house-by-house basis.

  It is often argued that energy efficiency gains can be reduced by the behaviour of house occupants. In this case sunset in the top of the South Island is about 5pm in winter, so if the house is occupied by 5.30pm, the lights will be turned on thus ensuring the calculated peak power benefits will be obtained.

- **Appliances – standing by**
  Standby power is drawn by some appliances when not in operation but connected to the mains. Depending on the appliance type and age, the standby can range from zero (e.g. a non-electronic dryer with a clockwork timer) to 20 W or more (e.g. many televisions). These power consumptions may seem trivial (1W continuous is approximately 9 kWh per year and costs about $1.20), but since most households have many such appliances, the energy consumption may be a significant fraction of the total household electricity use.

Standby power also appears to be growing rapidly, due to the proliferation of electronic and computer controllers in appliances, and the increasing ownership of electrical goods.

The baseload electricity demand of a house is the typical lowest power consumption when there is no occupant demand. It includes the standby power of appliances (e.g. microwave ovens, VCRs, multiple TVs, video games, dishwashers, etc), plus any appliances that operate continuously (e.g. heated towel rails, clocks, security systems etc).

HEEP monitoring results were the first quantification of the impact of standby and baseload power for New Zealand houses. HEEP data suggests that standby and baseload power accounts for about 12% of household electricity – about 4% from heated towel rails, 5% from major appliances (e.g. washing machines, TV, etc) and the remaining 3% from a wide range of smaller or less popular appliances.

These results have already provided critical data to support the development of appropriate testing and Standards for Minimum Energy Performance Standards and Energy Labels. Further analysis can be undertaken of the HEEP data to better identify key growth areas, and their likely impact on the electricity system.

- **Faulty appliances**
  As the number of appliances in New Zealand homes increase, it is to be expected that some will fail. In many cases the failure will be obvious e.g. the television fails to work, and the appliance will be replaced. However, the HEEP monitoring results are showing that when some appliances fail the failure mode does not alert the users to the failure. Such appliances may continue to consume more energy than necessary, but not provide the expected service.

  For example, refrigeration equipment (refrigerators, refrigerator/freezer combination or freezers) use about 10% of household electricity. The HEEP survey has found that 55% of the refrigerators, 50% of the refrigerator/freezer combinations and 80% of the freezers are more than 10 years old (i.e. manufactured before 1994). This age is significant, as ozone depleting CFC refrigerants and blowing agents were phased out in 1994.

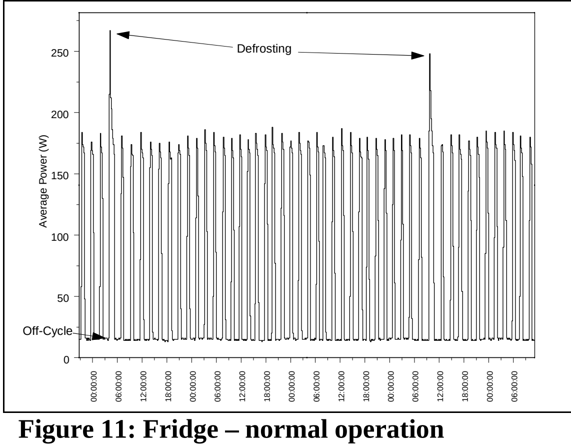

Figure 11: Fridge – normal operation

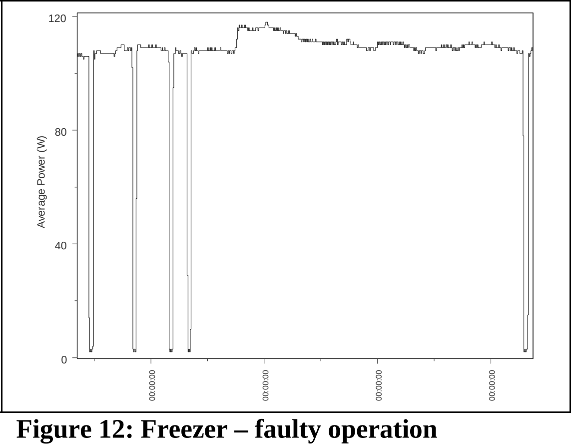

Figure 12: Freezer – faulty operation

What happens when refrigeration appliances fail? HEEP monitoring has found that nearly one in five refrigeration appliances have a problem – approximately 10% are faulty, with a further 8% are marginal. Nationwide, this is equivalent to over 400,000 appliances.

A typical example of the electricity use of a refrigeration appliance in normal operation is given in Figure 11. In this case, the compressor power is approximately 170 W, the offcycle (baseload) power consumption is about 15 W, and defrosting occurs about once every three days.

An example of a faulty freezer is given in Figure 12, in which the compressor stays on for long periods of time and occasionally switches off. Some faulty refrigeration appliances never switch off.

Without the HEEP monitoring this issue would not have been either identified or quantified. The number of refrigeration appliances with problems is so large that there is an opportunity for real benefits – not only to the individual household (through improved food storage and energy savings), but also to the nation (through reduced electricity demand) and to the wider world (through correct identification of failure and recovery of the CFC gas).

HEEP estimates that each faulty refrigeration appliance uses about 550 kWh per year more than they would if operating properly – a cost of about $90 a year per appliance. Taking into account the faulty and marginal refrigeration appliances, the unnecessary expenditure could easily reach $30 million per year. If these appliances were replaced by modern appliances using half the energy of a correctly operating old appliance, the benefits could easily double.

Discussion

Over 150 years ago, Charles Dickens' Mr Micawber neatly summed up the consequences of a mismatch between income and expenditure. We now must question whether today's society has learnt the consequences of an ever-increasing energy demand.

This paper has reviewed the availability of energy supply and demand data, and found that official statistics provide information on energy supply and sectoral energy demand. At the more detailed energy demand level, except for the residential sector as reported in this paper, the end-use data is out-of-date and inadequate.

Liquid transport fuel (in the main oil) was identified in the 1970s as New Zealand's main energy problem (e.g. Harris et l., 1977). Today, as the world looks towards a future with increasingly expensive petroleum-based transport fuels, we hold confidence in our abilities to deal with this, but based on a lack of knowledge of demand and a belief that investment in supply will be sufficient.

Can a society built on the assumption of readily available, low-cost oil continue without major change? For example, 'just-in-time' manufacturing expects a flexible, responsive transport system to be able to deliver any required component within a well-defined timeframe. Such a transport system, in turn, is supported by low-cost fuel which can allow trucks (or cars) to travel with less than full loads

In the main, sectoral energy demand changes slowly. Apart from step increases, for example due to the construction of a major base metals processing facility, changes in energy demand tend to be composed of a large number of small shifts. For example, the effect of more energy-efficient new houses and new appliances will take time to impact on the national averages. In the year end August 2004, consents were issued for a total of 32,169 dwelling units (including 5,942 apartments) (Statistics NZ, 2004a). The average over five years (2000-2004) is 25,534 dwelling units per year – which would take 62 years to completely replace the estimated 1.58 million private dwellings in New Zealand at 30 September 2004 (Statistics NZ, 2004b).

The HEEP research is changing our understanding of household energy use. The preliminary analysis reported here shows that there have been critical changes in the demand for fuels over the past 30 years. For example, although total electricity use per household has not changed greatly, houses, households and the patterns of electricity use by these households have changed. The consequences of this shift have yet to be understood.

This lack of understanding can be traced to a lack of data, which in turn traces to a lack of investment in understanding energy demand. The majority of current New Zealand energy research is directed towards energy supply and conversion, and even energy demand statistics are in limited supply.

The HEEP work is providing new knowledge on the use of energy in the residential sector, and this in turn will provide significant opportunities – not only for energy supply but also for a wide range of other businesses involved in the provision of energy using and conserving products and appliances.

The examples presented here resulting from the HEEP improved understanding of household energy end-use include:

- possibilities of time-of-use profiles for different consumer groups
- different importance of standing losses for different types of hot water cylinders
- impact on energy and water costs of low-flow shower heads
- patterns of heating and actual winter temperatures in New Zealand houses
- impact of thermal insulation on living room and bedroom temperatures
- importance of lighting on peak power demand
- appliance 'standby' power
- importance of faulty refrigeration appliances.

In some cases these results come within the initial research goals, while in others they are a serendipitous discovery. The paper has provided examples of how the results of the HEEP research can lead to significant opportunities. How many other opportunities remain to be discovered is unknown, but then that is the objective of scientific research.

Conclusions

A budget advisor attempting to review New Zealand's energy income (supply) and expenditure (demand) would be faced with major difficulties – far more difficulties than faced by Mr Micawber with his detailed understanding of his pitiful situation.

There is a considerable knowledge of energy supply, but this is not the case for energy demand; although as a result of the research reported here we are beginning to better understand the residential sector. Although the residential sector only directly accounts for 12% of consumer energy, changes in the performance of this sector reflect throughout the economy.

The HEEP work, even though far from complete, has already identified a range of important energy demand issues in the residential sector that have important implications for national energy supply. These issues create new opportunities for science and business to create innovative solutions:

- what energy demand issues exist for other sectors in the economy?
- could these energy demand issues result in improved or even in sustainable energy supplies?
- what are the opportunities to reduce the energy-related greenhouse gas emissions?

There are no answers to these and many other questions, as we as a society lack the basic knowledge. This lack of knowledge does not seem to be an appropriate basis on which to build a national energy policy.

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