Electricity Networks Association

Trends in Residential Electricity Consumption

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sapere research group

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1. Background

National electricity demand in New Zealand has remained largely constant since 2007. This is a major departure from the historical trend of relatively stable growth exhibited since the 1960s of, on average, 650GWh per annum.

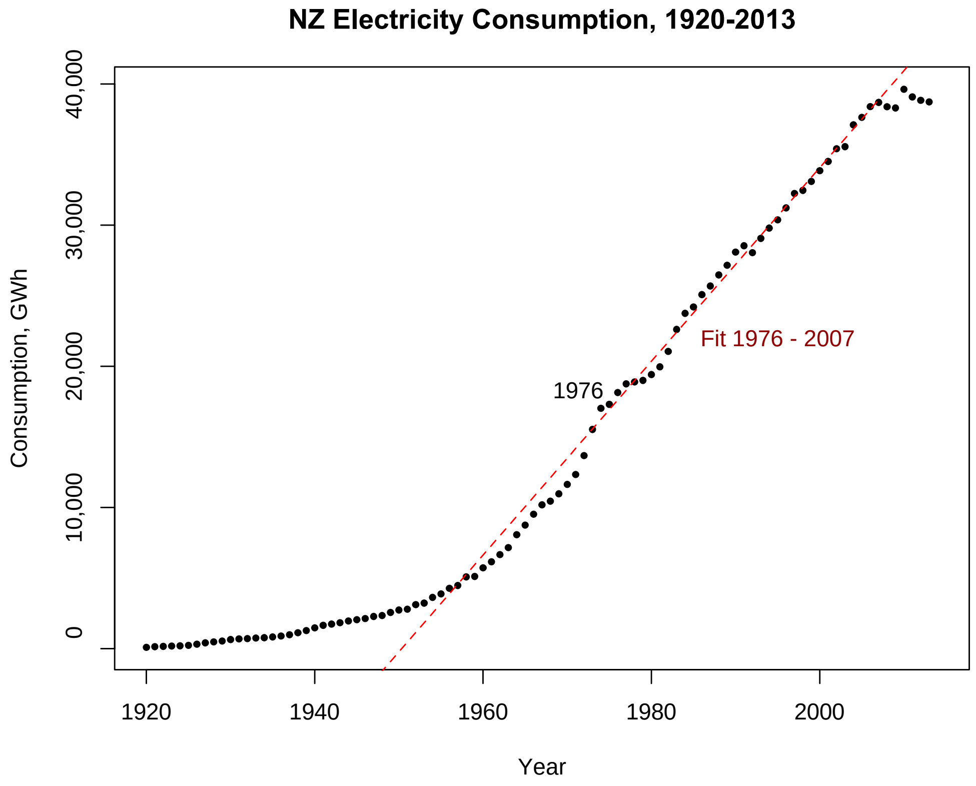

Figure 1 - Annual electricity consumption in New Zealand (MBIE, Whiteboard Energy)

Within this overall pattern, however, there are different effects manifesting at different levels (Figure 2):

- Industrial demand has substantially reduced since 2005, dominated by reductions in consumption at Rio Tinto's Tiwai Point Aluminium Smelter and Norske Skog Tasman's pulp and paper facility
- Residential demand has experienced four successive years of flat or declining growth.
- Agricultural demand has continued to grow through the global recession
- Commercial demand was flat during the recession, but is now at higher levels than prior to the GFC

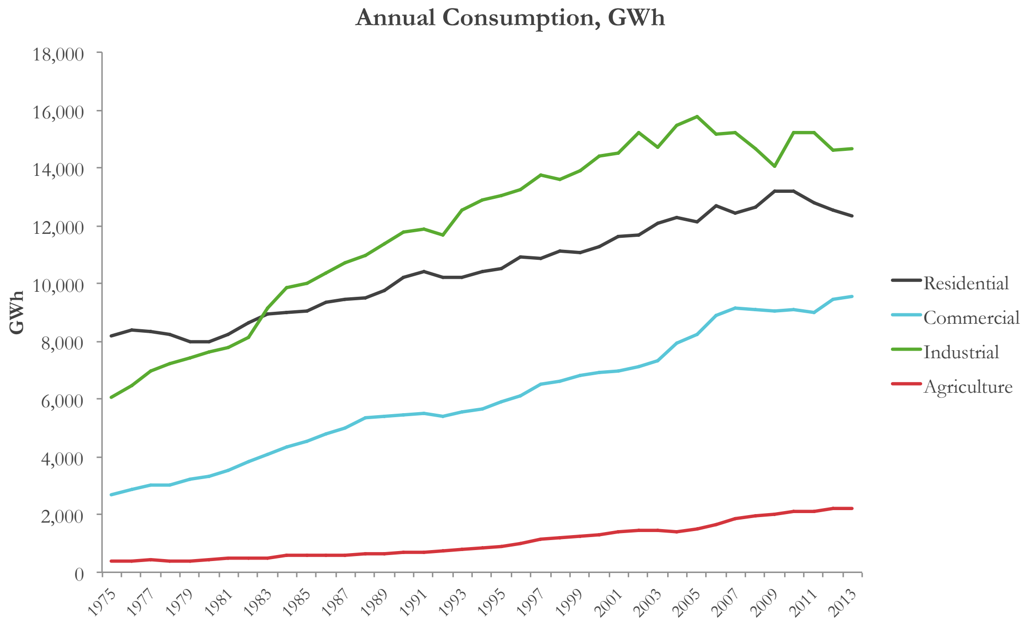

Figure 2 - Consumption by major sector, 1975-2013 (MBIE)

Traditional econometric models, based on (for example) the number of households and GDP, have struggled to capture this change in dynamic, although will invariably be re-calibrated to accommodate this recent trend. However, re-calibrating regression parameters does not tell us *why* this recent pattern has emerged, and shouldn't necessarily give us any confidence that we fully understand the underlying drivers.

Our focus in this paper is the residential sector. As we will show below, the reduction in residential demand since 2009 is a function of both a reduction in the number of households, but (more significantly) a reduction in the consumption *per* household. Important questions for the sector include:

- Did the demand "system" substantially change in 2007, or were the changes more long term, reaching a turning point in 2007?
- What were the underlying influencers of this change?
- Are the changes temporary, persistent, or likely to undergo further changes?

The Commerce Commission, in its Low Cost Forecasting Approaches Paper[1], has stated a position that

"…electricity consumption by the average residential user is unlikely to fall over the next 5-7 years. Electricity price increases are starting to moderate, economic activity is picking up, and electric cars are becoming viable. Taken together, our expectation is that electricity use per user is more likely to remain broadly constant."

We find this prediction surprising given the significance of the recent trend, as will be presented below. However, we note that, due to lack of a comprehensive dataset on the age

1 Commerce Commission, Low Cost Forecasting Approaches for Default Price-Quality Paths, 4 July 2014

and efficiency profile of current houses, we can only infer trends for the future. But a prediction that consumption per household is unlikely to fall requires a particular (and, we think, unreasonable) view on the nature of changes being experienced by households currently, as we will show below.

2. Residential Demand

There are two high-level effects that drive changes in total residential demand:

1. The growth in the *number* of households (driven by population growth)
2. Changes in per-household consumption, which includes the effect of prevailing weather conditions

In the second category, we will focus on changes within the household. We do not consider in any detail the (somewhat small) component of change in the national average household consumption which is due to the population growth being dominated by warmer areas (e.g., Bay of Plenty and Auckland). Here, average household consumption is lower – ceteris paribus - due to lower heating requirements. As a result, proportionally greater population growth in these areas will bring the national average household consumption down.

2.1 Growth in households

Population growth in New Zealand has been 25% lower over the last 6 years (~1%) than the previous 15 years[2] (1.21%), although broadly similar to the average growth since 1980. Growth in the number of households has been commensurately lower (Figure 3). Hence, holding average household electricity consumption constant, there is a component of reduced residential demand which is due to lower growth in the number of consuming entities.

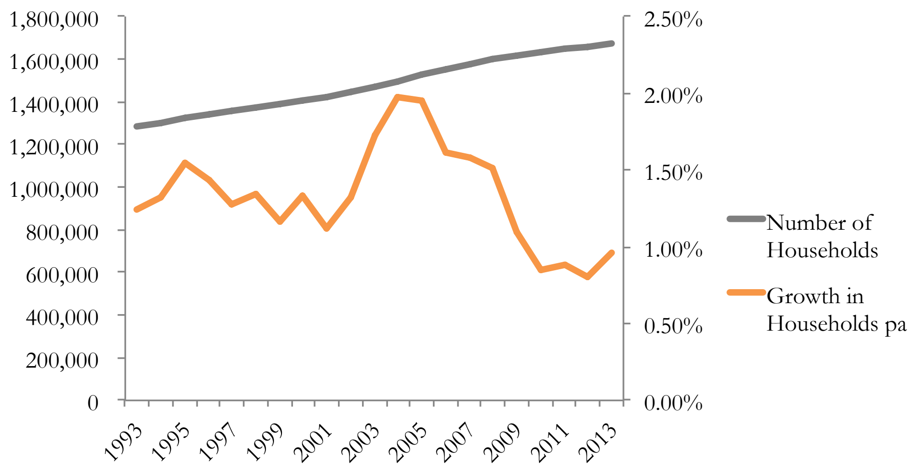

Figure 3 - Household Numbers and growth rate in NZ, 1991-2013 (Statistics NZ)

We note:

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2 We have used the previous 15 years as a comparator due to the fact that reliable estimates of household numbers are only available since 1993.

- The 15 year average growth rate in household numbers is ~21,500 households per year.
- The growth rate in households between 2003 and 2008 was 26,000 households per year, 20% higher than the average rate since 1993. This would have put upwards pressure on electricity demand (compared to the longer term trend).
- Over the last 5 years, the growth rate dropped markedly to ~15,000 per year (a drop of 75% compared to the previous 5 year period). If households had grown at the same rate as experienced between 1993 and 2008, an additional 6,500 households would have been created each year. Assuming that average household consumption had remained constant at 8,000kWh), this factor alone have would have increased residential growth by 30%, or 52GWh per annum.

2.2 Weather

In order to provide an approximation of the impact of weather trends on residential consumption, we have conducted a high-level "heating degree day" analysis (HDD). HDDs measure the duration, specified in days, that the temperature fell below a reference temperature[3]. Hence the number of HDDs for a year gives a good indication of how cold it was[4].

Figure 4 illustrates the relationship between per-household consumption, and the demand-weighted sum of HDDs in Auckland, Wellington and Christchurch.

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3 Data sourced from cliflo.niwa.co.nz. NIWA have used 18 degrees as the reference temperature. The engineering standard is 15 degrees, however, 15deg HDDs are only available back to 2004. We have compared the two periods and the general trend is relatively unchanged for the period 2004-2012.

4 Cooling Degree Days, which effectively measure the need for cooling when temperatures exceed a reference level, are also available. This may be a worthwhile analysis for Auckland. However, residential demand is not available for Auckland only.

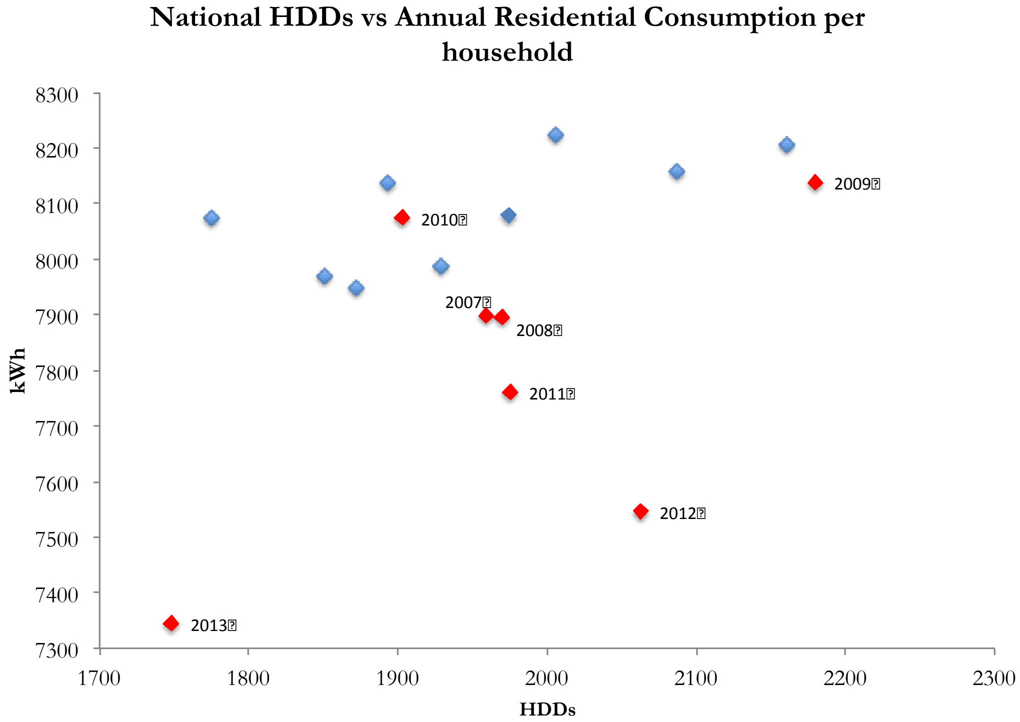

Figure 4 - National Heating Degree Days vs Average Household Consumption 1995-2013 (NIWA, MBIE)

While only a modest sample (1995-2013), overall, there is an unsurprising increasing relationship between HDDs and household consumption.

The points highlighted in red in this chart are 2007-2013. Other than perhaps 2010, these points suggest lower consumption, for a given number of HDDs, than for the preceding period (blue points), although we have not assessed whether the difference is statistically significant. Of particular note:

- 2011 had a higher number of HDDs to 2010, but nearly 4% (314kWh) lower consumption. However, the 2011 figure is undoubtedly impacted by the Christchurch earthquake. As outlined above, the earthquake possibly reduced national average demand by 56kWh in 2011, although this only explains 18% of the reduction[5].

- 2013 had the fewest HDDs in this limited record, and well below the other years in the 2007-2013 period. However, we note that 1998 had a similar number of HDDs (the left-most blue point in the figure), yet had nearly 10% higher average household consumption.

[5] We acknowledge that 2011 also contained one of the most extreme cold weather events of the last century on August 15th. Snow fell in Auckland for the first time in 80 years. However, we suspect that a few cold days in Auckland wouldn't greatly offset the impact of parts of Christchurch being without power for many weeks, even adjusting for the population effect.

Normalising for temperature effects can be done in a relatively straightforward way, by estimating the energy consumption (in kWh) that an extra HDD requires – effectively the coefficient of a best-fit upward sloping line in Figure 4. However, it is not clear from Figure 4 which data points to use in order to estimate this coefficient. Using all data points would clearly over-estimate the sensitivity to weather (a high slope), due to the effect of the 2011-2013 data points which we have argued are outliers. There is no obvious answer to how to estimate this relationship in the face of a changing dynamic that is unrelated to weather effects. However, estimating this relationship using all data up to (and including) 2010 suggests that 2013 consumption – temperature adjusted – is still lower than 2012.

We also acknowledge that HDDs are not a conclusive measure of the effect of weather on demand. Even the effect of temperature alone is likely to be non-linear. However, we present this analysis here to illustrate that it is unlikely that the downward trend can be explained by temperature effects.

2.3 Changes within the household

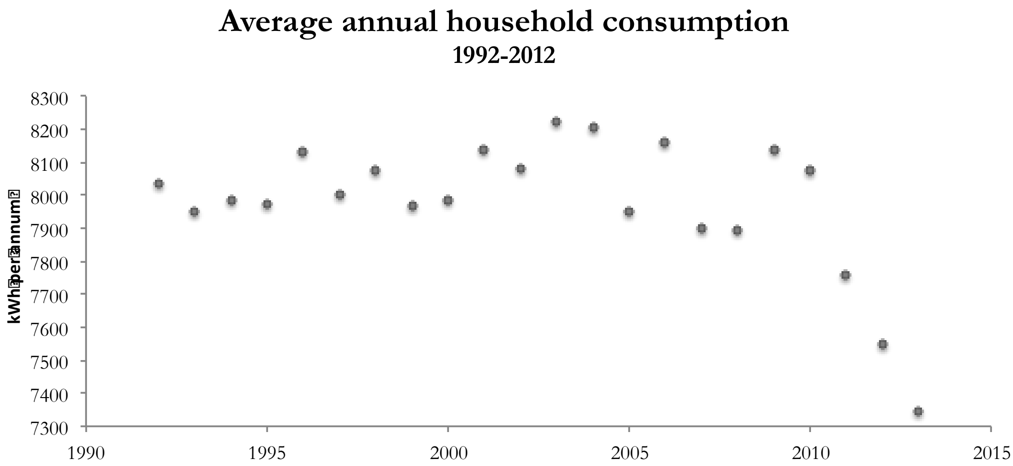

Figure 5 - Average Annual Household Consumption 1992-2013 (MBIE, Statistics NZ)

Figure 5 illustrates residential consumption per household between 1992 and 2013[6]. 2011-2013 are clear outliers, and follow a declining pattern which is unheralded in the 20-year period illustrated.

We acknowledge that the Christchurch earthquake had a major impact on demand in 2011 and 2012. We estimate that the earthquake reduced non-industrial demand by 270GWh in

[6] There is no reliable source of annual (occupied) households prior to 1992. Yearbook data has occupied dwelling figures at each census, but these do not appear to correlate with Statistics NZ's annual estimates for the period after 1992. The difference is relatively constant, however, and the historical census data suggests that average annual household consumption between the 1976 and 1991 censuses was between 7,900kWh and 8,500kWh.

2011, 150GWh in 2012 and 40GWh in 2013. Assuming a third[7] of this reduction occurred in the residential sector, national average annual household consumption would have been 56kWh and 31kWh higher in 2011 and 2012 respectively. This is approximately 25% and 18% of the decline in each year (respectively).

In order to understand the materiality of each of the effects outlined in this Section, it is useful to know how household consumption is broken down. Probably the most comprehensive assessment of household consumption was BRANZ's Household Energy End-Use Project (HEEP). Unfortunately, the HEEP results are nearly a decade old, and much could have changed by now. However, there is little more reliable data on what is happening inside NZ homes.

Space and water heating	46%
Appliances	19%
Refrigeration	15%
Lighting	12%
Range	9%

Table 1 - Makeup of household consumption, 2005 (BRANZ)

In the sections that follow, after considering any weather effects on the recently observed pattern, we consider changes underway in each of the top four categories in Table 1. We will then consider changes that might have more relevance to the future (solar and electric vehicles). We conclude by considering the role that price and income potentially has on consumption.

2.3.1 Space Heating, Insulation and Building Size

The improvement of the thermal efficiency of homes – primarily through better insulation - is often cited as a reason why residential demand is declining. Improvements in the home's ability to capture and hold heat (in a temperate zone) is a key driver of heating requirements.

Insulation is now a requirement under building standards. Minimum standards for insulation were introduced in 1978, and have been revised periodically since. Since 1978 we have consented approximately 700,000 residential dwellings (see Figure 6). Assuming all of those consented were built, just over 40% of our current housing stock has been built since the introduction of the building standards. Even for homes built prior to 1978, major renovations require the renovated area to be brought up to the current standard, and in many

[7] This is a difficult number to estimate. While total residential demand will be more than 33% of non-industrial GXP demand, the question we are addressing here is what proportion of the *reduction* is in the residential sector. Once population effects have been accounted for (which may have been substantial in 2011), the resident population still consumed electricity in Christchurch, even if it wasn't in their original home. However, many businesses ceased operation altogether for some time, and it appears likely this made up a greater proportion of the decrease

cases, owners of older houses will elect to retrofit insulate anyway[8]. The materials available to insulate has also improved.

More recently, EECA has run two subsidised domestic insulation programmes ("Warm up New Zealand – Healthy Homes" and "Warm Up New Zealand – Heat Smart"). Overall, 295,000 homes have been retrofitted with subsidized insulation and/or clean energy heating. Of these, EECA figures suggest only 59,000 procured subsidized insulation between 2009 and 2014. This of course does not account for those who insulated without the subsidy, either during the subsidy period or prior to it.

However, an assessment of the impact of Warm Up New Zealand: Heat Smart[9] concluded that electricity consumption only decreased 1% after insulation was installed. An earlier report by Taylor and Lloyd[10] demonstrates that a house in a colder climate may use the reduction in energy losses to increase the temperature in living rooms and bedrooms rather than reduce energy consumption. The improvement in living conditions conferred significant health and wealth benefits on those living in previously very cold homes.

Consistent with this, analysis by Saddler (2013)[11] suggests that household insulation programs in Australia also had a very minor effect on electricity consumption over recent years (although, in the Australian case, it did slightly reduce overall consumption). However, it is important to recognize that these studies were primarily of low-income households that were *retrofitted* with insulation. It is unclear as to whether these results can be extrapolated to the general population of houses, many of which were constructed with adequate insulation, and by a higher-income demographic.

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8 According to McChesney, Cox-Smith and Armitrano (2008), insulation of new houses had commenced well prior to 1978, and at the 1976 Census, some 300,000 homes had some form of wall and/or ceiling insulation, a third of homes at the time. That said, the level of insulation would largely be considered inadequate under the current building standards.

9 Cost Benefit Analysis of the Warm Up New Zealand: Heat Smart Programme - Final Report October 2011 - Arthur Grimes, Tim Denne, Philippa Howden-Chapman, Richard Arnold, Lucy Telfar-Barnard, Nicholas Preval and Chris Young - http://www.motu.org.nz/files/docs/NZIF_CBA_report_Final.pdf

10 A Cost-Benefit Analysis of an Insulation Retrofit to a Southern New Zealand State House - T.N. Taylor and C.R.(Bob) Lloyd - http://solar.org.au/papers/03papers/Taylor.pdf

11 Saddler, H (2013) "*Powering Down*", The Australia Institute

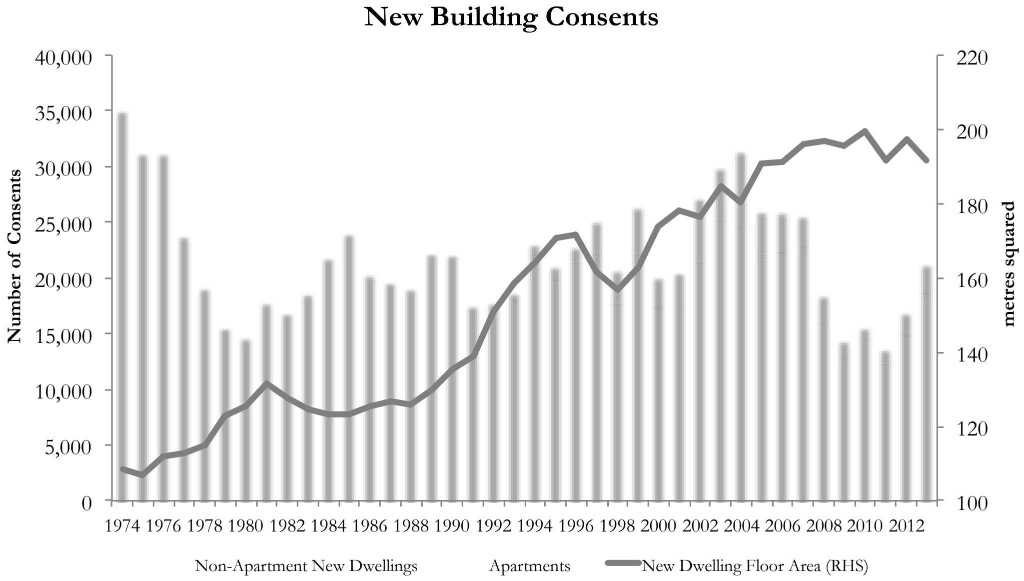

Figure 6 - New Dwelling Consents in NZ 1974-2013 (Statistics NZ)

Over the period since insulation standards were introduced, we progressively built larger and larger houses (Figure 6). House sizes have been generally increasing, with some fluctuation, for at least the last 38 years.

Since 1976, we have nearly doubled the floor area of new dwellings[12] (see Figure 6 above). The volume-weighted average area of dwellings added since 1976 is 156m². We might speculate that the average house size in 1976 was less than 100m², meaning we have increased the average floor area of our overall housing stock by at least 25-30% over this period.

Although there is some evidence to suggest that this effect may have reached a zenith.

One potential driver of this is the growth of apartments, especially in Auckland. Over the period 1996 to 2006 the number of apartment dwellers in New Zealand almost quadrupled to 19,020. 70% of this growth occurred in Auckland[13]. The growth in floor area in Figure 6 includes the effects of apartments. Apartment sizes averaged 90-100m2 over the period 2007-2013. Apartments are likely to have disproportionately better thermal efficiency than an equivalent standalone house, due to the presence of common walls with other apartments, but this may be offset with poorer natural lighting and solar gain. As apartments have accounted for, on average, 12% of new domestic dwelling consents over the past 10 years[14], this may be a significant effect, especially in Auckland.

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12 Note that these figures pertain to consents issued, rather than dwellings constructed, but we expect the difference in general trend to be immaterial

13 Apartment dwellers: 2006 Census – Statistics New Zealand

14 We acknowledge that apartment consent numbers may not correctly represent the number actually built, especially during the period of the global recession. But they are still a substantially more significant feature

The net effect of thermal efficiency and floor area on heating is unclear. The US Residential Electricity Consumption Survey[15] reports that, in the US, a 30% increase in the floor area of *new* homes since 2000 (compared to homes built prior to that) has only led to a 2% increase in space heating consumption[16], due to the space heating requirements of the new homes being 21% lower than those built prior to that period[17]. They attribute this to "improved energy efficiency of heating equipment along with better window design and insulation to more effectively seal homes, although some of the decline is associated with population movements towards warmer areas". The same could potentially be said of New Zealand, with a population drift to Auckland reported above, although our increase in floor area has been much more significant (around 60% since 2000, compared to homes built prior to 2000)[18].

While exact conclusions are not possible, it does appear that:

- The heating requirement, resulting from our aggregate choice to build bigger houses (proliferation), is likely to have been substantially met by better thermal insulation (efficiency).
- Part of this may be only a feature at the aggregate level, due to an increasing number of apartments, and the non-linear relationship between heating requirements and floor areas.
- Evidence suggests that retrofitting insulation to older homes is most likely to result in little change in energy consumption, as the homeowner enjoys an increase in their standard of living through warmer indoor temperatures. This is an increase in efficiency, but not one which reduces electricity consumption.

In terms of the efficiency of heating appliances, heat-pumps are being increasingly installed and supported by programmes such as EECAs Warm Up NZ programme. In many cases heat-pumps will be offsetting less efficient sources of electrical heating, but they will also be substituting for other fuels (particularly wood and coal burners). Again, the net effect is not clear.

of the domestic building portfolio than they were in the period prior to 2000, when they averaged 5% of consents in the 1990s

15 Available from http://www.eia.gov/consumption/residential/

16 http://www.eia.gov/todayinenergy/detail.cfm?id=9951

17 For this reason we would approach BRANZ information on the energy requirements of a home with great caution. The Household Energy End-use Project (HEEP) collected data over 1999-2005. The US data shows how out-of-date this information might be.

18 That said, American homes are historically much larger than in New Zealand, so were starting from a higher base. The average American home built in 1976 was 148m², compared to 112m² in New Zealand

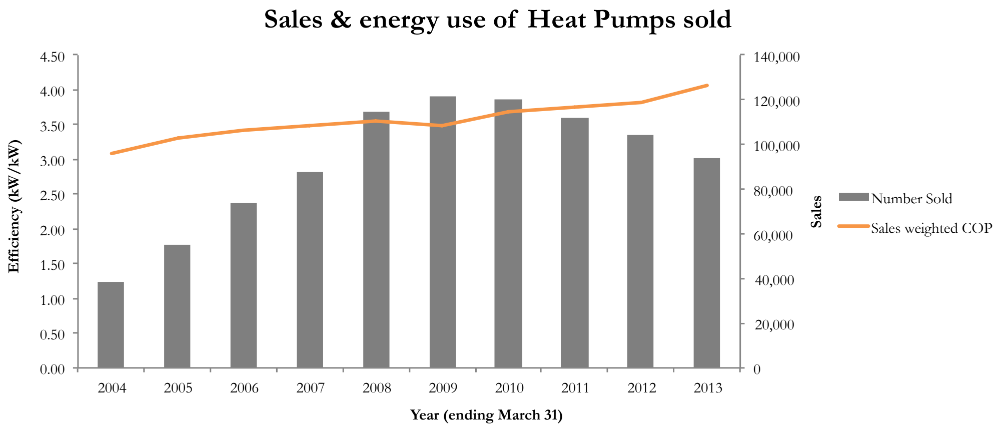

Figure 7 - Sales and consumption of heat pumps sold in NZ 2004-2013 (EECA)

2.3.2 Appliances and Electronics

New Zealand is a participating jurisdiction in the Council of Australasian Government's National Strategy on Energy Efficiency (NSEE). New Zealand has implemented some aspects of NSEE directly, such as appliance labelling and building codes, and the phasing out of incandescent light bulbs.

Other aspects of the NSEE are likely to affect New Zealand indirectly even if they are not mandated. This most notably relates to the availability of appliances and other equipment, given that Australasia is a single market for these goods.

NSEE was first established in 1992. The first Minimum Energy Performance Standards (MEPS) for appliances in New Zealand were introduced for residential (refrigerators/freezers, and electric water heaters), industrial (three phase electric motors) and commercial (fluorescent lamp ballasts) appliances and equipment in 2002[19]. Minimum Energy Performance Labelling (i.e., Energy Rating) was introduced at the same time.

As a result, efficiency labeling is now commonplace in the major energy-using appliances in the household. While MEPS will strongly influence the products imported into New Zealand, similar performance standards in bigger countries will actually be driving the technological advancement process itself.

General Appliance Replacement and Proliferation

There is plenty of evidence of significant improvements in energy efficiency both in the home and in electrical appliances, and we will outline this below. However, Figure 8 shows that there has also been a significant increase in spending on electrical appliances, and that (unlike overall retail spending) continued relatively unabated by the global recession.

[19] Energy Efficiency (Energy Using Products) Regulations 2002

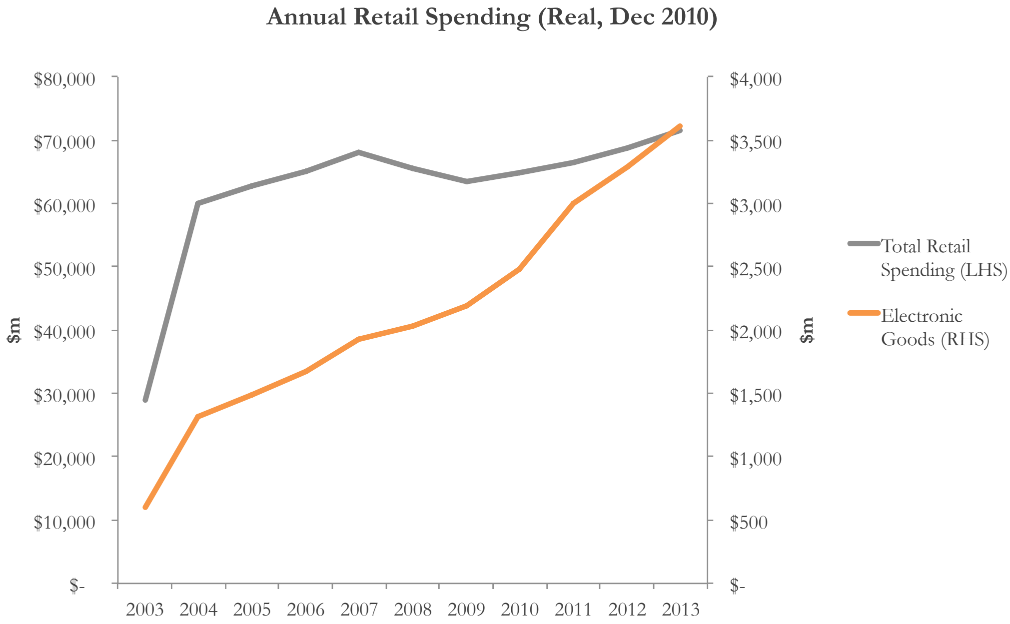

Figure 8 - Annual Real Retail Spending in NZ ($m) - Statistics NZ

Most electrical goods have reduced in price at least in real terms over the past decade. A large part of this has been the 20% appreciation in the New Zealand dollar over the same period[20], but even internationally competition, technological advancement and innovation has driven the cost of appliances down significantly.

According to Statistics NZ, the average cost of an LCD TV dropped from $3,500 in 2004 to $1,400 in 2008 (in nominal dollars). US data suggests that refrigerator prices have dropped 30% in real terms since 1999[21]. Overall, Statistics NZ's basket of home appliances has dropped 10% in real terms since 1999[22].

Together, this makes the seven-fold increase in electrical good spending in the last decade an impressive commentary on proliferation. Little public data is available in New Zealand on the household landscape today, but the US Residential Energy Consumption Survey (RECS) reports:

- *Appliances and Electronics now make up 31% of household consumption (compared with 17% in 1978)*
- *43% of households now have more than 4 rechargeable devices (8% have more than 9).*

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20 Real Trade-Weighted Index, Reserve Bank of NZ

21 Presentation by Ana Maria Carreno, CLASP, December 2012

22 http://www.stats.govt.nz/tools_and_services/newsletters/price-index-news/apr-13-article-chores.aspx

- *In 1978, most households had only one television. In 2009, the average household had 2.5 televisions. Over 45 percent of homes have at least one television with a screen size of 37 inches or larger.*

- *DVD players and Digital Video Recorders (DVR), which did not exist 15 years ago, are now widespread. As of 2009, 79 percent of homes had a DVD player, and 43 percent had a DVR*

- *Set top boxes and gaming consoles are other examples of devices that did not exist 15 years ago but are now common.*

Televisions

Television has been around for a comparatively long time – since 1920 in limited numbers but increasingly until it has become ubiquitous. The energy hungry and large Cathode Ray Tube has been the normal technology for most of that period. The CRT has been rather quickly replaced by flat screen TVs. This began with plasma TVs, typically larger and more energy hungry. However, more recently LCD screens and LED screens have significantly increased the energy efficiency of TVs[23].

New Zealand had 1.93m TVs in 2003[24] (1.5 per household). This is broadly consistent with the RECS survey 6 years later in the US. In that survey, households had on average 2.5 TVs and the largest proportion of TVs (44%) were still CRT with LCDs a close second at 40%.

However, it is likely that a general move to digital TV and the phasing out of analogue (concluding in December 2013) will have increased the uptake of high-efficiency LCD televisions. Statistics NZ report about 300,000 per annum "in recent years", while EECA reports 417,000 sold in 2013. It is not hard to believe that TV sales over the last 5 years was equivalent to one for every household in New Zealand. Those sold in 2013 had a sales weighted annual energy consumption of 128kWh, with most rated at greater than 6 energy stars and therefore likely to be highly efficient LCDs.

Again, we have to make assumptions to estimate the net effect:

- Assume that in 2003, our 1.93m TVs were made up of 90% CRTs and plasmas, with an average annual energy consumption of 250kWh[25], and 10% LCDs, with an average consumption of 125kWh. Together, these would consume 475GWh per annum, or 4% of residential consumption at the time.

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23 Reliable historical data on the energy consumption or CRTs, plasmas and LCD TVs is difficult to come by. A variety of web-based estimates suggest that Plasma TVs were approximately twice the consumption of a CRT at the time they were introduced, but were much larger screens. LCDs were approximately half the consumption of a CRT when they became mainstream.

24 http://www.nationmaster.com/country-info/profiles/New-Zealand/Media

25 In 2005, US figures indicate that more than half the number of TVs *sold* were over 200kWh. Hence an assumption that the stock averaged 250kWh is entirely plausible. From National Resource Defence Council report on Televisions.

- Between then and now, we have reached 2 TVs per household (3.2m TVs). All new TVs are LCDs/LEDs and 1.5m CRTs (and perhaps plasmas) have been replaced by LCDs. Increases in the efficiency of LCD TVs has been offset by larger screen sizes. This would result in 427GWh per annum being consumed by televisions, a net reduction of ~50GWh.

While these are somewhat hypothetical numbers, they illustrate that under some plausible assumptions proliferation is more than offset by efficiency.

Standby

International efficiency standards have drastically reduced the standby consumption of appliances. In the middle of the last decade, Lawrence Berkeley Labs reported that the standby consumption of a typical TV was between 20 and 50 watts. However, on 6 January 2010 the European Commission (EC) Regulation No 1275/2008 came into force. The regulations mandated that "off mode" and standby power for electrical and electronic household and office equipment shall not exceed 1 watt. While we acknowledge that it takes some time for appliances that met these standards to infiltrate households and businesses, due to the short replacement cycle outlined above, and the fact that major manufacturers are likely to have moved in advance of these regulations, the standards are probably now having an appreciable effect.

Mobile Devices

Manufacturers have strong commercial incentives to improve energy efficiency for mobile devices. For mobile and portable devices consumers are demanding ever more powerful devices with expectations of increasing battery life. While the incentives are not as strong, influences such as increasing energy efficiency regulation, branding and social responsibility means it is likely manufacturers will be increasingly use the advanced energy and power management technology in static electronics, including battery chargers.

The mobile revolution drives other technology change as well. Already most new watches are solar powered and will never need a battery change. Such recharging and energy recovery techniques are also being developed for mobile phones, laptops and tablets. There is talk of recharging small appliances using solar panels designed into clothing. There are already solar charging devices available and a plethora of solar powered devices available. Few would now wire in garden lights, for example.

The proliferation of small devices has been very dramatic but the energy efficiency, generation and recovery developments have also been dramatic. It seems likely that proliferation will probably slow before the energy efficiency gains. Although, if small devices up to even small laptops can become energy self-sufficient, not beyond the bounds of credibility, then proliferation won't affect conventional energy consumption anyway.

2.3.3 Refrigerators and water heaters

As outline in the previous section, proliferation is one side-effect of the increase in affordability ushered in by low prices. Crucially relevant to the efficiency of the home is the rate at which appliances are replaced with newer versions – "life-cycling". Historically the lifecycle of electrical appliances was quite long. Even small appliances were relatively expensive and were expected to last a long time. The development of plastics, in particular, helped change this paradigm somewhat as appliances became cheaper and replacement could occur more often. However, building the mechanical and structural components of devices cheaper doesn't necessarily mean they are always more energy efficient, but it does mean for many appliances the lifecycle is now quite short and energy efficiency benefits can roll out quite quickly.

Historically the household appliances with the greatest energy consumption have also been those with the longest lifecycles – water heaters and refrigerators. Both these items have, historically, been very expensive with long lives and therefore have not been replaced very frequently. To an extent, though, both of these appliances have been through an energy efficiency generation well before other appliances. Post the oil shocks of the 1970s and a trend of generally increasing energy costs from that period on the two largest appliances in the home received attention. There was significant effort over the 1980s in particular to improve the plumbing on hot water systems (ensuring no leaks), install larger and better insulated cylinders, install line tempering valves, cylinder wraps and lagging. On refrigerators seals were replaced and there was a general replacement with far more compact and efficient models. However, these new appliances were still expensive and were expected to last a long time.

Nevertheless, significant gains in the efficiency of refrigerators seems to now be having a marked effect on consumption – the average (sales-weighted) consumption of a new refrigerator in NZ has dropped 25% since 2002 (Figure 9). But compounding this improvement is the rate at which we have absorbed those efficiency improvements into our homes: nearly 2m refrigerators have been sold over the same period (1.3 for every household). This must have almost replaced the entire refrigerator stock.

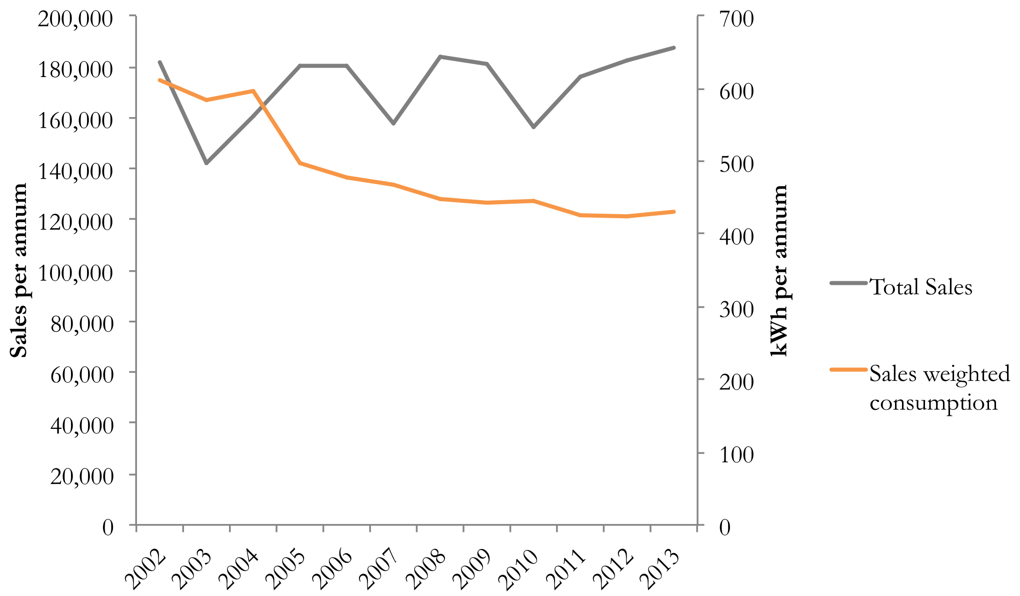

Figure 9 - Refrigerator sales and consumption, 2002-2013 (EECA)

Conservatively assuming that:

- The entire stock of refrigerators in 2002 had 1.5 times the average efficiency of a new refrigerator at that time (1200kWh per year), refrigerator consumption would have equaled approximately 1700GWh at a rate of 1 refrigerator per household. This would have made up 15% of household consumption, in line with the BRANZ estimates.

- That this stock was replaced at the average efficiency of new refrigerators over the period 2002-2012 (488kWh), even allowing an increase in ownership to 1.3 per household, total consumption from refrigerators would have dropped 724GWh to 976GWh.

These assumptions are illustrative, but not unreasonable, indicating that the life-cycling of refrigerators could have reduced household demand considerably, even in the face of some increased proliferation. Since there is still a 14% gap between our assumed volume-weighted efficiency, and currently available efficiency, more efficiency gains are possible.

We are aware that heat-pump technology for water heating is imminent. We have not reviewed the technology in detail, but, given that hot water accounts for ~30% of household consumption[26], the significant efficiency improvements afforded by heat pumps could significantly decrease household consumption.

2.3.4 Lighting

The Compact Fluorescent Light bulb (CFL) – with energy savings of over 50% - is now relatively mainstream technology. Once considered economic, the in-service stock of incandescent bulbs (with a much shorter life) can be replaced very quickly, especially if there is an explicit assistance to overcoming consumer conservatism and capital constraints (which occurred in New Zealand with EECA's incandescent bulb replacement subsidy). In many other countries incandescent light bulbs have been effectively banned.

At the same time, lighting has proliferated over the past decades. Older houses would typically have a single globe in each room; now rooms may have more than a dozen ceiling-mounted lights. Over a period from (say) the 1980s to the introduction of CFLs, we would have expected proliferation to overwhelmingly dominate. But proliferation has a natural limit – there are only so many bulbs that can be installed in a room. As proliferation reaches its limit, the additional efficiency gains proffered by Light Emitting Diodes (LEDs), with further energy savings, will have a more substantial effect. The difficulty here is that the three phases – proliferation, transition to CFL, and transition to LEDs – are all overlapping, and different parts of the housing stock are at different phases. Some households may even skip the CFL phase altogether, and move straight to LEDs.

Canadian data suggests that 27% of light bulbs in residential homes in 2010 were CFLs. This has led to a 21% reduction in the electricity use per household for lighting[27].

New Zealand statistics on lighting are frustratingly thin[28], and offer no help here. EECA has only collected sales statistics for CFLs for 2013 (2.6m sold), and suggest that this was a

[26] Energy Use in NZ Households, Report on the Year 10 Analysis for the Household Energy End-use Project, BRANZ.

[27] Energy Efficiency Trends in Canada, 1990-2010, Office of Energy Efficiency, Natural Resources Canada.

market share of 27% of sales[29]. One data point is insufficient to base any assessment of the absorption of CFLs into NZ homes. Even the Canadian statistic of 27% *in situ* is now four years out of date; although it may point to more rapid uptake in the last 2-3 years, when we have observed falling per-household demand.

A 10%-15% replacement rate (per annum) – of incandescents with CFLs – does not seem implausible, given the 27% market share figure. Under this scenario, given the potential savings from CFLs (75%) and their role in household consumption (12%), a 0.9% - 1.3% per annum reduction in household demand due to lighting alone is possible.

Now, LEDs – even more efficient again – are starting to become widely available, although their uptake could be slower due to the longevity of the CFL. Notwithstanding that, it is a plausible scenario that LEDs will all but replace CFLs over the next 5-10 years.

2.3.5 Electric Vehicles

Electric vehicles (EVs), including plug-in hybrids (PHEVs) are now readily available in New Zealand. While the current uptake is – at best – nascent, these could prove to add significant consumption to a household which has one, and therefore are worthy of consideration when taking a forward looking view.

The intensity of EVs ranges between 150W/km[30] and 240W/km[31]. On average, New Zealanders drive over 12,000km (per car) each year[32]. We would reasonably expect that, due to limited range, that the average range driven in an electric vehicle might be lower. Should we assume this to be 10,000km, the annual consumption of an EV would be between 1,500kWh and 2,400kWh. Clearly, this would be a substantial increase in an average household's consumption

However, we are at a very early stage of EV vehicle uptake. A study undertaken by Sapere for another client modeled EV uptake in New Zealand. Under a best case scenario, this presented an aggressive target predicated on possible interventions which resulted in an uptake which reached 33,000 vehicles by 2020. The impact on average residential usage – approximately annualized at 0.13% per annum - is illustrated in Table 1.

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[28] We find this remarkable, given they were an early focus of government efficiency campaigns over the last decade.

[29] http://www.scoop.co.nz/stories/BU1308/S01104/energy-efficient-light-bulb-sales-on-the-rise-in-nz.htm. We note that, together with the EECA sales numbers, it suggests that 10m bulbs were sold in NZ in 2013, which appears extraordinarily high for the residential sector alone

[30] Nissan Leaf, see http://www.nextgreencar.com/view-car/45426/NISSAN-Leaf-Electric-Car-80kW-Auto-Electric-%28av-UK-mix%29

[31] Range for Mitsubishi Outlander, see http://www.mmnz.co.nz/plug-in-hybrid/options/4wd-hybrid-specifications/

[32] The New Zealand Vehicle Fleet: Annual fleet statistics 2013, Ministry of Transport, February 2014

Year	Cars	Consumption (GWh per annum)	Percentage of residential demand	Effect on average household demand (kWh/household)
2015	1,500	3.75	0.03%	2.3
2016	3,800	9.5	0.08%	5.8
2017	7,300	18.25	0.15%	11.2
2018	12,500	31.25	0.26%	19.3
2019	20,400	51	0.43%	31.4
2020	33,000	82.5	0.69%	50.9

Table 2 - Impact of EV uptake on average residential demand

In the MBIE's Energy Outlook: Electricity Insight, MBIE have modeled uptake of EVs in a "Global Low Carbon" scenario. Here, MBIE assume:

"…electric vehicles do eventually become economic, with over a quarter of new car sales assumed to be electric in 2030, increasing to over 40% of new cars by 2040. Under these assumptions, electric vehicle electricity demand accounts for 3% of total electricity demand in 2040."

3% of total electricity demand approximately equates to 9% of residential demand. At current per-household residential demand, this equates to ~660kWh. Hence, EVs have the potential to return per-household demand to its historic average of 8,000kWh, but not until 2040.

Based on these projects, we do not believe EVs are a material driver of increased per-household consumption within the next 5 years.

2.3.6 Solar PV

Solar PV has played a significant role in the reduction in electricity demand in Australia – approximately 4,000GWh of an overall 11,000GWh decline in demand since 2007 is attributed to solar installations.

In New Zealand, solar PV is yet to reach this level of penetration. There are a number of differences between New Zealand and Australia:

- The Australian rollout has been heavily subsidized by federal programs
- Australia has a significant solar resource
- Australian wholesale prices are more correlated with solar resource (i.e., peak prices often occur mid-afternoon). Insofar as this profile correlation makes up the business case from the customer's perspective, the volume-weighted average price effects will be superior.

The Sustainable Energy Association of NZ have reported a 370% increase in solar installations over the last two years, to 50 installations per week as at the end of 2013. While the full survey is not available, SEANZ did report publicly that 77% of these installations were on-grid[33].

Electricity Authority data suggests there are currently 2,500 residential installations of solar[34]. With an average 2.5kW average installation, and 14% yield, this would currently account for around 8GWh per annum of substitution from grid-sourced power. Looking forward, if SEANZ's installation rate persists, and additional 7.6GWh per annum would be substituted (equivalent to 0.02% downward pressure on demand).

We have not verified installation costs in NZ. One solar installer quotes an "average installation" of 2.5kW costs around $6,500. At current mortgage rates and retail prices, this implies a 10-12 year payback[35].

2.3.7 Prices, Income and Wealth

Traditional economic theory suggests that there is an "elasticity" to consumption based on the economic structure of the decision to consume. Typically it is assumed that the primary response is to the electricity price, and the literature is replete with attempts to estimate what the short, medium and long term elasticity of consumption with respect to the retail price is[36].

Prices

Retail electricity prices are highly political and have received some attention in the last 2-3 years. A consumer response to prices which have grown, in real terms, 41% since 2002 (88% nominal) is a plausible explanation for a reduction in demand growth (Figure 10).

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[33] http://www.nzherald.co.nz/business/news/article.cfm?c_id=3&objectid=11185248

[34]http://www.emi.ea.govt.nz/Reports/VisualChart?reportName=GUEHMT&categoryName=Retail&reportGroupIndex=4&reportDisplayContext=Gallery#reportName=GUEHMT

[35] Ibid

[36] Specifically, price (income) elasticity is the percentage change in consumption for a percentage change in price (income). Various studies suggest that the long-term price elasticity for electricity is between -0.3 and -0.7. See Fan and Hyndman, 2010, "*The price elasticity of electricity demand in South Australia*", for a good summary of the international literature

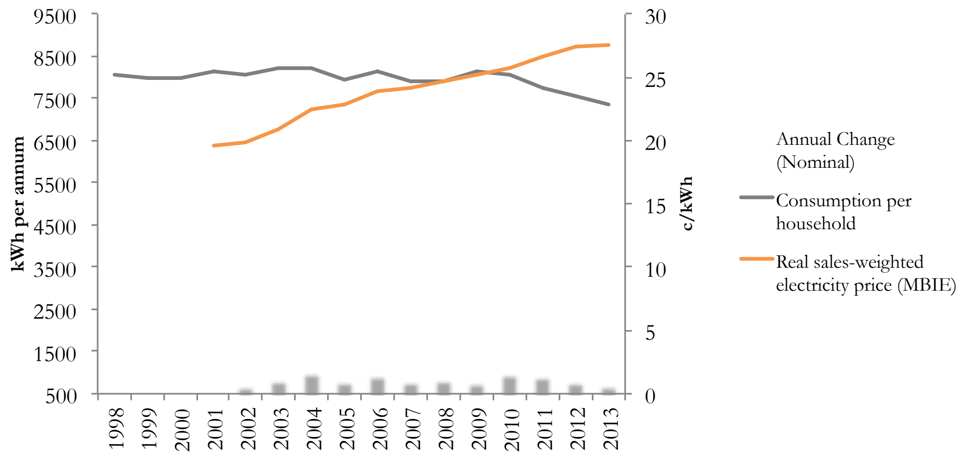

Figure 10 - Retail Electricity Prices and Consumption per Household 1998-2013 (MBIE)

Further, it appears that years with the greatest nominal price changes (2004, 2010 and 2011) were followed by a reduction in average household demand, lending weight to the "bill shock" behavioural response (Figure 11). While this may explain temporary consumption responses, it is not clear whether these bill shocks persist by permanently reducing consumption, or whether consumption gradually returns to trend as the memory of the shock fades.

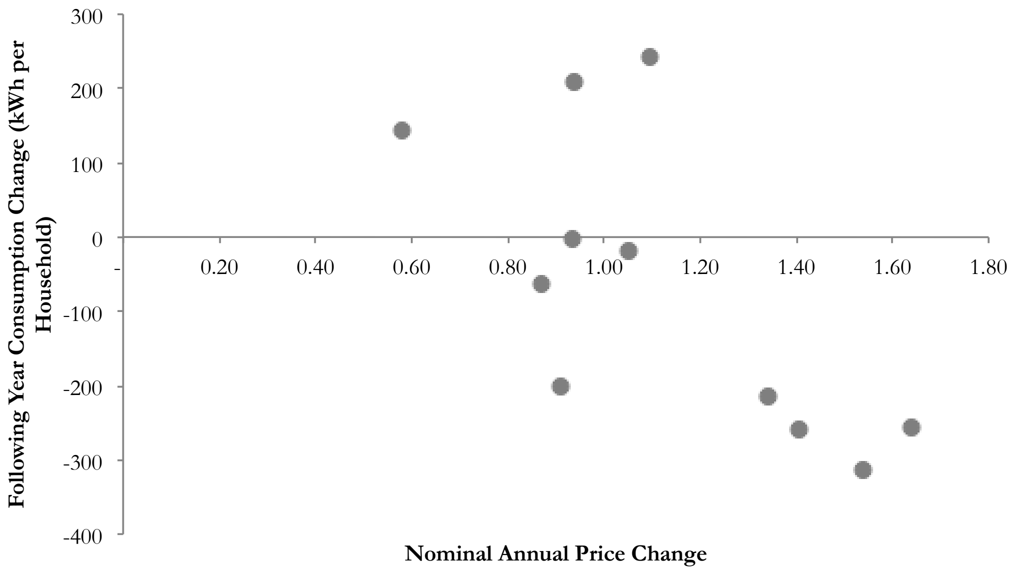

Figure 11 - Lagged consumption change vs Nominal Price change (MBIE)

We also note that price shock is only one driver of a consumer reaction. Generally speaking, electricity is a low engagement product. However, public consciousness of prices and bills can be triggered by retailer acquisition campaigns and switching, the political and media spotlight on the industry (especially retail) and conservation campaigns resulting from dry years. All of these events have been a feature of the last 6 years, and bring electricity more firmly into the householder's consciousness. Commensurately, opportunities for conservation and efficiency will be considered.

It is tempting to conclude from Figure 10 that the period 2009-2013 confirms the presence of a traditional "elasticity", i.e., that rising prices led to reducing consumption. Consumption per household dropped 10% over a period where prices rose 9%. While this elasticity is at the upper end of those reported in international studies[37], it naturally begs the question as to why consumption stayed static over the previous period, when prices experienced a 28% rise.

Incomes

The householder's response to a change in the retail price cannot be considered in isolation of their economic context – income, purchasing power, and more broadly, wealth:

Firstly, a rise in retail prices may not trigger a consumption response if incomes increase at the same rate or faster. Over the period 2002-2013, nominal average household incomes rose nearly 45%. While this was still less than the nominal retail price rise, combined with the gradual reduction in average household electricity consumption, it meant that average household expenditure on electricity only grew from 2.26% of average income, to 2.45% of average income[38] (**Figure 12**).

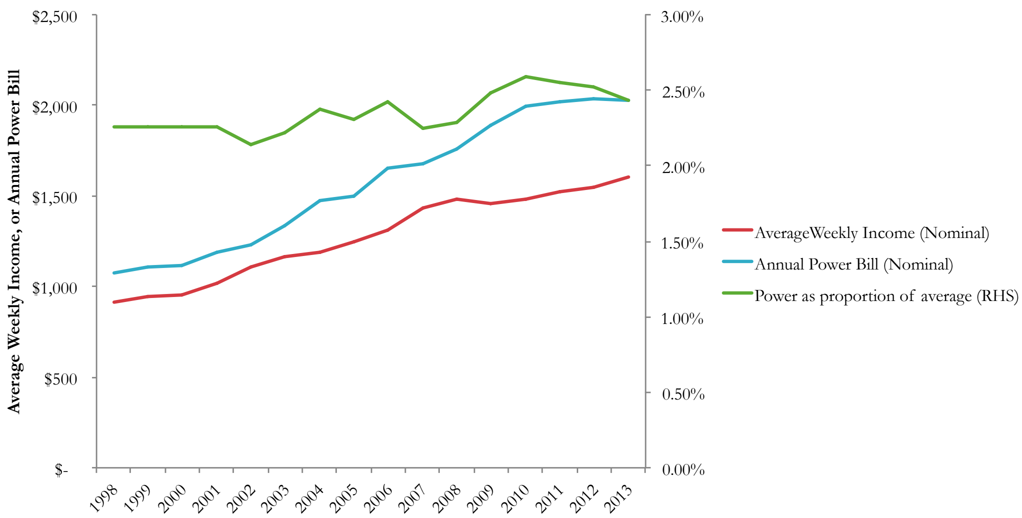

Figure 12 - Average Weekly Income, Annual Power Bill and Power as a Proportion of Income (Statistics NZ, MBIE)

The response of electricity consumption to changing incomes is complex. Holding price constant, greater levels of income may lead to greater consumption, either through direct additional consumption (e.g., more heating on colder days), but also through the affordability of a greater number of appliances and other electricity-consuming devices. However, in

[37] Ibid

[38] Statistics NZ data suggests that Auckland experienced a greater proportional increase than the national average, but this is for household *energy* costs, rather than electricity alone. However, this might (partly) explain why Vector's per-household consumption displays a greater decreasing trend than the national average.

recent times, the same argument applies to the replacement of existing appliances, which, as discussed above, may usher into the home a greater level of electricity efficiency. Intriguingly, the chart above shows that average household power expenditure has decreased as a proportion of income over the period that per-household consumption has decreased. This is somewhat a chicken-and-egg problem, for which there are a variety of possible explanations:

- The reduction in consumption (conservation) may have come about due to the income constraint being hit in 2010, or
- Consciousness of power price rises triggered investments in higher-efficiency appliances which have had a consequential effect on consumption, or
- Factors unrelated to price have triggered the downward trend in consumption, e.g., the desire to renew appliances.

Haas and Schipper (1998) considered the effect of energy efficiency on elasticity of consumption. The authors show that, once household investment in "energy efficiency" (new appliances, insulation, fuel switching etc) is explicitly modelled, price elasticity failed to feature as a significant variable. This reflects the "irreversibility" of investment decisions and the asymmetric effect inherent in elasticity; prices rises may trigger investment in energy efficiency, but price reductions don't result in people reversing their investment decisions. The efficiency impacts on consumption are permanent, irrespective of the future direction of price.

However, in their model, income elasticity then became very significant. Their conclusion is that electricity consumption is far more responsive to income, and its commensurate ability to fund the purchase of new/alternative appliances (which in turn has an indirect impact on electricity consumption).

Haas and Schipper's analysis reveals the importance of income elasticity, but did not incorporate the additional purchasing power of income which comes about through falling appliance prices. As outlined above, many of our energy-hungry devices are not only more efficient, but also substantially cheaper. Hence the combined effect of greater incomes, lower appliance costs and greater efficiency on consumption might be negative overall – for a period.

One Australian analysis studied price and income elasticities over the period 1970 and 2012, and found a "structural break" in income elasticity in 2005. At this break point, income elasticity dropped from 1.0 to 0.3, i.e., prior to this point, a 10% increase in income led to a 10% increase in consumption, whereas after 2005, a 10% increase in income only led to a 3% rise. A similar breakpoint (and reduction) in the 1980s was found for price elasticity. The authors posit that the price elasticity reduction was due to the start of the proliferation of energy intensive appliances (air conditioners, dishwashers), but have no explanation for the breakpoint in income elasticity[39]. We would suggest that it reflects a point where income and purchasing power driven life-cycling drove efficiency gains which offset proliferation.

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39 They do suggest that the uptake of distributed generation – especially rooftop solar, which has grown from nearly zero in 2006 to 4,000GWh in 2013 – has partly offset the drop in income elasticity. That is, rather

Wealth

Finally, this discussion would not be complete without mentioning wealth. Beyond income, New Zealand home-owners (and particularly Aucklanders) have enjoyed over a decade of rising house prices. The resulting equity growth, combined with low interest rates, has led to a substantial increase in housing investment. Notwithstanding the fact this has led to an unprecedented level of household indebtedness, net household wealth has grown remarkably over the first decade of the 21st century.

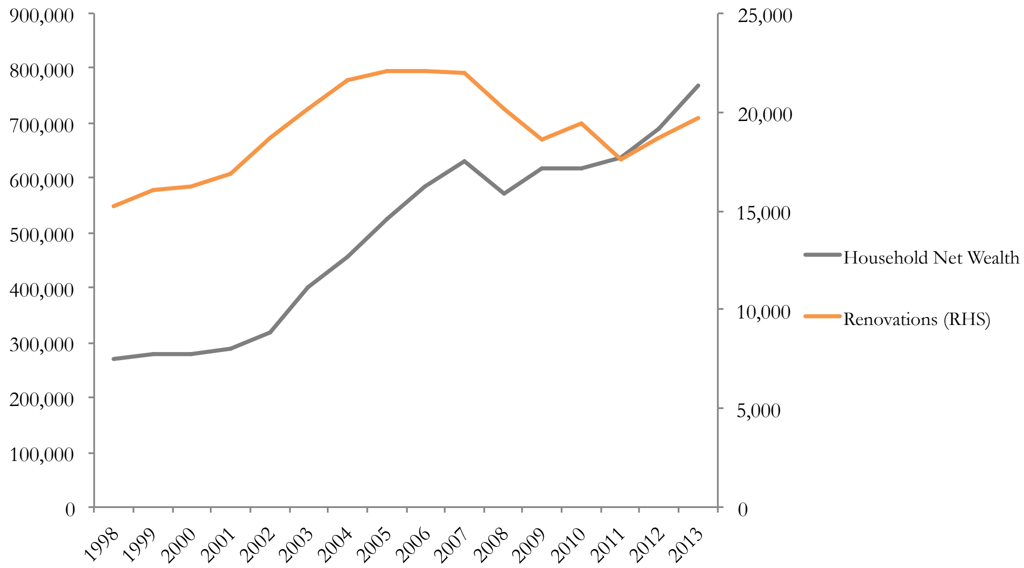

Figure 13 - Household Net Wealth vs Altered Building Consents 1998-2012 (Reserve Bank, Statistics NZ)

Some of this wealth has been leveraged into renovations. Figure 13 illustrates that, for at least the period 2000-2005, the growth in housing wealth was mirrored by an increase in consents for altered residential buildings (a proxy for renovations). Renovations are typically an opportunity for purchasing new appliances, heating options, lighting and bringing older houses up to post 1978 insulation standards (or higher). Further, they can make better use of solar gain and improve thermal efficiency through glazing.

Summary

There is not time in this paper to review the enormous – and sometimes contradictory – literature on the price and income elasticity of demand. Irrespective, this discussion highlights that prices, income and wealth are relevant, and highly interconnected.

It is likely that increasing prices over the past 10 years led to a budget constraint effect, and that this effect played a role in reducing per-household consumption after 2007. However, looking forward, the impact of moderating prices on consumption is a complex interplay of

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than reducing overall consumption, consumers have substituted away from grid consumption to on-site generation.

many factors. If we could isolate the effect of price, we expect a stabilized price would lead to a stabilizing effect. However, in reality, the impact of price needs to be considered in the context of a number of other highly inter-related variables, for example:

- It is possible that periodic price "events" trigger the consumption or investment response, but only if incomes (or, more correctly, the purchasing power of incomes) permit the investment in new technology. Further, it is not obvious that the consumption response persists, or rebounds.

- Further, the response to price takes place in the context of a broader consumer consciousness – switching campaigns, the political spotlight, and hydro conservation campaigns – which all bring the cost of electricity, and opportunities for conservation and efficiency into the public consciousness. Hence a view on future price changes is inadequate to predict future consumption response.

- Income and wealth-driven renovations further accelerate the introduction of efficiency through new technology. Moderation of electricity prices, along with rising incomes, may – at the margin – incentivize *greater* investment in new appliances (perhaps for reasons other than reducing energy consumption), as these appliances become more affordable.

- The consumption response via technology investment is permanent (since the investment is irreversible), and behaves less like a symmetric response that the traditional elasticity arguments suggests. Consequentially, the argument that price reductions (in the limit) lead to increased consumption suggests that householders have been *withholding* consumption (i.e., conserving energy) as a result of high prices. While we accept that this is possible in some situations, we do not believe this is likely to be material at an aggregate level.

Hence there is an equally plausible scenario where, under price moderation (or, in the limit, price reductions), consumption per household continues to fall as a result of the reasons proffered in the rest of Section 2.2, i.e., that, due to rising incomes and wealth, falling appliance prices, and increasing efficiency, uptake of appliances (including lighting) continues, and continues to dominate proliferation.

3. Future Predictions

Unpacking why per-household consumption has fallen is complex. From even a cursory consideration of the drivers we have considered, it is clear that there are many factors, and they are often highly inter-related. For example, the growth in wealth arising from the increase in house values has driven renovations, at which time home owners make appliance and building envelope decisions.

We have presented an argument that residential consumption has declined due to a complex dynamic between affordability, proliferation, life-cycling, technological advancement and efficiency. The general theme outlined above is that efficiency has "fought" against proliferation very dynamically. And the battle is a function of wider trends, fueled by factors such as technological advancement, increasing income, wealth, increased energy and environmental consciousness, retail prices and competition, and media scrutiny of the energy industry.

We have argued how this helps explain why residential consumption was so stable for so long.   The rate of technology advancement, coupled with a slow replacement cycle and few opportunities for proliferation, meant that this year's household consumption was highly likely to be the same as last years' (adjusted for weather) – nothing had changed.

This is illustrated in a simplistic way in Figure 14.

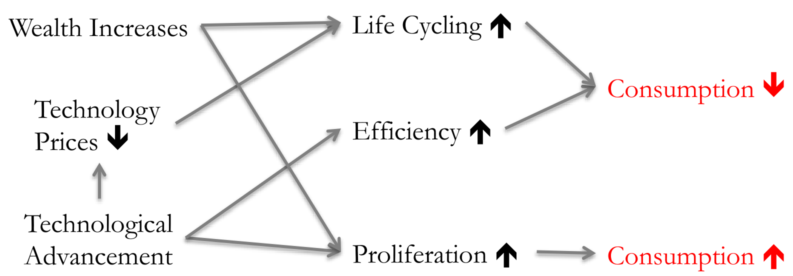

Figure 14 - Proliferation vs Efficiency Dynamic

Below we summarise the factors we have discussed above, and the likely trajectory in the future.

Factor	Historical Trend	Future Direction of consumption
Heating and building envelope	Improved building envelopes (thermal insulation, better solar gain) and improvements in heating efficiency have offset the increased heating need of larger houses. In insulation retrofits, householders have experienced an increase in warmth, rather than a saving in energy. It is possible that the average floor area of a new house has reached a	Flat

Factor	Historical Trend	Future Direction of consumption
	zenith, while there remain significant efficiency gains in e.g., heatpump efficiency which are likely to yet be absorbed by households.	
Lighting	Improved lighting efficiency (CFLs) has driven a reduction in lighting load. A single CFL represents a 75% reduction in lighting load compared to its incandescent equivalent. Under a 10%-15% annual bulb replacement scenario, this could reduce household consumption by 0.9%-1.3% per annum. Further, LEDs are now being introduced, which will drive even greater efficiency gains, albeit at a slower rate	Decreasing
Refrigerators	Refrigerator efficiency has increased substantially over the last 10 years, although appears to be levelling out. However, even the current available efficiency will take 5-10 years to be absorbed into the population, which allows for a further 14% reduction in refrigerator efficiency. As refrigerator consumption makes up approximately 15% of household load, we believe there is a ~2.2% efficiency gain over the next 10 years (0.2% annually assuming no further efficiency gains in technology), since we doubt that much more proliferation is likely.	Decreasing
Televisions	In televisions, energy hungry CRTs have all but been phased out due to the end of analog broadcasting. Some early generation plasma TVs have probably also been replaced by high efficiency LED/LCDs. Further, standby regulations have eliminated standby power in modern televisions. However, given the affordability, TVs have probably experienced the greatest proliferation	Flat

Factor	Historical Trend	Future Direction of consumption
	inside the home, which may have offset the efficiency gains.	
Water heating	We are aware that the next generation of heat-pump water heaters is likely to begin penetration soon. If they match the coefficient of performance of those used for heating space, this could hold potential to dramatically reduce water heating requirements.	Decreasing
Mobile electronics	Likely continued proliferation, partly offset by decreased energy requirements as technology provides seek better battery life through improved energy consumption. Possibility of solar charging.	Flat, possibly increasing
Electric Vehicles		Very small impact in the next 5 years

Table 3 - Summary of factors influencing household demand

On balance, the factors in Table 3 suggest a continued dominance of efficiency over proliferation[40], especially since the efficiency gains are being experienced in the most energy-hungry appliances, and proliferation in the small mobile devices. Even considering lighting and refrigeration alone, we suspect that **1.1-1.5% per annum net efficiency gains over the next 5 years are plausible** (in the context of 1.7% over the past 4 years).

This may be partly offset by the uptake of EVs, continued proliferation of electronics and the moderation of prices. However, we note:

- Under some ambitious uptake assumptions, EVs are like to only add 0.13% to demand growth over the next 5 years. This could, in turn, be largely offset by uptake of rooftop solar, which is estimated to be 0.08% at current uptake rates.

[40] Many of the questions about the future boil down to one key issue, for which we have little reliable data for New Zealand: How far through the transition away from 20th century technology are we? We have used reliable international estimates to proxy, but acknowledge this is an uncertainty in our analysis.

- While it has undoubtedly played *some* role, it is not clear the extent to which price rises alone have driven decline of residential consumption. Real electricity prices, as reported by MBIE, rose less than 1% in 2013, yet consumption continued its downward trend[41]. The impact of price on behaviour is a complex interplay of many variables, of which consciousness, income and wealth are important.

- The net effect of proliferation and efficiency on electronic devices is not clear, but it has not been sufficient to arrest a declining trend in consumption over the last four years. This is despite rapid proliferation occurring over that time, and prior.

We conclude that the direction of movement in average household consumption will continue to be downward for the next 5 years. We acknowledge that our analysis requires a number of assumptions. We believe these are plausible, but are frustrated by a paucity of relevant, current data on consumption inside the home.

That said, we certainly believe that our conclusions are no less plausible, and – in our view, more likely – than a view that EVs, moderating prices and economic output will completely offset the clear efficiency increases that are currently being absorbed into New Zealand households.

[41] Although weather played a role here too