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Review of electricity demand forecast model

Report to the Electricity Commission

8 September 2009

Preface

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NZIER was established in 1958.

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Executive summary

Under Part F of the Electricity Governance Rules 2003 (the Rules), the Electricity Commission (the Commission) is required to publish electricity demand forecasts as part of the grid planning assumptions that underpin the *Statement of Opportunities*. These forecasts inform decisions on new investments in transmission, generation and demand-side response.

The Commission's forecasting model has been reviewed and refined several times over recent years. Updating the forecasts in 2009 with Statistics New Zealand's latest population projections resulted in a significant jump in forecast electricity consumption. The Commission therefore asked NZIER to provide a high-level independent review of its electricity demand forecast model, focusing on the relationship between electricity consumption, gross domestic product (GDP) and population.

Given the strengths and weaknesses of the different methods for forecasting electricity demand, we agree with the Commission's use of the econometric method. This is generally the most suitable method for long-run forecasting and is widely used in other countries. More recently developed advanced modelling methods, such as neural networks, may provide more reliable and stable forecasts, but have the particular disadvantage of lacking the transparency required of the Commission's electricity demand forecasts under Part F of the Rules. This does not, however, preclude them being used to test the accuracy of the Commission's econometric models, if the Commission has sufficient modelling resources available for such a "multiple methods" approach.

NZIER's 2004 review of the Commission's electricity demand forecast model, as it was then specified, did not detect any substantial problems, omissions or errors in the Commission's methodology, but did make a number of suggestions for improvement and future development. We are satisfied that the Commission has addressed these suggestions to the extent feasible and practical, given the constraints it faces in terms of availability of data and the objective of simplicity and transparency of methodology. We endorse "sanity checking" the forecast model results against "naïve" forecasts, such as might be provided by the trend method, or testing their accuracy using more advanced modelling methods, such as neural networks.

In reviewing the relationship between electricity demand, GDP and population, we consider three aspects – the explanatory variables modelled as drivers of electricity demand, the functional form modelled as representing the relationship between electricity demand and these drivers, and the time period over which this relationship is derived from historical data.

The explanatory variables adopted by the Commission reflect the strong empirical relationship between these drivers and electricity demand and are commonly selected as the most significant explanatory variables in other countries. Potential alternative explanatory variables available from Statistics New Zealand include real private consumption, for residential demand, and real business investment and export revenue, for commercial and industrial demand. We find GDP to appear slightly superior overall. In determining long-run relationships, it is preferable to use as long a time series as available, reliable and technically valid. GDP is therefore particularly useful for the residential model which still uses historical data back to 1974, which is not available for the alternative explanatory variables. Should the Commission wish to explore further the use of the above alternative explanatory variables, it would be feasible to extend NZIER's existing forecasts of these variables to 2050. It would also, potentially, be possible to construct a model to "backcast" these variables to 1986 for commercial and industrial demand and 1974 for residential demand, although these would probably be derived from the GDP series in any case. We therefore do not consider it unreasonable for the Commission to continue using GDP.

We understand that, for each of residential demand and commercial and industrial demand, the Commission has tested a number of different functional forms, including linear, log, per capita, first differences and lagged dependent variable, and selected the model that performed best. This inevitably involved some compromise, such as between goodness of fit, stability and robustness to the common problems of multicollinearity, cointegration/non-stationarity and autocorrelation. The choice of functional form has also been constrained by the objective of simplicity and transparency of methodology. Although a common model structure across the three demand sectors would further this simplicity, we recognise that no one model structure performs well for all three sectors. We do not consider the selected model structures so different as to impede understanding. Nor do we consider their functional forms too complex, although the residential demand model, in using variables in log and per capita form, may be approaching the limits of what can be intuitively understood widely. We recommend that the Commission continue to verify the validity of the selected model by comparing it with potential alternatives at each future update. With the updating of data or introduction of further refinements to the model, which functional form performs best may change.

The question that prompted this review was whether the relationship between electricity demand, GDP and population has changed over the time period of historical data used to derive the coefficients for forecasting future electricity demand. If so, different starting points in regression analysis of the historical data can result in different values of these coefficients and therefore different forecasts.

We find the average ratio of residential demand to GDP to have differed significantly from other decades only in the 2000s, at the 95% level of confidence. We suggest that this may reflect consumer response over time to sustained rises in real residential electricity prices. We find the high negative correlation between real prices and the ratio of residential demand to GDP to be more pronounced in the 2000s, when prices were highest and the ratios of demand to GDP lowest. We find average residential demand per capita to have risen significantly with each successive decade, at the 95% level of confidence. This implies that regression coefficients representing the average relationship over the entire period 1974 to 2008 may underestimate future demand, even with use of the latest population projections.

Together, these two findings suggest that the relationships between residential demand and GDP, and residential demand and population, do appear to have changed somewhat over the past 35 years and particularly since 2000. We suggest that a structural break around 2000 is only now emerging, as sufficient years of data become available for the change in relationships to show as significant. The nine years of 2000 to 2008 would, however, be a short time period for robust regression analysis. We recommend that the Commission test the sensitivity of its regression coefficients to different starting points over 1974 to 2000, through Chow tests, for its 2009 update as it did for its earlier modelling, to determine the optimal trade off in length of time period.

The Commission has already reduced the time period for modelling commercial and industrial demand to 1986 to 2008 due to changes in electricity's share of total energy demand, which caused a structural break in the relationship between GDP and electricity demand. We find that the average ratio of commercial and industrial demand to GDP was significantly higher in the 1990s, but has fallen again since. It is now its lowest since before 1986. The average ratio for the 2000s is not yet significantly lower than in the late 1980s at the 95% confidence level, but is approaching the lower bound and is significantly lower than the average over the entire period 1986 to 2008.

This again suggests that a structural break around 2000 may be starting to emerge. It is too soon to tell if the ratio of commercial and industrial demand to GDP has stabilised or will continue its downward trend. We recommend that, until this becomes clear, the Commission continue to use the full period 1986 to 2008 for deriving coefficients to forecast commercial and industrial demand, but reassess this as further years' data become available.

We are satisfied with the approach adopted by the Commission of forecasting heavy industrial demand as remaining constant over the forecast period at the highest annual level observed to date. Although simple, this approach does not seem unreasonable given that the Tiwai aluminium smelter's demand has remained fairly constant over recent years and no major expansion or downsizing is expected. For a more thorough approach, the Commission could consider the option of adopting the approach followed in Covec (2006), which is based on the markets for aluminium, including price trends and competing production in other countries, as well as production costs and energy intensity at the Tiwai Point aluminium smelter. We do not consider it unreasonable for the Commission to retain its existing approach, however, given that this produces similar forecasts from a simpler model.

Contents

Appendices

Figures

Tables

1. Purpose

Under Part F of the Electricity Governance Rules 2003 (the Rules), the Electricity Commission (the Commission) is required to publish electricity demand forecasts as part of the grid planning assumptions that underpin the *Statement of Opportunities* (Electricity Commission, 2008a). These forecasts inform decisions on new investments in transmission, generation and demand-side response.

The Commission's forecasting model has been reviewed and refined several times over recent years, including a previous review by NZIER in 2004.

Updating the forecasts in 2009 with Statistics New Zealand's latest population projections resulted in a significant jump in forecast electricity consumption. The Commission therefore asked NZIER to provide a further high-level independent review of its electricity demand forecast model, starting with a brief review of the overall methodology, but focusing on the relationship between electricity consumption, gross domestic product (GDP) and population. The purpose of the review is to advise on whether the existing forecast model provides a reasonable reflection of the historical relationship between electricity consumption and its key drivers and whether there are any practical options for improvement available.

An important concern for the Commission has been to adopt a methodology that, whilst sufficiently robust for the purpose of informing decision-making, is also sufficiently transparent and accessible to stakeholders and the public for them to understand and have confidence in its forecasts. Review of the forecast model and any suggested improvements must recognise this constraint on the methodology's complexity.

2. Current forecast model

The Commission's electricity demand forecast model originated in forecasts developed by Transpower New Zealand Limited for its asset valuation process and long-run network planning. In 2004, the Commission replicated this model, tested it against alternative models and selected the preferred model (Electricity Commission, 2004a). In each of 2006 and 2008, the Commission updated the selected model, reviewed its performance and amended it accordingly (Electricity Commission, 2006; Electricity Commission, 2008b).

The Commission's forecasts of total electricity demand have five components:

- residential demand
- commercial and industrial demand
- heavy industrial demand
- distribution losses and
- embedded generation.

As well as point estimates, the Commission forecasts a range in demand to reflect the uncertainty in the model's inputs. It also forecasts peak demand, both expected and "prudent". Additionally, it estimates the distribution of its national forecasts by region and individual grid exit point.

2.1.1 Residential demand

Residential demand is modelled as a function of real GDP, population, households[1] and real residential electricity price. All variables are logged and demand, GDP and households are expressed per capita. The model derives its coefficients from regression analysis of historical data back to 1974 and applies these coefficients to NZIER forecasts of GDP, Statistics New Zealand projections of population and households and the Commission's modelling of prices to 2050.

2.1.2 Commercial and industrial demand

Commercial and industrial demand is modelled as a function of real GDP, with adjustment for years when there was a perceived electricity supply shortage. The model is a linear regression. It derives its coefficients from historical data back to 1986 only due to changes in electricity's share of total energy demand in the mid to late 1970s and early 1980s, which caused a structural break in the relationship between GDP and electricity demand (NZIER, 2005).

Commercial and industrial demand excludes the Tiwai Point aluminium smelter, which is modelled separately as heavy industrial demand.

2.1.3 Heavy industrial demand

Heavy industrial demand is represented by the Tiwai Point aluminium smelter. Other large grid-connected industrial loads are included in the commercial and industrial model as their inclusion did not significantly alter the regression coefficients for this model. The smelter's electricity demand has remained fairly constant over recent years. With no major expansion or downsizing expected, the Commission therefore, for simplicity, models the smelter's annual demand to remain constant over the forecast period at the highest historical level to date[2].

2.1.4 Distribution losses and embedded generation

As the above models forecast end use demand, the Commission adds distribution losses and subtracts embedded generation to forecast demand at grid exit points. The Commission assumes lines company losses to remain at their current rate of 5.75%. The Commission assumes embedded generation to remain constant as a share of total generation and therefore to grow at the same rate as total demand.

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[1] Statistics New Zealand data on households are adjusted for the slightly different definition of residential electricity consumers used in the Ministry of Economic Development's Energy Data File.

[2] The year ending March 2008 in the 2009 update. Previously, the year ending March 2005 was used in the 2008 *Statement of Opportunities*.

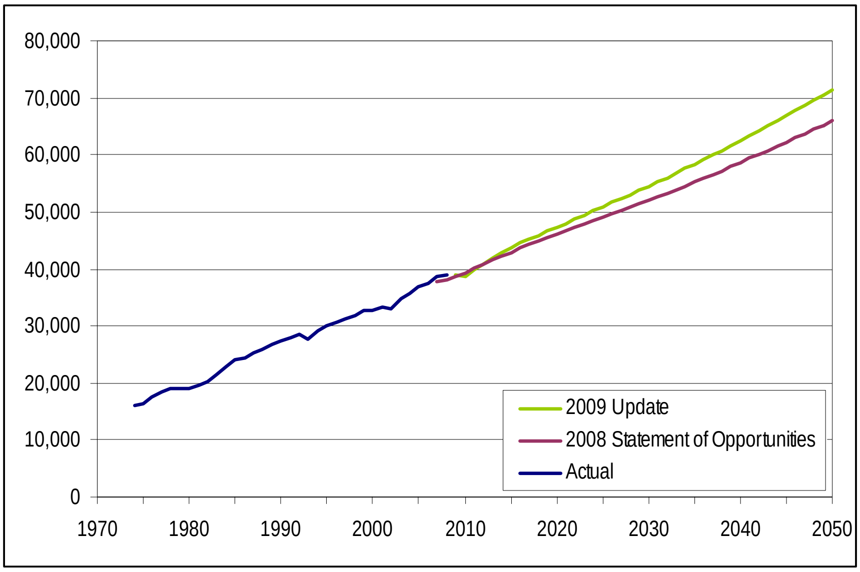
2.1.5 2009 update

The Commission has recently updated its forecasts, including with the latest GDP forecasts from NZIER (NZIER, 2009, extended to 2050 using Statistics New Zealand's population and labour force projections and assumed changes in productivity) and the latest population projections from Statistics New Zealand (Statistics New Zealand, 2007). The current economic recession slows forecast demand growth in the short run only (2009 to 2012). More substantial and enduring is the impact of Statistics New Zealand's upwards revision in its population projections.

Figure 1 compares the Commission's previous forecasts of total electricity demand published in the 2008 *Statement of Opportunities* with the recently updated forecasts.

Figure 1 Electricity Commission's electricity demand forecasts

GWh



Source: Electricity Commission

The 2008 *Statement of Opportunities* forecasts average annual growth to 2050 of 1.3%. Updating the forecasts with the latest data raises this to 1.5%. Annual electricity demand is 5,411 GWh (8.2%) higher by 2050 than previously forecast. The greatest impact is on residential demand. Residential demand in 2050 is 12.5% higher than previously forecast, commercial and industrial demand is 6.0% higher and heavy industrial demand is 2.3% higher.

3. Review of methodology

The focus of this review is the relationship between electricity consumption, population and GDP growth, but we start with a brief review of the overall methodology used by the Commission to forecast electricity demand.

There are several methods available for forecasting electricity demand:

- trend method – extends the historical trend over time, without considering explanatory variables; does not reflect cause and effect; most suitable for short-run projections
- end use method – models the energy use patterns of various devices and systems (e.g. household electrical appliances) and aggregates across end uses and end users; incorporates device use rates, energy efficiency improvements and fuel substitution; most effective for new technologies and fuels, which lack time series data, but requires detailed data on each end use and can overlook behavioural responses of consumers
- econometric method – establishes causal relationships between electricity demand and various economic, demographic and climatic variables from statistical analysis of historical data; then uses these relationships and forecasts of explanatory variables to project future electricity demand; requires a consistent set of data over a long time period; any future change in relationships, such as due to economic shocks or government policy, must be built into the model explicitly
- time series method – uses econometric models in which the only explanatory variables are lagged electricity demand, on the assumption that future demand is related to past actual and expected demand, with adjustment for how actual past demand differed from expected; requires data over a long time period; does not reflect cause and effect; most suitable for short-run forecasts
- more advanced modelling methods such as neural networks, chaos analysis and fuzzy logic – develop mathematical or computational models to determine complex relationships between inputs and outputs or to find patterns in data and then simulate the structure and/or functional aspects of behaviour; often adaptive models that "learn" from the external or internal data they process and evolve accordingly; can produce more reliable and stable forecasts than more traditional modelling methods; still somewhat experimental, but increasingly used overseas for short–run forecasts; require expert skills and forecasts are not transparent to non-experts; have tended to be used more for short-run forecasting and
- hybrids of the above methods, such as combining econometric models with time series models or the end use approach.

For its forecasting of residential demand and commercial and industrial demand, the Commission uses the econometric method. Its forecasting of heavy industrial demand is best described as the time series method, in its simplest form.

A variation of the econometric method is the fuel share model. This approach forecasts total energy demand, as a first step, before dividing this total between different energy sources or "fuels", one of which is electricity. A strength of this method is its explicit recognition of substitution between fuels according to relative fuel prices. A weakness is that it does not reflect the interdependence between price and quantity. Its sequential estimation procedure assumes that fuel prices are determined independently of both total energy demand and the distribution of demand by fuels, and that total energy demand is independent of fuel shares

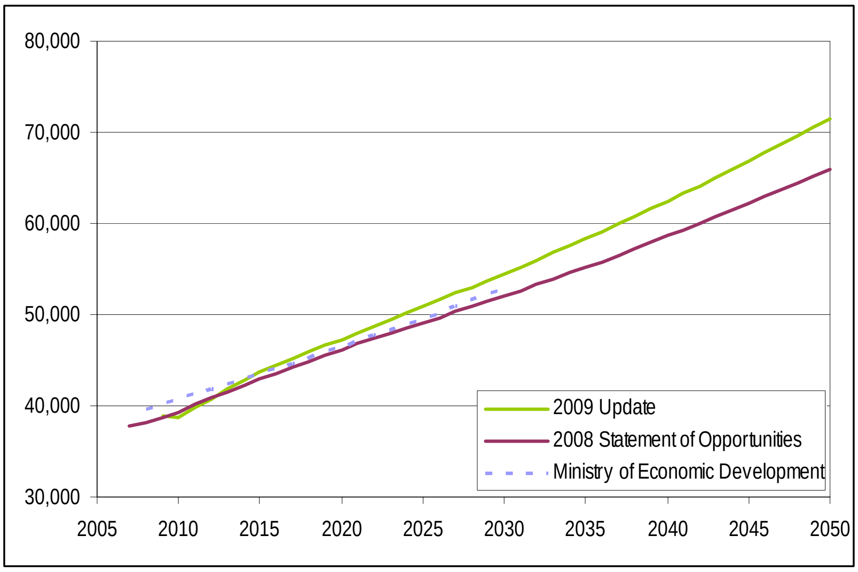
(Meetamehra, 2009). A rise in price may not only cause consumers to switch to another fuel, but cause a reduction in total energy demand. A fall in one fuel's share of total energy demand is not necessarily matched by an equal and opposite rise in another fuel's share.

In contrast, the econometric method assumes that relationships, such as between electricity demand and GDP, remain constant. This may not be valid where there is a significant shift in the composition of total energy demand, as NZIER (2005) finds there to have been in the mid to late 1970s and early 1980s. In focussing on shares, the fuel share approach can also overlook important drivers of the level of demand, such as demand for the end products produced using fuel inputs.

The Ministry of Economic Development (2006) uses this fuel share approach, although with re-estimation of total energy demand if the prices implied by modelling supply are inconsistent with the prices used to determine initial demand. The electricity component of these energy demand forecasts differ slightly from those derived by the Commission, as shown in Figure 2.

Figure 2 Ministry of Economic Development's electricity demand forecasts

GWh



Source: Electricity Commission, Ministry of Economic Development

Given the strengths and weaknesses of the different methods for forecasting electricity demand, we agree with the Commission's approach. The econometric method is generally the most suitable method for long-run forecasting and is widely used in other countries, although with some variation in explanatory variables and functional forms. The Commission has shortened the historical data series used for the commercial and industrial model to post 1986, to address the structural break in the relationship between electricity demand and GDP arising from change in the share of electricity in total energy demand. Estimates of energy demand equilibria in NZIER (2005) suggest that electricity demand is becoming increasingly de-linked from demand for other fuels and is converging towards a more stable equilibrium relative to GDP.

More recently developed advanced modelling methods, such as neural networks, may provide technically superior forecasts, but have the particular disadvantage of lacking the transparency required under Part F of the Rules. This does not, however, preclude them being used to test the accuracy of the Commission's econometric models, if the Commission has sufficient modelling resources available for such a "multiple methods" approach.

NZIER's 2004 review of the Commission's electricity demand forecast model, as it was then specified, did not detect any substantial problems, omissions or errors in the Commission's methodology, but did make a number of suggestions for improvement and future development. The Commission addressed these suggestions, as appropriate (Electricity Commission, 2004b).

We consider the suggestions relating to explanatory variables and functional form in Section 4 below. On the suggestions applying to the overall methodology, we are satisfied that the Commission has addressed these to the extent feasible and practical, given the constraints it faces in terms of availability of data and the objective of simplicity and transparency of methodology. We endorse "sanity checking" the forecast model results against "naïve" forecasts, such as might be provided by the trend method, or using the potentially more reliable and stable but less transparent advanced modelling methods, such as neural networks, to test the accuracy of the Commission's econometric models.

4. Review of relationship with GDP and population

In reviewing the relationship between electricity demand, GDP and population, there are three aspects to consider – the explanatory variables modelled as drivers of electricity demand, the functional form modelled as representing the relationship between electricity demand and these drivers, and the time period over which this relationship is derived from historical data.

4.1 Explanatory variables

Econometric modelling of electricity demand as a function of economic, social and demographic variables, as well as climatic factors, is a widespread approach in long-run forecasting of electricity demand. For example:

- Italy – GDP, population, GDP per capita (Bianco *et al*., 2009)
- France – climatic temperature and cloudiness, economic activity, price (sales offers) and season (whether on daylight saving time) (RTE, undated)
- Cyprus – number of customers, price and number of tourists (Egelioglu *et al.*, 2001)

- Hong Kong – climatic variables (Yan, 1998) and GDP, deflated domestic exports, population and price (Fung and Tummala, 1993)
- Singapore – GDP, population and price (Liu *et al*., 1991)
- India – population and weather (Rajan and Jain, 1999) and
- Maryland, USA – per capita income, price and long-run elasticity of demand (Lakhani and Bumb, 1978).

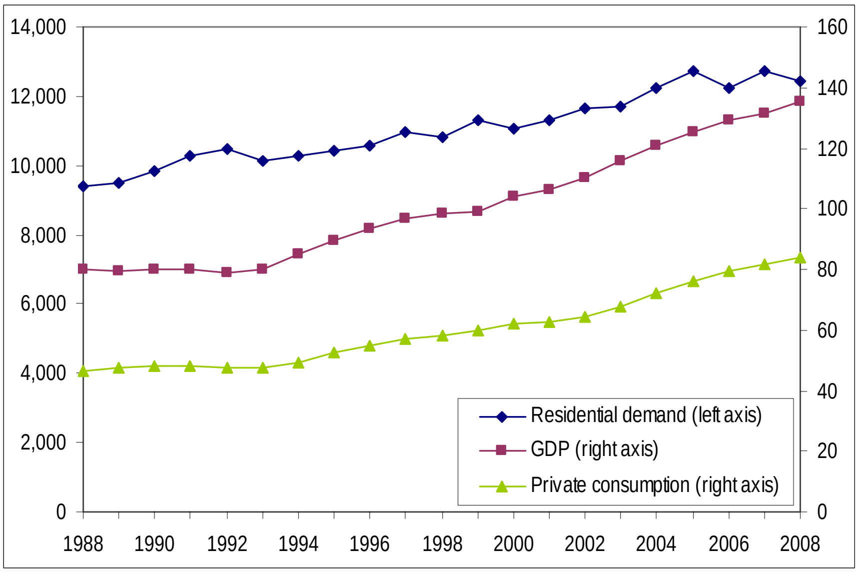
GDP, population and price are commonly selected as the most significant explanatory variables. The variables adopted by the Commission in forecasting residential demand and commercial and industrial demand in New Zealand – GDP, population, households and price – reflect the strong empirical relationship between these drivers and electricity demand. The residential demand model originally included a climatic temperature adjustment, but this was removed in the 2006 review as it made the modelling more complex for a negligible impact on the long-run forecasts.

NZIER (2004) questions whether there might be explanatory variables available other than GDP that would better reflect the influence of income or standard of living on residential demand and of output or revenue on commercial and industrial demand. An advantage of GDP is the availability of historical data for as long as reliable data on electricity consumption have been available, whilst many other official data series are available from 1987 only. The Commission has, however, already shortened the time period of historical data used for the commercial and industrial model to since 1986, due to a structural break in the relationship between GDP and electricity demand.

Potential alternative explanatory variables available from Statistics New Zealand include real private consumption, for residential demand, and real business investment and export revenue, for commercial and industrial demand. NZIER also routinely provides medium-run forecasts of these variables as part of its quarterly macroeconomic forecasting. We compare these historical series in Figure 3 and Figure 4.

Figure 3 Residential demand and private consumption

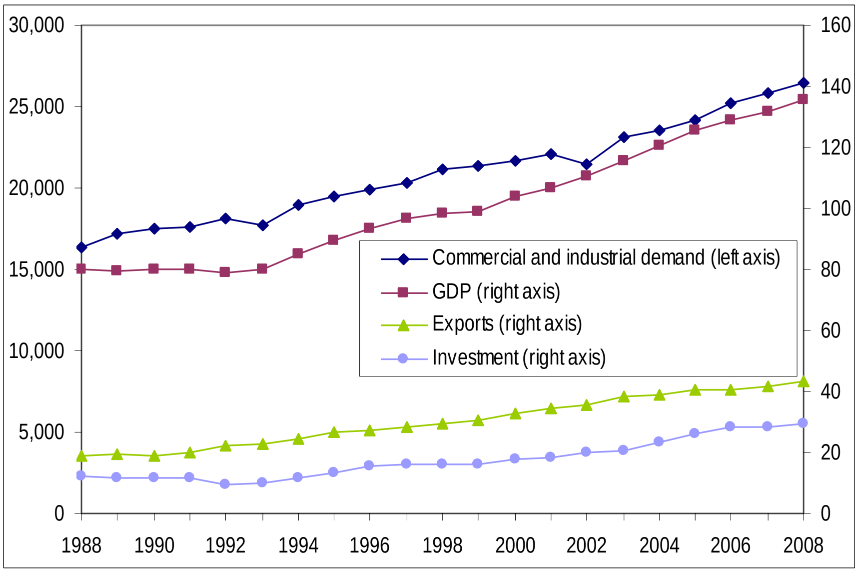
Year ending March, GWh, $ billion, 1995/96 prices



Source: Electricity Commission, Statistics New Zealand

Figure 4 Commercial and industrial demand, investment and exports

Year ending March, GWh, $ billion, 1995/96 prices



Source: Electricity Commission, Statistics New Zealand

Table 1 indicates that these alternative explanatory variables are strongly correlated with demand, but not quite as strongly as GDP.

Table 1 Correlation coefficients

1988 to 2008, year ending March

	Residential demand
GDP	0.961
Population	0.975
Households	0.976
GDP per capita	0.947
Households per capita	0.829
Residential electricity price	0.947
Private consumption	*0.957*

	Commercial and industrial demand
GDP	0.986
Business investment	*0.983*
Export revenue	*0.965*

Source: Electricity Commission, Statistics New Zealand

GDP appears slightly superior overall. In determining long-run relationships, it is preferable to use as long a time series as available, reliable and technically valid. GDP is therefore particularly useful for the residential model which still uses historical data back to 1974, which is not available for the alternative explanatory variables. Should the Commission wish to explore further the use of the above alternative explanatory variables, it would be feasible to extend NZIER's existing forecasts of these variables to 2050. It would also, potentially, be possible to construct a model to "backcast" these variables to 1986 for commercial and industrial demand and 1974 for residential demand, although these would most likely be derived from the GDP series in any case. We therefore do not consider it unreasonable for the Commission to continue using GDP.

4.2 Functional form

We understand that, for each of residential demand and commercial and industrial demand, the Commission has tested a number of different functional forms, including linear, log, per capita, first differences and lagged dependent variable, and selected the model that performed best. This inevitably involved some compromise, such as between goodness of fit, stability and robustness to the common problems of multicollinearity (correlation between explanatory variables), cointegration/non-stationarity (similar trends over time in explained and explanatory variables, which may be coincidental rather than directly causal) and autocorrelation (correlation between an explanatory variable's current and past values). The choice of functional form has also been constrained by the objective of simplicity and transparency of methodology.

Although a common model structure across the three demand sectors, as suggested by NZIER (2004), would further this simplicity, we recognise that no one model structure performs well for all three sectors. We do not consider the selected model structures so different as to impede understanding. Nor do we consider their functional forms too complex, although the residential demand model, in using variables in log and per capita form, may be approaching the limits of what can be intuitively understood widely.

We recommend that the Commission continue to verify the validity of the selected model by comparing it with potential alternatives at each future update. With the updating of data or introduction of further refinements to the model, which functional form performs best may change.

4.3 Time period

The question that prompted this review was whether the relationship between electricity demand, GDP and population has changed over the time period of historical data used to derive the coefficients for forecasting future electricity demand. If so, different starting points in regression analysis of the historical data can result in different values of these coefficients and therefore different forecasts. If a significant structural break has occurred, the time period may need to be shortened, as it has been already for the commercial and industrial model, or time dummy variables introduced to reflect more accurately the more recent relationship.

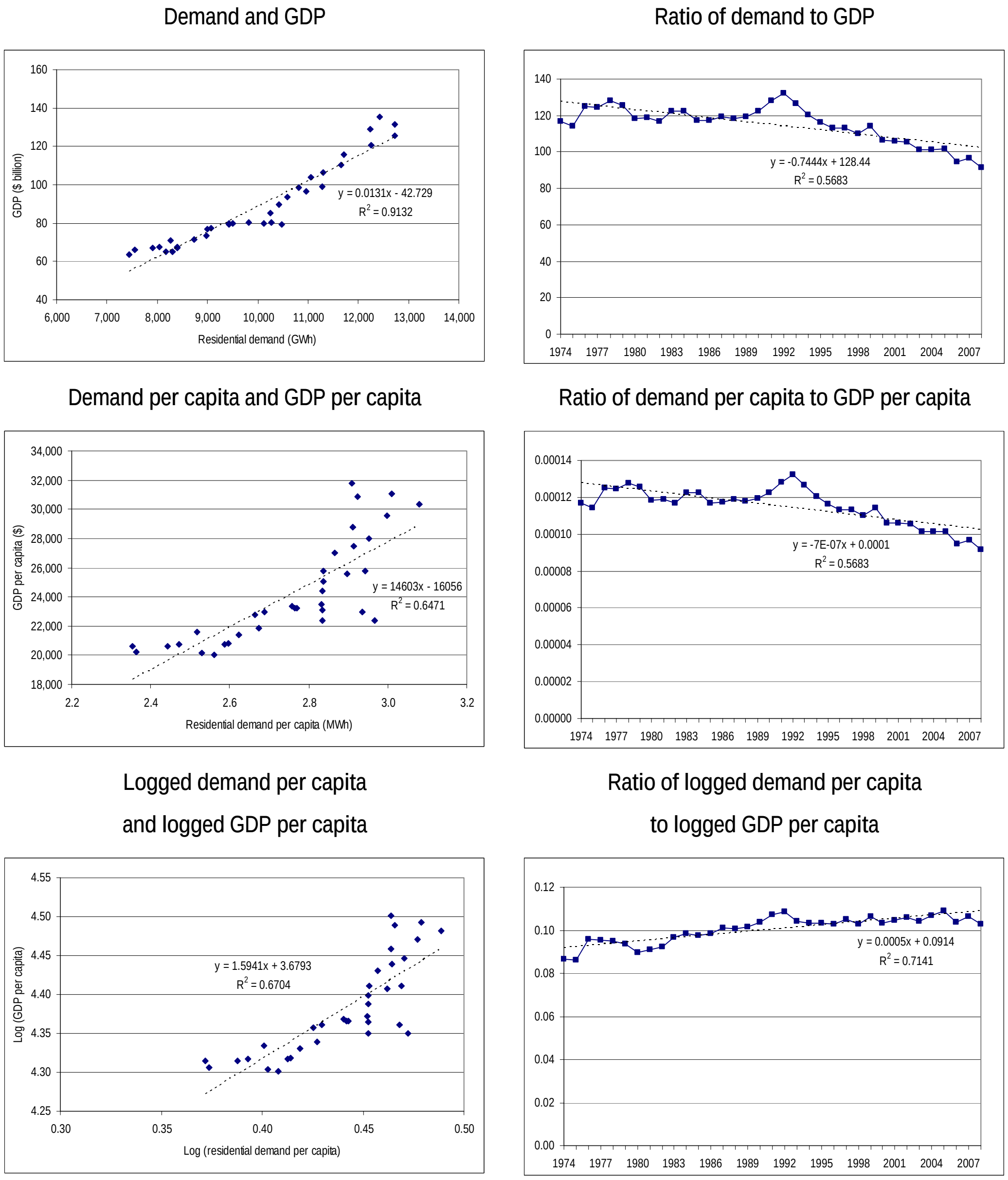
4.3.1 Residential demand

The first two charts in Figure 5 show a strong correlation between residential demand and GDP, but also an apparent downward trend over time in the ratio of residential demand to GDP. Regression analysis, in deriving a single coefficient per explanatory variable, effectively reflects its “average” relationship with demand over the time period modelled. The downward trend shown suggests that the relationship between residential demand and GDP may have changed over the past 35 years.

The further charts in Figure 5 suggest that this trend is less pronounced when these variables are expressed in logged per capita terms, which is the form in which they are modelled in the Commission’s regression analysis. Declining demand per dollar of GDP has coincided with rising demand per capita, as shown in Figure 6, as New Zealand’s GDP has grown faster than its population. Average demand per household has remained fairly stable, increasing only slightly as average household size has gradually declined.

Figure 5 Residential demand and GDP

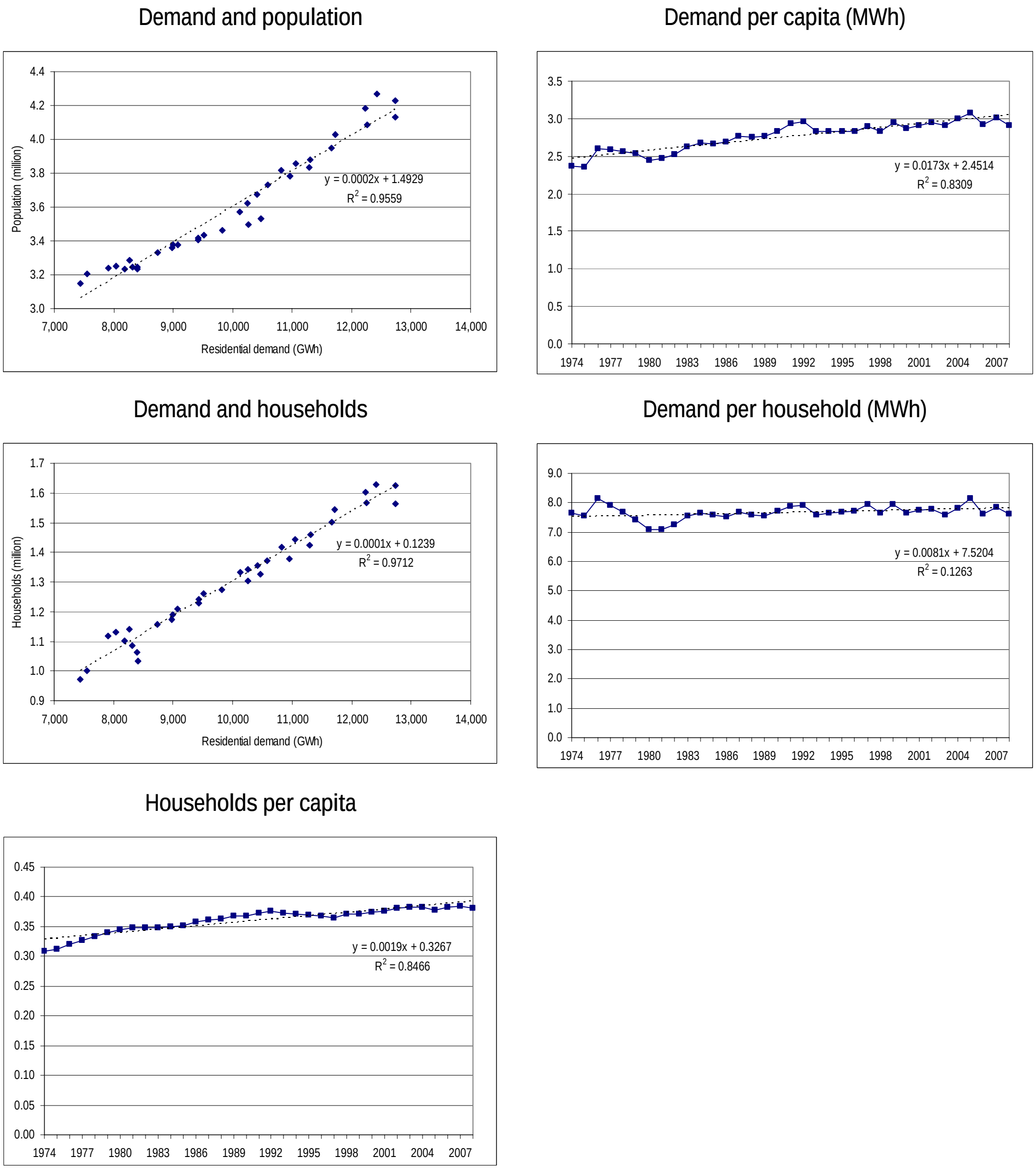
1974 to 2008, year ending March, 1995/96 prices



Source: Electricity Commission, Statistics New Zealand

Figure 6 Residential demand, population and households

1974 to 2008, year ending March



Source: Electricity Commission, Statistics New Zealand

Table 2 highlights how the ratios of residential demand to GDP and population have declined and risen respectively over successive five year periods, although again less noticeably in logged per capita terms.

Table 2 Residential demand – average ratios by five year period

	Demand/GDP (GWh per $ billion)	Demand/population (MWh per capita)	Log (demand per capita)/ log (GDP per capita)
1974-78	122	2.49	0.092
1979-83	120	2.52	0.093
1984-88	119	2.71	0.099
1989-93	126	2.87	0.105
1994-98	115	2.85	0.103
1999-2003	107	2.92	0.105
2004-08	97	2.98	0.106
1974-2008	115	2.76	0.100

Source: NZIER

Table 3 shows that the average ratio of residential demand to GDP differed significantly from other decades only in the 2000s, at the 95% level of confidence. In contrast, average demand per capita differed significantly in each decade, at the 95% level of confidence.

Table 3 Residential demand – confidence intervals by decade

	Demand/GDP (GWh per $ billion)		
	Average	95% confidence interval	
		Lower bound	Upper bound
1974-79	122.4	118.4	126.3
1980-89	119.0	117.7	120.2
1990-99	119.7	115.3	124.1
2000-08	100.6	97.4	103.8
1974-2008	115.0	111.7	118.3
	Demand/population (MWh per person)		
	Average	95% confidence interval	
		Lower bound	Upper bound
1974-79	2.50	2.42	2.58
1980-89	2.64	2.57	2.71
1990-99	2.88	2.84	2.91
2000-08	2.95	2.91	2.99
1974-2008	2.76	2.70	2.83

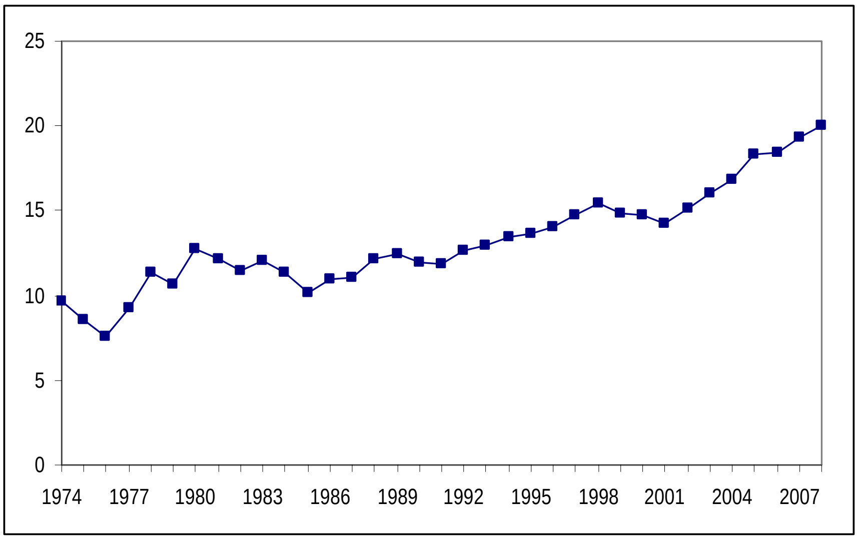
Source: NZIER

We consider first why the ratio of demand to GDP has been significantly lower, on average, since 2000 than in previous decades. A possible explanation is consumer response to rising real residential electricity prices. Estimates of the price elasticity of demand suggest that elasticity is low in the short run, but higher in the longer run[3]. Residential consumers in particular are unresponsive to short run price fluctuations, regarding electricity as an “essential” service, but may change their behaviour, such as in terms of the electrical appliances they purchase, over the longer run in response to persistent price rises.

The residential demand model already includes real residential price as an explanatory variable. Figure 7 and Figure 8 show how real residential electricity prices have risen over the past 35 years.

Figure 7 Residential price

Year ending March, $/KWh, excl. GST, 2008 prices



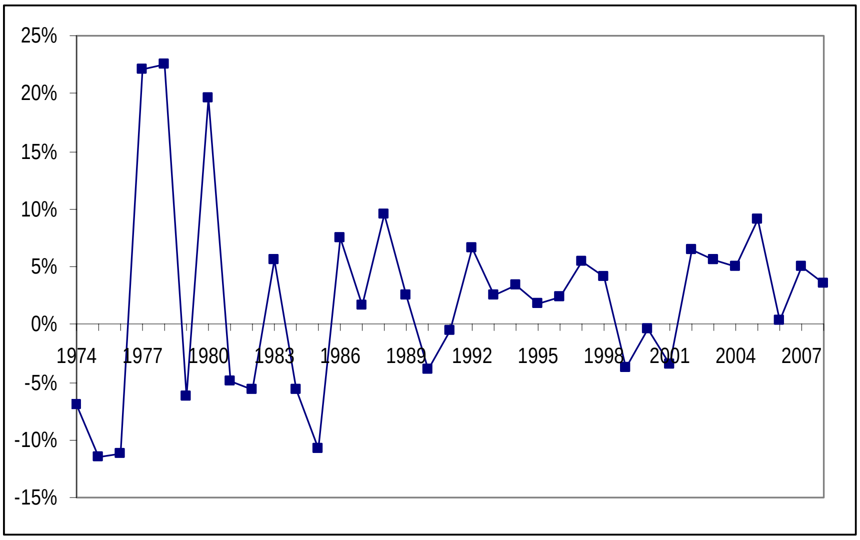
Source: Electricity Commission, Statistics New Zealand

Average prices rose significantly with each decade. Table 4 suggests that prices have been significantly higher since 2000 than the long-run average over the entre period 1974 to 2008, as well as significantly lower in the 1970s and 1980s. Prices have risen faster, on average, since 2000, but not significantly more than in other decades at the 95% level of confidence, although this reflects the degree of price volatility in 1970s and 1980s.

[3] See, for example, Sinclair Knight Merz (2005) *National Cost Benefit Analysis of Proposals to Take Water from the Waitaki River*, final report to Ministry of Economic Development, Appendix H.

Figure 8 Change in residential price

Year ending March, $/KWh, excl. GST, 2008 prices



Source: Electricity Commission, Statistics New Zealand

Table 4 Residential prices – confidence intervals by decade

Year ending March, $/KWh, excl. GST, 2008 prices

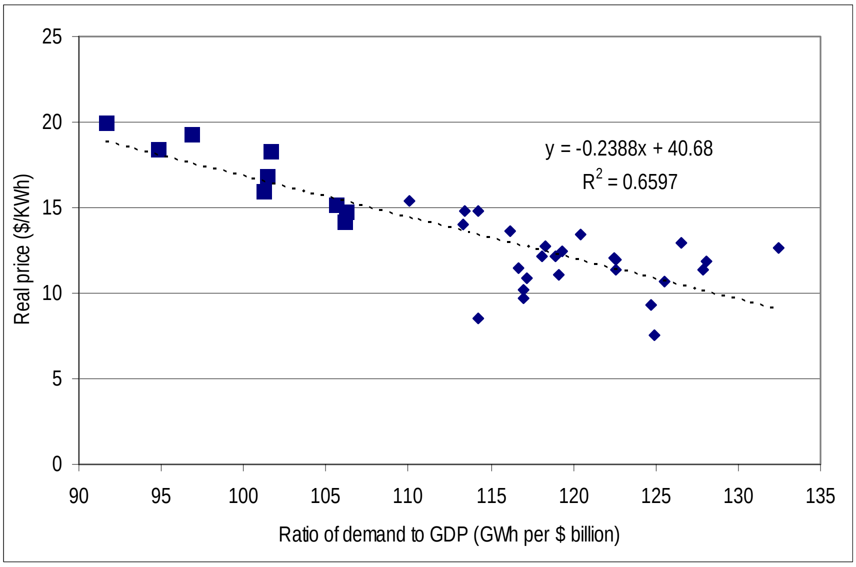
	Residential price		
	Average	95% confidence interval	
		Lower bound	Upper bound
1974-79	9.5	8.5	10.5
1980-89	11.6	11.2	12.1
1990-99	13.6	12.9	14.3
2000-08	17.0	15.7	18.3
1974-2008	13.2	12.2	14.2
	Annual change in residential price		
	Average	95% confidence interval	
		Lower bound	Upper bound
1974-79	1.5%	-10.5%	13.4%
1980-89	1.9%	-3.4%	7.3%
1990-99	1.8%	-0.3%	3.9%
2000-08	3.5%	1.1%	5.9%
1974-2008	2.2%	-0.5%	4.9%

Source: NZIER

Figure 9 shows the negative correlation (-0.81) between real prices and the ratio of residential demand to GDP. This correlation seems to be more pronounced in the 2000s (shown with square markers), when prices were highest and the ratios of demand to GDP lowest.

Figure 9 Residential price and ratio of residential demand to GDP

Year ending March, $/KWh, excl. GST, 2008 prices, GWh per $billion, 195/96 prices



Notes: 2000 to 2008 are shown with square markers

Source: Electricity Commission, Statistics New Zealand

The second main finding from Table 3 above was that average demand per capita has risen significantly with each successive decade. This can be attributed to rising living standards as New Zealand's GDP has grown faster than its population. An acceleration in the rate of energy efficiency improvement, including in response to persistent price rises, would have provided a countervailing influence, but this cannot be examined explicitly from these data.

The implication of rising demand per capita over time is that regression coefficients representing the average relationship over the entire period 1974 to 2008 may underestimate future demand, even with use of the latest population projections.

In conclusion, these two findings together suggest that the relationships between residential demand and GDP, and residential demand and population, do appear to have changed somewhat over the past 35 years and particularly since 2000. We suggest that a structural break around 2000 is only now emerging, as sufficient years of data become available for the change in relationships to show as significant.

The nine years of 2000 to 2008 would, however, be a short time period for robust regression analysis. In testing for parameter stability previously, the Commission modelled a minimum period of 10 years (Electricity Commission, 2004b). We recommend that the Commission test the sensitivity of its regression coefficients to different starting points over 1974 to 2000, through Chow tests, for its 2009 update as it did for its earlier modelling (Electricity Commission, 2004b), to determine the optimal trade off in length of time period.

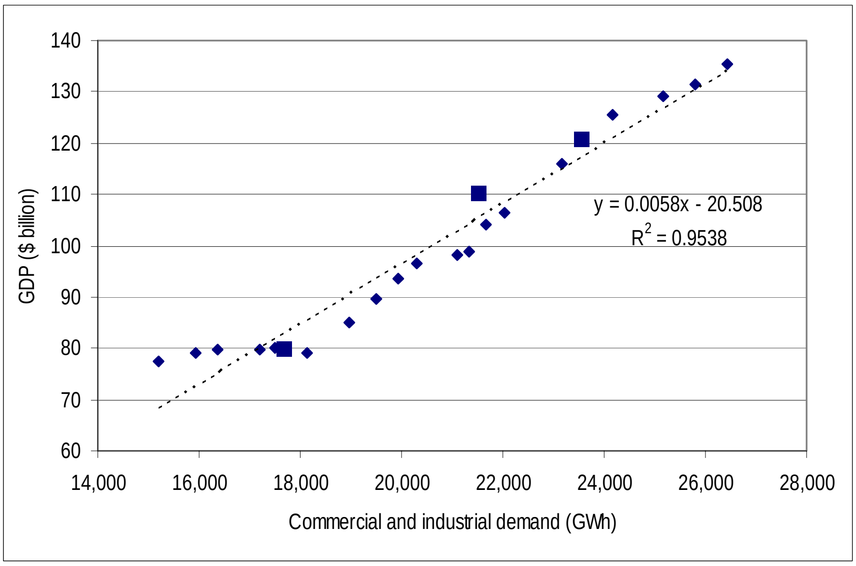
4.3.2 Commercial and industrial demand

The Commission's 2009 update for the latest GDP and population data has less impact on the commercial and industrial demand forecasts. In addition, the Commission has already reduced the time period for modelling commercial and industrial demand to 1986 to 2008 due to changes in electricity's share of total energy demand, which caused a structural break in the relationship between GDP and electricity demand.

Figure 10 shows a strong correlation between commercial and industrial demand and GDP over this period.

Figure 10 Commercial and industrial demand and GDP

1986 to 2008, year ending March, 1995/96 prices



Notes: Shortage years are shown with square markers

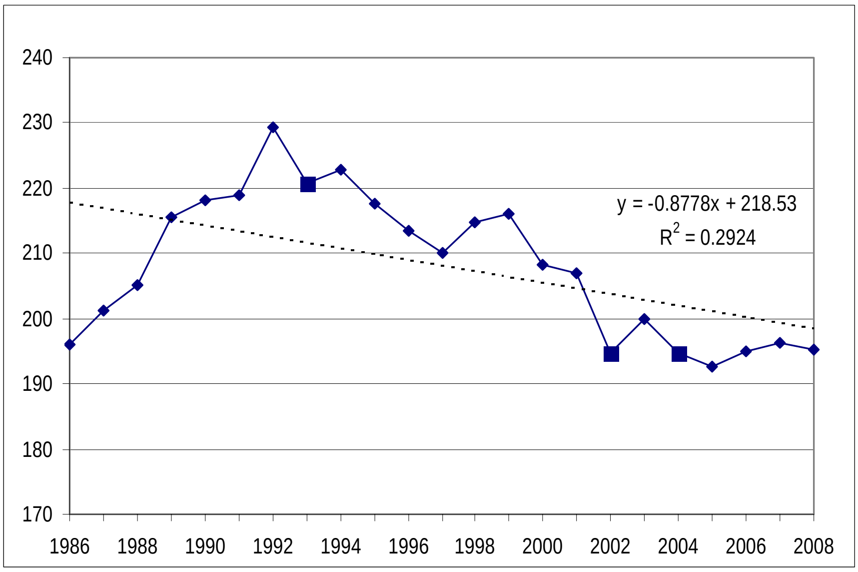
Source: Electricity Commission, Statistics New Zealand

Figure 11 and Table 5 suggest that the average ratio of commercial and industrial demand to GDP was significantly higher in the 1990s, but has fallen again since. It is now its lowest since before 1986. The average ratio for the 2000s is not yet significantly lower than in the late 1980s at the 95% confidence level, but is approaching the lower bound and is significantly lower than the average over the entire period 1986 to 2008.

This again suggests that a structural break around 2000 may be starting to emerge. It is too soon to tell if the ratio of commercial and industrial demand to GDP has stabilised or will continue its downward trend. We recommend that, until this becomes clear, the Commission continue to use the full period 1986 to 2008 for deriving coefficients to forecast commercial and industrial demand, but reassess this as further years' data become available.

Figure 11 Ratio of commercial and industrial demand to GDP

Year ending March, 1995/96 prices



Notes: Shortage years are shown with square markers

Source: Electricity Commission, Statistics New Zealand

Table 5 Commercial and industrial demand – confidence intervals by five year period

	Demand/GDP (GWh per $ billion)		
	Average	95% confidence interval	
		Lower bound	Upper bound
1986-89	204.6	197.6	211.6
1990-99	218.2	215.0	221.3
2000-08	198.2	194.7	201.7
1986-2008	208.0	203.6	212.4

Source: NZIER

5. Review of heavy industrial demand model

Heavy industrial demand is driven less by domestic GDP or population, but more by product demand in export markets and total input costs. We are satisfied with the approach adopted by the Commission of modelling the smelter's demand to remain constant over the forecast period at the highest annual level observed to date. Although simple, this approach does not seem unreasonable given that the smelter's demand has remained fairly constant over recent years and no major expansion or downsizing is expected.

For a more thorough approach, the Commission could consider the option of adopting the approach followed in Covec (2006). Covec (2006) investigates the markets for aluminium, including price trends and competing production in other countries, as well as production costs and energy intensity at the Tiwai Point aluminium smelter. From these, Covec (2006) forecasts the smelter's electricity demand to 2050. Note that these forecasts were prepared prior to the international financial crisis and global economic slowdown of 2007 and 2008, so would need updating.

Reassuringly, the forecasts of Covec (2006) are close to the Commission's previous forecasts for heavy industrial demand in the 2008 *Statement of Opportunities* at a little over 5,200 GWh per year. Like the Commission, Covec (2006) forecasts constant annual demand for much of the forecast period. Its forecasts differ slightly from the Commission's in the first half of the forecast period in showing an initial small increase in annual electricity demand, as the effect of rising production outweighs that of slowing improvement in energy efficiency, followed by a gradual decline, as energy efficiency continues to improve after production passes its peak.

We do not consider it unreasonable for the Commission to retain its existing approach, given that this produces similar forecasts from a simpler model.

Covec (2006) similarly develops forecasts for five other heavy industrial sectors – steel, petrochemicals, oil refining, forest products and the dairy sector – should the Commission wish to reconsider modelling these separately from its commercial and industrial demand model.

6. Conclusions

Given the strengths and weaknesses of the different methods for forecasting electricity demand, we agree with the Commission's use of the econometric method. This is generally the most suitable method for long-run forecasting and is widely used in other countries. More recently developed advanced modelling methods, such as neural networks, may provide more reliable and stable forecasts, but have the particular disadvantage of lacking the transparency required of the Commission's electricity demand forecasts under Part F of the Rules. This does not, however, preclude them being used to test the accuracy of the Commission's econometric models, if the Commission has sufficient modelling resources available for such a "multiple methods" approach.

NZIER's 2004 review of the Commission's electricity demand forecast model, as it was then specified, did not detect any substantial problems, omissions or errors in the Commission's methodology, but did make a number of suggestions for improvement and future development. We are satisfied that the Commission has addressed these suggestions to the extent feasible and practical, given the constraints it faces in terms of availability of data and the objective of simplicity and transparency of methodology. We endorse "sanity checking" the forecast model results against "naïve" forecasts, such as might be provided by the trend method, or testing their accuracy using more advanced modelling methods, such as neural networks.

In reviewing the relationship between electricity demand, GDP and population, we consider three aspects – the explanatory variables modelled as drivers of electricity demand, the functional form modelled as representing the relationship between electricity demand and these drivers, and the time period over which this relationship is derived from historical data.

The explanatory variables adopted by the Commission reflect the strong empirical relationship between these drivers and electricity demand and are commonly selected as the most significant explanatory variables in other countries. Potential alternative explanatory variables available from Statistics New Zealand include real private consumption, for residential demand, and real business investment and export revenue, for commercial and industrial demand. We find GDP to appear slightly superior overall. In determining long-run relationships, it is preferable to use as long a time series as available, reliable and technically valid. GDP is therefore particularly useful for the residential model which still uses historical data back to 1974, which is not available for the alternative explanatory variables. Should the Commission wish to explore further the use of the above alternative explanatory variables, it would be feasible to extend NZIER's existing forecasts of these variables to 2050. It would also, potentially, be possible to construct a model to "backcast" these variables to 1986 for commercial and industrial demand and 1974 for residential demand, although these would most likely be derived from the GDP series in any case. We therefore do not consider it unreasonable for the Commission to continue using GDP.

We understand that, for each of residential demand and commercial and industrial demand, the Commission has tested a number of different functional forms, including linear, log, per capita, first differences and lagged dependent variable, and selected the model that performed best. This inevitably involved some compromise, such as between goodness of fit, stability and robustness to the common problems of multicollinearity, cointegration/non-stationarity and autocorrelation. The choice of functional form has also been constrained by the objective of simplicity and transparency of methodology. Although a common model structure across the three demand sectors would further this simplicity, we recognise that no one model structure performs well for all three sectors. We do not consider the selected model structures so different as to impede understanding. Nor do we consider their functional forms too complex, although the residential demand model, in using variables in log and per capita form, may be approaching the limits of what can be intuitively understood widely. We recommend that the Commission continue to verify the validity of the selected model by comparing it with potential alternatives at each future update. With the updating of data or introduction of further refinements to the model, which functional form performs best may change.

The question that prompted this review was whether the relationship between electricity demand, GDP and population has changed over the time period of historical data used to derive the coefficients for forecasting future electricity demand. If so, different starting points in regression analysis of the historical data can result in different values of these coefficients and therefore different forecasts.

We find the average ratio of residential demand to GDP to have differed significantly from other decades only in the 2000s, at the 95% level of confidence. We suggest that this may reflect consumer response over time to sustained rises in real residential electricity prices. We find the high negative correlation between real prices and the ratio of residential demand to GDP to be more pronounced in the 2000s, when prices were highest and the ratios of demand to GDP lowest. We find average residential demand per capita to have risen significantly with each successive decade, at the 95% level of confidence. This implies that regression coefficients representing the average relationship over the entire period 1974 to 2008 may underestimate future demand, even with use of the latest population projections.

Together, these two findings suggest that the relationships between residential demand and GDP, and residential demand and population, do appear to have changed somewhat over the past 35 years and particularly since 2000. We suggest that a structural break around 2000 is only now emerging, as sufficient years of data become available for the change in relationships to show as significant. The nine years of 2000 to 2008 would, however, be a short time period for robust regression analysis. We recommend that the Commission test the sensitivity of its regression coefficients to different starting points over 1974 to 2000, through Chow tests, for its 2009 update as it did for its earlier modelling, to determine the optimal trade off in length of time period.

The Commission has already reduced the time period for modelling commercial and industrial demand to 1986 to 2008 due to changes in electricity's share of total energy demand, which caused a structural break in the relationship between GDP and electricity demand. We find that the average ratio of commercial and industrial demand to GDP was significantly higher in the 1990s, but has fallen again since. It is now its lowest since before 1986. The average ratio for the 2000s is not yet significantly lower than in the late 1980s at the 95% confidence level, but is approaching the lower bound and is significantly lower than the average over the entire period 1986 to 2008.

This again suggests that a structural break around 2000 may be starting to emerge. It is too soon to tell if the ratio of commercial and industrial demand to GDP has stabilised or will continue its downward trend. We recommend that, until this becomes clear, the Commission continue to use the full period 1986 to 2008 for deriving coefficients to forecast commercial and industrial demand, but reassess this as further years' data become available.

We are satisfied with the approach adopted by the Commission of forecasting heavy industrial demand as remaining constant over the forecast period at the highest annual level observed to date. Although simple, this approach does not seem unreasonable given that the Tiwai aluminium smelter's demand has remained fairly constant over recent years and no major expansion or downsizing is expected. For a more thorough approach, the Commission might like to consider the option of adopting the approach followed in Covec (2006), which is based on the markets for aluminium, including price trends and competing production in other countries, as well as production costs and energy intensity at the Tiwai Point aluminium smelter. We do not consider it unreasonable for the Commission to retain its existing approach, however, given that this produces similar forecasts from a simpler model.

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