Ministry of Economic Development
Manatū Ōhanga

Review of MED's demand forecasting methodology

Final version

25th November 2011

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Contents

1 Executive summary

Each year the Ministry of Economic Development (MED) produces the Energy Outlook, a projection of NZ's energy supply and demand out to 2040. The Outlook includes forecasts of energy demand from the residential, commercial and industrial sectors (as well as transport demand which is not considered in this review).

Total energy demand for the residential, commercial and industrial sectors is forecast using econometric relationships with GDP or household numbers. This is called the "stage one" forecast.

Total energy demand is then broken down into demand for individual fuels (where electricity is classified as a fuel source). Fuel market shares are calculated based on forecasts of relative fuel prices and estimates of cross elasticities. This is called the "stage two" forecast.

MED has reviewed the current demand models and found the Residential and the "General Industrial" sector models could be substantially improved. Comprehensive testing of various alternative model specifications and exogenous drivers has resulted in selecting the following models for the "stage one" forecast:

- Residential energy demand per household is a function of Income, Energy Price, and Autonomous demand;
- Commercial sector energy demand is a function of Commercial sector GDP and demand in the previous year;
- Industrial sector demand is a function of Industrial sector GDP and Energy Price.

The "stage two" method for estimating fuel market shares has also been refined. The fuel cross elasticities will now be estimated using a mathematical optimisation algorithm, subject to refinement based on the forecasters informed judgement. Previously the elasticities were estimated based solely on informed judgements (from literature reviews and peer discussions). The previous model also included a "fuel conservation" price elasticity parameter which has now been removed, since in the new model specification an Energy Price variable is included in the stage one econometric model.

Forecast accuracy has been improved significantly with the new demand models, and the analysis suggests they are "fit for purpose".

MED also has a new role in determining some of the Grid Planning Assumptions (GPAs) which are used by Transpower and the Commerce Commission for evaluating transmission investment proposals. As part of this, the MED will be required to provide national electricity demand forecasts. It is proposed that the SADEM electricity demand forecasts be used as a basis for the GPAs. However, MED also proposes that electricity forecasts from alternative sources (Transpower, Electricity Authority) are also considered. MED will consult with stakeholders on its specific approach to an electricity demand forecast for the GPAs at a later date.

NZIER have been engaged by MED to review this document and provide a view on the demand models. NZIER support the majority of conclusions and recommendations made by MED in this report.

This demand model review has also resulted in historical data revisions for some fuels and sectors. Data reliability and consistency has been considered when designing the demand models.

2 Background

2.1 MED's energy models

The Ministry of Economic Development's (MED) current approach to energy modelling for the Energy Outlook uses five distinct but interrelated models:

- Supply and Demand Energy Model (SADEM),
- electricity Grid Expansion Model (GEM),
- electricity price forecast model,
- oil and gas models, and the
- Vehicle Fleet Model (VFM).

These models are used to produce forecasts of energy supply and demand, prices and energy sector greenhouse gas emissions.

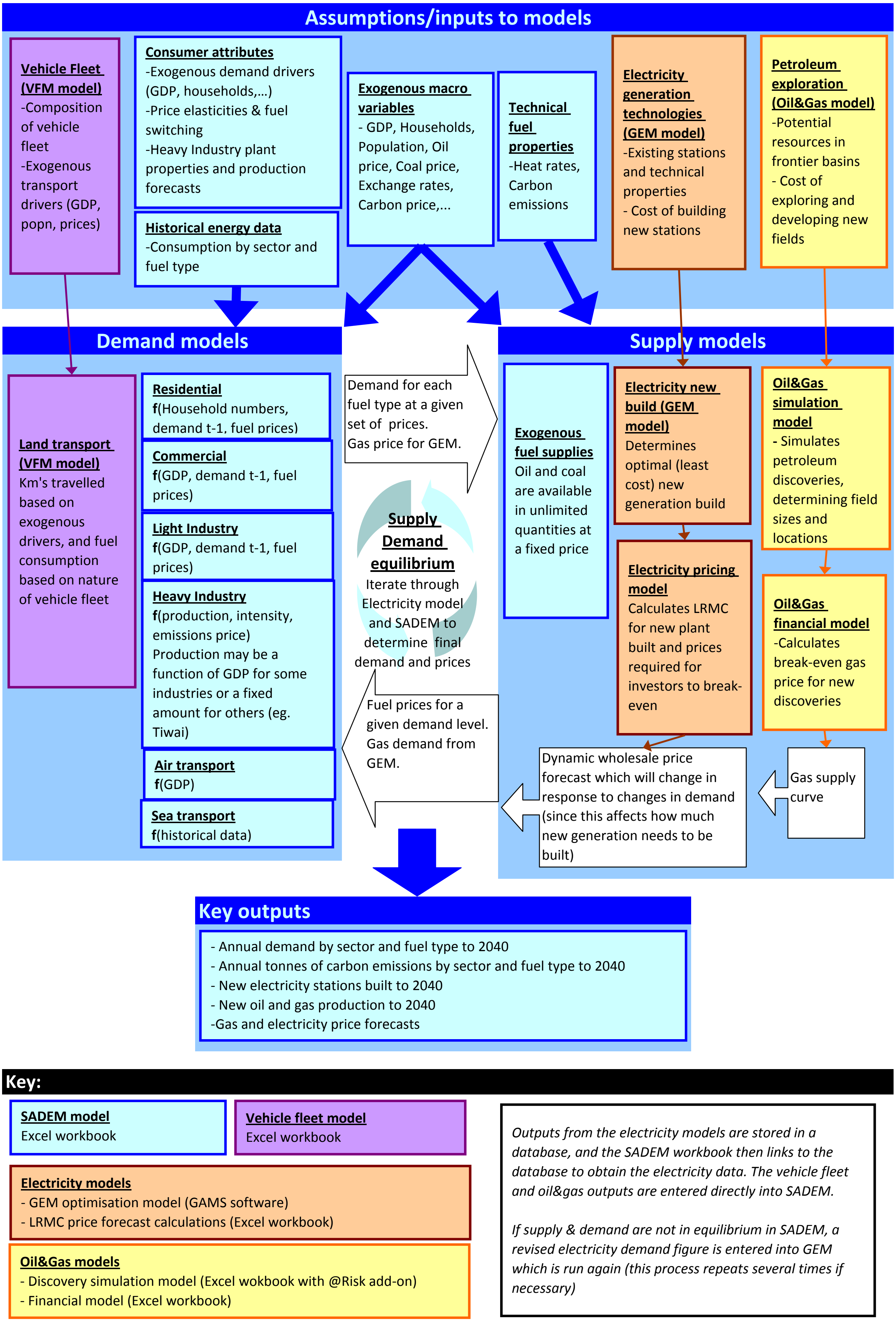
SADEM is a partial equilibrium model of the energy sector and key drivers such as GDP and oil price are exogenous, meaning that the potential link between the price of oil and GDP is not modelled explicitly.

SADEM performs three key functions:

1. It projects energy demand for all sectors of the economy (excluding land transport) using econometric relationships with exogenous drivers (such as GDP and households) and relative price levels.
2. It provides a central hub, coordinating electricity supply information from GEM and land transport demand information from the VFM.
3. It projects energy sector greenhouse gas emissions.

The following diagram outlines at a high level the key interactions between the various energy models. There are many more complex linkages within the system which are explained in a technical document available on the MED website[1].

[1] Available at: www.med.govt.nz/energyoutlook.


Assumptions/inputs to models
Vehicle Fleet (VFM model)
-Composition of vehicle fleet
-Exogenous transport drivers (GDP, popn, prices)
Consumer attributes
-Exogenous demand drivers (GDP, households,...)
-Price elasticities & fuel switching
-Heavy Industry plant properties and production forecasts
Historical energy data
-Consumption by sector and fuel type
Exogenous macro variables
- GDP, Households, Population, Oil price, Coal price, Exchange rates, Carbon price,...
Technical fuel properties
-Heat rates, Carbon emissions
Electricity generation technologies (GEM model)
-Existing stations and technical properties
- Cost of building new stations
Petroleum exploration (Oil&Gas model)
-Potential resources in frontier basins
- Cost of exploring and developing new fields
Demand models
Land transport (VFM model)
Km's travelled based on exogenous drivers, and fuel consumption based on nature of vehicle fleet
Residential
f(Household numbers, demand t-1, fuel prices)
Commercial
f(GDP, demand t-1, fuel prices)
Light Industry
f(GDP, demand t-1, fuel prices)
Heavy Industry
f(production, intensity, emissions price)
Production may be a function of GDP for some industries or a fixed amount for others (eg. Tiwai)
Air transport
f(GDP)
Sea transport
f(historical data)
Demand for each fuel type at a given set of prices.
Gas price for GEM.
Supply Demand equilibrium
Iterate through Electricity model and SADEM to determine final demand and prices
Fuel prices for a given demand level. Gas demand from GEM.
Supply models
Exogenous fuel supplies
Oil and coal are available in unlimited quantities at a fixed price
Electricity new build (GEM model)
Determines optimal (least cost) new generation build
Electricity pricing model
Calculates LRMC for new plant built and prices required for investors to break-even
Oil&Gas simulation model
- Simulates petroleum discoveries, determining field sizes and locations
Oil&Gas financial model
-Calculates break-even gas price for new discoveries
Dynamic wholesale price forecast which will change in response to changes in demand (since this affects how much new generation needs to be built)
Gas supply curve
Key outputs
- Annual demand by sector and fuel type to 2040
- Annual tonnes of carbon emissions by sector and fuel type to 2040
- New electricity stations built to 2040
- New oil and gas production to 2040
-Gas and electricity price forecasts
Key:
SADEM model
Excel workbook
Vehicle fleet model
Excel workbook
Electricity models
- GEM optimisation model (GAMS software)
- LRMC price forecast calculations (Excel workbook)
Oil&Gas models
- Discovery simulation model (Excel wokbook with @Risk add-on)
- Financial model (Excel workbook)
Outputs from the electricity models are stored in a database, and the SADEM workbook then links to the database to obtain the electricity data. The vehicle fleet and oil&gas outputs are entered directly into SADEM.
If supply & demand are not in equilibrium in SADEM, a revised electricity demand figure is entered into GEM which is run again (this process repeats several times if necessary)

2.2 The current energy demand models in SADEM

SADEM contains four "sub-models" which forecast demand by sector:

- Residential
- Commercial
- General Industry
- Specific Industry

Residential, Commercial and General Industrial demand are currently modelled using the same two-stage forecasting process, but with different exogenous drivers and parameter values.

The first stage of the modelling process is to forecast "effective" energy demand. Effective energy is the net petajoules (PJ) of total energy consumed (the sum of all the fuel consumed, taking into consideration the "efficiency" of each fuel). The effective demand forecast is based on an econometric relationship with an exogenous driver and an autoregressive parameter is also used due to the strong autocorrelation in the historical data series. The exogenous driver for Residential demand is household numbers, while Commercial and General Industry are related to GDP.

The second stage breaks down the effective energy demand forecast (from stage one) by fuel. This breakdown (or "market share") for each fuel is calculated based on the relative fuel price forecasts and a market share elasticity parameter which allows "fuel switching" in response to relative price changes. There is also a "fuel conservation" effect which allows overall demand to respond to changes in the overall price level (based on a price elasticity parameter).

The full mathematical description for these models can be found in the appendices (section 7.1).

The elasticity and lag values were initially based on a literature search, providing generic elasticities. Over several years of modelling these have been revised based on fine tuning and calibration of the model outputs. The sub-models are not very sensitive to these variables and because of the dominance of electricity (particularly in the residential and commercial sub-models) these variables do not significantly influence the results.

Specific Industry has not been included in this demand review[2].

[2] Specific Industry is limited to a handful of facilities consuming a considerable proportion of total energy demand (aluminium, NZ Steel, NZ Refinery, methanol and urea). Energy demand for these industries is a "bottom-up" forecast based on production and energy intensity estimates.

3 Historical data

SADEM uses the historical energy demand data published in MED's annual Energy Data File (EDF). The EDF demand data is gathered from energy retailers at sub-sector level (based on ANZSIC codes).

Demand data from the EDF is used in the four sub-models described in the previous section (Residential, Commercial, General and Specific Industry). General Industrial demand is estimated by taking total Industrial demand and subtracting Specific Industrial demand.

Data collection methods occasionally change and close analysis of the historical data identified some "break points" where what may appear to be a structural shift is more likely to be a change in the way the data was captured. Whilst total fuel demand across all sectors is a reliable and consistent series over time, some of the more granular data is less reliable. Energy consumption data before 1990 is far less reliable and has not been used.

Several improvements have been made to the historical data series as a result of this review. These improvements generally involve checking that sub-sector data is consistent over time (ie. identifying periods when retailer data may have been classified under differing ANZSIC codes). Electricity, gas and diesel sectoral data is probably the most reliable, however fuel oil, petrol (non-transport) and coal is less reliable at a sectoral level.

Substantial revisions have also been made to the way we classify General versus Specific Industry. The following industries have been migrated from Specific to General Industry:

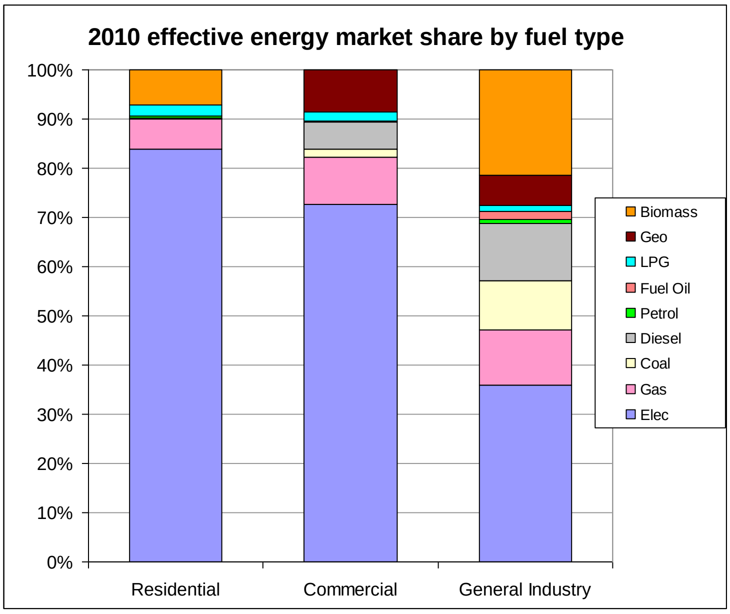
- Dairy, Wood and Meat processing, and
- Cement and Lime.

3.1 Fuel groupings included in this review

In addition to the data revisions mentioned above, we have also re-assessed which fuels should be included in the core forecasting models, and which should be forecast outside these models. The fuels in the generic models need to have reliable historical and forecast price data for the market share elasticity calculations. The fuels highlighted in yellow in the below table are those included in the core models.

The fuels highlighted in blue in the below table are not included in the core models. Biomass and geothermal energy are not included as they have no reliable price series. Other fuels omitted are those with "niche" applications which are not expected to follow the general trends of the other major fuels, and/or those that are insignificantly small.

The fuels forecast outside the core models generally use a very simple method (e.g. average of last 3 years). However, for biomass and geothermal some additional information is applied, using GDP or production forecasts and energy intensities. These separate fuel forecasts are not discussed further in this document.



2010 effective energy market share

	Residential	Commercial	General Industry
Elec	83.9%	72.7%	35.9%
Gas	6.1%	9.5%	11.2%
Coal	0.3%	1.7%	10.1%
Diesel	na	5.6%	11.6%
Petrol	0.3%	0.1%	0.7%
Fuel Oil	na	0.1%	1.8%
LPG	2.2%	1.8%	1.2%
Biomass	7.2%	na	21.4%
Geo	na	8.6%	6.1%

* The yellow highlighted fuels are those which are included in the generic modelling, and the blue fuels are forecasted individually

4 Demand model analysis

NZIER suggested the following framework for evaluating MED's forecasting models:

- Transparency,
- Simplicity,
- Stability of parameter values,
- Sensitivity of the forecast to parameters,
- Feasibility,
- Consistency with forecasts from other agencies, and
- Explicability.

MED's existing and alternative demand models were assessed against these criteria.

The current stage one econometric model used a log transformation when estimating the regression parameters, and in this phase of the demand review we also tested the series with no transformation and also a simple growth model (i.e. regressing the percentage annual growth in the series).

Alternative explanatory variables for the stage one econometric forecast were also tested:

- Household numbers,
- Population,
- GDP,
- GDP by sector (industrial versus commercial),
- GNE,
- GDP or GNE per capita or per household, and
- Aggregate price (a weighted average fuel price, using fuel demand as the weighting).

The regression analysis was performed in Matlab using a "stepwise" technique which adds or subtracts explanatory variables depending on marginal gains to overall model fit. Further analysis was also performed in Excel and Stata. Standard statistical tests were used to select the best fit variables and models. In the next section we show some diagnostics for the Current and Proposed models, and this is the sort of analysis that was conducted on all the potential models, which were eliminated one by one until we arrived at the more favoured options (the "proposed models").

This analysis was performed on the effective energy demand for each sector. Alternative methods for producing the stage two forecasts for individual fuels were also considered. We removed the "fuel conservation" parameter, replacing it instead with the aggregate price variable in the initial stage one forecast. We then refined the market share elasticity parameters and tried to estimate them based on a "least-squared errors" approach.

This means that we are evaluating a "two-stage" forecasting approach (stage one = econometric forecast for effective energy, stage two = market shares for individual fuels).

Alternative methods for forecasting the individual fuel series were also considered. NZIER explored a "demand system" approach. This involved regressing individual fuel demands on GDP and the prices of substitute fuels, and solving this system of equations simultaneously. However, this produced coefficients with counterintuitive signs and a poor fit, so the approach was rejected.

The next sections describe the alternative models tested, diagnostics, and the recommended modelling approach.

4.1 Residential stage-one econometric model

4.1.1 Description of the models tested

The existing residential demand model is:

R1. Log demand ~ f (log Household numbers, log Demand t-1, Constant).

Alternative explanatory variables were tested as well as different data transformations (as described previously).

We also investigated a theoretical consumption function, where energy demand was a function of income, prices and some autonomous level of consumption. When considering the demand of a typical household this approach has some appeal. There will be a minimum energy requirement regardless of income and prices, for example, hot water, lighting, cooking. As incomes rise residential energy demand can be expected to increase, for example, by having warmer houses and purchasing more electronic goods. Similarly, as energy prices rise, consumers will become more conscious of conserving energy (eg. insulation and more efficient appliances and heaters).

We transformed demand and income data series by dividing by the number of households, and tested the following models:

R2. Demand per Household ~ f(Income per household, Aggregate Price, Constant)

R3. Log Demand per Household ~ f(Log Income per household, Log Aggregate Price, Constant)

Total demand is then equal to (Demand per Household) * (number of households)

Two alternative measures of income were tested, GDP per household and GNE per household. We also tested population as the denominator in R2 and R3.

The Electricity Authority's electricity demand model is a function of (GDP per capita, Households per capita, Price, Constant). This contains similar explanatory variables to the MED proposed models, however the EA use population as the denominator and MED use households.

4.1.2 Results

The lagged demand variable is not significant in the current model however households is (refer to the t-statistics in following table). In fact, households was the most significant variable regardless of which series was examined (i.e. raw data, log transformed, and percentage growth). GDP and population were insignificant when included in the same model as households (due to multi-collinearity).

The overwhelming significance of households as an explanatory variable also supports the approach taken with R2 and R3, since in these functional forms it is implicit that demand is linked to the number of households.

GDP per household was preferred to GNE per household because of a superior model fit (and any forecast of GNE is likely to be based on a GDP forecast so there may be no additional informational advantage in using GNE for forecasting purposes).

Population was tried as a denominator in R2 and R3, however using households was superior.

R2 and R3 both provided a very good fit model, however the raw data model (R2) was superior. The following table compares R2 and the Current model, and shows that R2 has better measures of accuracy.

The t-statistics for R2 show that Aggregate Price is not as significant a variable[3] as GDP per household or the constant, however it has some intuitive appeal and MED believes prices will affect consumer behaviour in the future.

Additional model diagnostics (residual plots, stability of parameters and tests of co-integration) are also provided in the appendices (refer to section 7.3.1).

Residential model diagnostics: Current vs Proposed

The econometric models

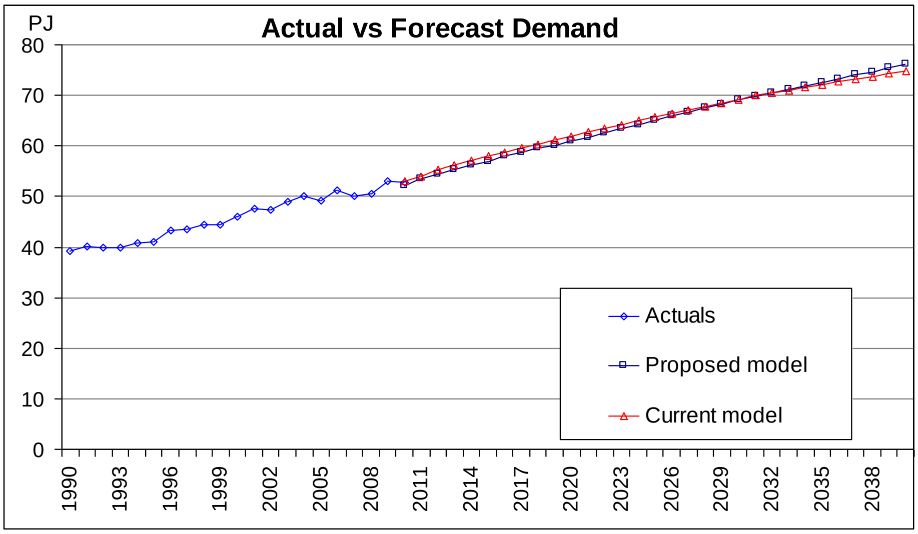
R1: Current demand model (log transformation)			
	Demand (t-1)	HH	Constant
Coefficients	0.22	0.86	-9.26
Std Error	0.24	0.28	3.00
t stat	0.93	3.13	-3.09
t 2 tail prob	36.7%	0.6%	0.7%

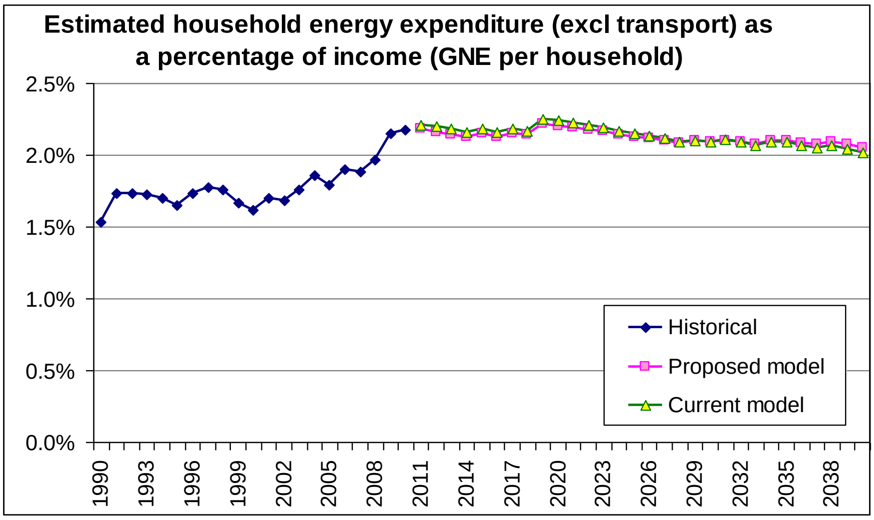
R2: Proposed model - Demand per Household (actual MJ)			
	Aggregate price	GDP p HH	Constant
Coefficients	-48.95	0.10	26,862
Std Error	29.48	0.03	1,563
t stat	-1.66	2.86	17.19
t 2 tail prob	11.4%	1.0%	0.0%

Model statistics

	R1: Current model	R2: Proposed model
Model accuracy		
MSE	0.860	0.771
MAPE	1.51%	1.28%
AIC	-0.001	-0.139
Back-forecast MAPE		
2005	3.7%	3.5%
2006	3.1%	2.9%
2007	3.9%	2.4%
Testing residuals for correlation & stationarity		
Durbin Watson	1.96	2.03
DW p value	50.4%	51.7%
ADF unit root test-stat	-4.42	-4.51
ADF 5% critical value	-1.95	-1.95

[3] Strong multicollinearity may also be increasing the variance of the parameter.





4.1.3 Recommendation

The current demand model has been rejected in favour of R2, based on the superior accuracy diagnostics and the theoretical appeal of the functional form. Another advantage with R2 is that it removes the need for the separate "fuel conservation" price elasticity parameter when forecasting individual fuels in the stage two forecast (since Aggregate Price is in the stage one forecast).

4.2 Commercial stage one econometric model

4.2.1 Description of the models tested

The current commercial demand model is:

C1. Log demand ~ f (log GDP, log Demand t-1, Constant).

We would expect commercial sector energy demand to be closely related to economic activity in that sector, so we have also tested commercial sector GDP as an explanatory variable. GNE has also been considered, since this is a good proxy for consumer expenditure. Aggregate price was also tested, since price may also be a consideration for commercial consumers.

The EA's electricity demand model has just commercial sector GDP as the predictor, on an untransformed data series.

4.2.2 Results

The current commercial model is quite sound, with all variables significant and good accuracy measures when compared to the alternative models.

The alternative explanatory variables of GNE and Commercial sector GDP were both statistically significant, however Aggregate Price was not significant. The energy intensity of commercial consumers is relatively low compared to industrial consumers so this is perhaps not an unexpected result. In 2010 Commercial sector intensity was 0.45GJ per $1000 of sectoral GDP, while General Industrial intensity was 2.45GJ. Using the Aggregate Price estimates for that year, this means that Commercial energy costs (excluding transport) were around $18 for every $1000 of GDP (1.8%) while General Industrial costs were around $72 (7.2%). The following page has a chart of historical and forecast intensities.

An autoregressive parameter was also included in the alternative models to help combat strong correlation in the model errors. The best fit models were:

C1. The current demand model: Log demand ~ f (log GDP, log Demand t-1, Constant)

C2. Log Commercial demand ~ f(log Commercial sector GDP, log Demand t-1, Constant)

C3. Log Commercial demand ~ f(log GNE, log Demand t-1, Constant)

C4. Annual % growth in Commercial demand ~ f(annual % growth in Commercial sector GDP)

The following table shows that diagnostics for these models were all reasonably close, with C2 and C3 slightly better fit.

The appendices (section 7.3.2) contain additional model diagnostics (residual plots, stability of parameters and tests of co-integration).

Commercial model diagnostics: Current vs Proposed

The econometric models

C1: Current demand model (log transformation)

	Demand (t-1)	GDP	Constant
Coefficients	0.62	0.39	-1.54
Std Error	0.10	0.10	0.42
t stat	6.11	3.86	-3.64
t 2 tail prob	0.0%	0.1%	0.2%

C2: Proposed model - log data

	Demand t-1	GDP (Commercial)	Constant
Coefficients	0.53	0.39	-1.27
Std Error Values	0.14	0.11	0.38
t stat	3.91	3.54	3.37
t 2 tail prob	0.1%	0.2%	0.3%

C3: Proposed model - log data (GNE)

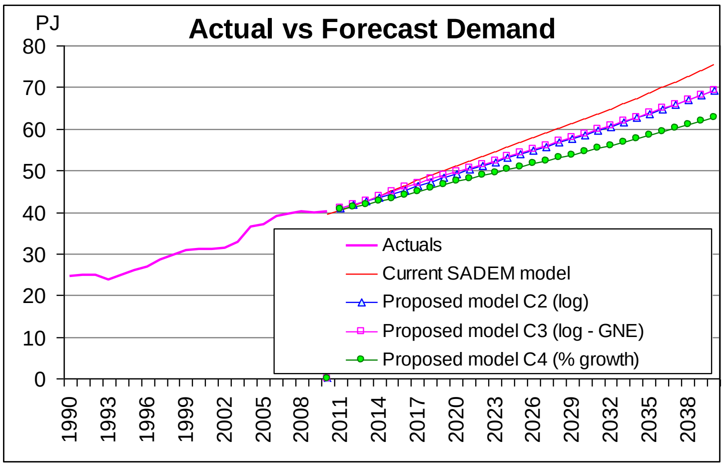
	Demand t-1	GNE ($m)	Constant
Coefficients	0.56	0.38	-2.88
Std Error Values	0.10	0.08	0.65
t stat	5.63	4.58	4.46
t 2 tail prob	0.0%	0.0%	0.0%

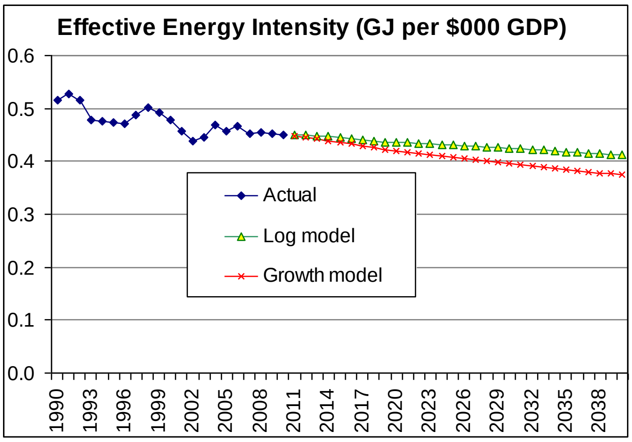
C4: Proposed model - %growth data

	GDP: Commerc
Coefficients	0.71
Std Error Values	0.19
t stat	3.78
t 2 tail prob	0.1%

Model statistics

	C1: Current model	Proposed models: C2: Log model	C3: Log model (GNE)	C4: Growth model
Model accuracy				
MSE	0.719	0.757	0.650	0.937
MAPE	1.65%	1.64%	1.54%	2.26%
AIC	-0.361	-0.272	-0.562	-0.031
Back-forecast MAPE				
2005	4.4%	3.1%	4.2%	1.4%
2006	3.5%	2.7%	3.5%	1.5%
2007	4.5%	4.4%	4.1%	2.2%
Testing residuals for correlation & stationarity				
Durbin Watson	1.77	1.53	1.87	1.64
DW p value	21.3%	7.3%	31.4%	28.3%
ADF unit root test-stat	-4.09	-3.53	-4.57	-3.87
ADF 5% critical value	-1.95	-1.95	-1.95	-1.95

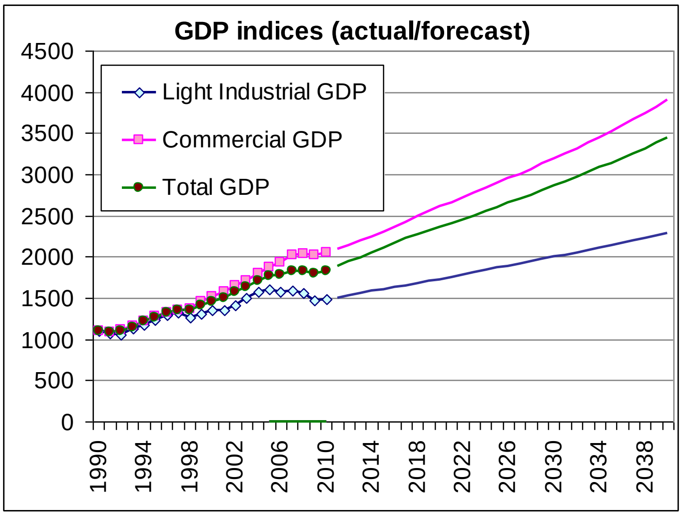




4.2.3 Recommendation

The Current model (C1) has been rejected in favour of one that uses sectoral GDP.

If we return to our evaluation criteria we need to consider simplicity and consistency as well as the model accuracy. Because C2 and C3 both produce almost identical forecasts, it probably doesn't matter which model is used, so the preference is C2 which uses Commercial sector GDP. Using sectoral GDP is more consistent with the preferred General Industrial model which also uses a sectoral GDP measure. The following chart shows the sectoral GDP forecasts for General Industry and Commercial which differ considerably.



The growth model (C4) also has some appeal due to its simplicity and close alignment with the preferred General Industrial model. C2 and C4 both use the same explanatory variables but are modelled using different methods, and produce different forecasts out to 2040 (refer to the chart in the results sections).

Therefore, the proposed model is a weighted average ("ensemble") of models (C2) and (C4) which mitigates the risk of model misspecification. It is proposed that the weightings for each model be 50/50.

4.3 General Industrial stage one econometric forecast

4.3.1 Description of the models tested

The current log demand model is:

I1. Log demand ~ f (log GDP, log Demand t-1, Constant).

Industrial sector energy demand is expected to be closely related to economic activity in that sector, so we have also tested industrial sector GDP as an explanatory variable (using the subset of ANZSIC codes that are included in the General Industrial demand data). Aggregate price was also tested, since price should also be a consideration for industrial consumers.

The EA's electricity demand model just has Industrial sector GDP as the predictor.

4.3.2 Results

The current model has very poor diagnostics – in the following table GDP is not significant and has a negative sign (implying that a rise in GDP reduces energy demand). The forecasts are also very unstable (refer to appendices section 7.3.3).

In terms of the alternative models, General Industry GDP and Aggregate Price were together the best explanatory variables. As discussed in the Commercial section, energy intensity is higher for the Industrial sectors so it is not surprising to see that price is significant. The two best models were:

I2. Log General Industrial demand ~ f(log General Industrial GDP, log Aggregate Price, log Demand t-1, Constant, Error t-1)

I3. Annual % growth in General Industrial demand ~ f(annual % growth in General Industrial GDP, Aggregate Price)

For the log transformed model I2, autoregressive and moving average terms were both required in order to mitigate strong autocorrelation in the errors. However, the following table shows that the Durbin-Watson statistic is only just significant even with the AR and MA terms in the model. Both I2 and I3 are quite similar in terms of the model accuracy, error autocorrelation tests and the forecast trajectories.

Industrial model diagnostics: Current vs Proposed

The econometric models

I1: Current demand model (log transformation)

	Demand t-1	GDP	Constant
Coefficients	0.92	-0.03	0.57
Std Error	0.20	0.12	0.26
t stat	4.56	-0.24	2.16
t 2 tail prob	0.0%	81.6%	4.6%

I2: Proposed model - log data

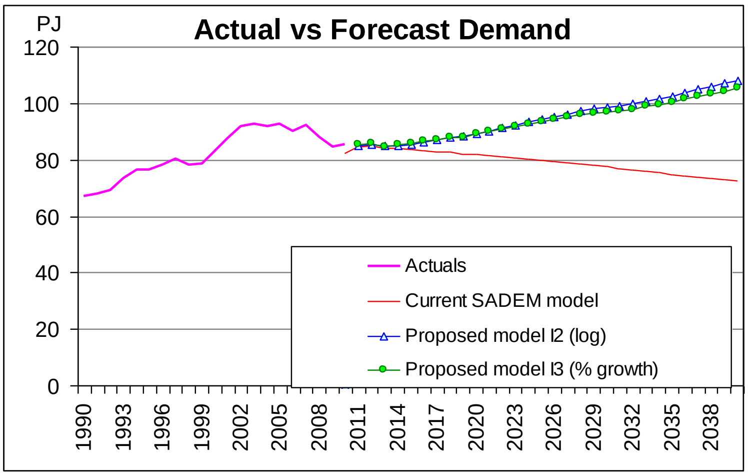
	Demand t-1	Aggregate price	GDP (Industrial)	Constant	MA
Coefficients	0.35	-0.15	0.54	-0.56	0.48
Std Error	0.23	0.04	0.20	0.43	
t stat	1.54	3.72	2.77	1.30	
t 2 tail prob	14.2%	0.2%	1.4%	21.1%	

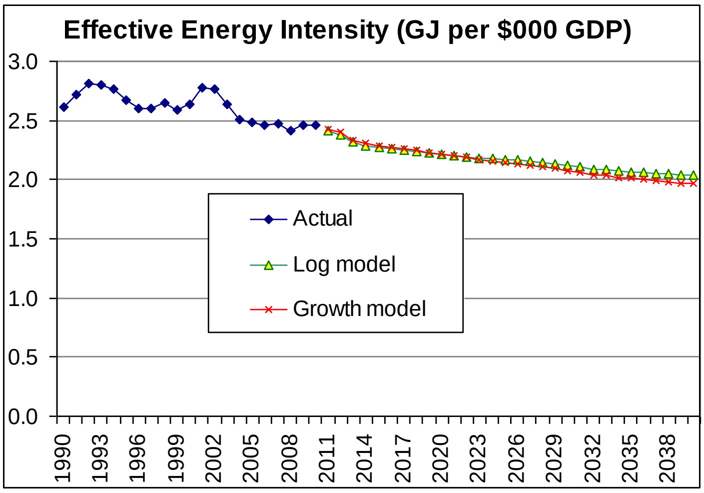
I3: Proposed model - %growth data

	Aggregate price	GDP (Industrial)
Coefficients	-0.20	0.69
Std Error	0.06	0.11
t stat	-3.44	6.51
t 2 tail prob	0.3%	0.0%

Model statistics

		Proposed models	
	I1: Current model	I2: Log model	I3: Growth model
Model accuracy			
MSE	2.369	1.463	1.464
MAPE	2.18%	1.44%	1.21%
AIC	2.025	1.551	0.984
Back-forecast MAPE			
2005	13.5%	2.0%	3.1%
2006	13.4%	2.0%	4.0%
2007	10.2%	2.4%	2.7%
Testing residuals for correlation & stationarity			
Durbin Watsor	1.45	1.36	1.28
DW p value	4.9%	6.3%	5.8%
ADF unit root t	-3.33	-2.56	-2.77
ADF 5% critica	-1.95	-1.95	-1.95





4.3.3 Recommendations

The current model has been discarded – the diagnostics are extremely poor and the forecasts very unstable.

Both (I1) and (I2) have good fit and produce very similar forecasts. Since (I2) is a simpler equation, it is proposed that this growth model be used.

4.4 Stage two market share model

4.4.1 Description of the models tested

The current stage two model assumes a market share elasticity parameter and a lag parameter for each demand sector (Residential, Commercial and General Industry). This elasticity parameter is applied to all fuels within that sector, based on the relative prices of the fuels.

The result is that all fuels are assumed to have the same ability to switch with each other, which is not the case in reality (for example an industrial boiler may be able to switch between gas and coal only). The parameters are estimated based on literature searches and qualitative views on the potential for fuel switching in the future.

An alternative approach has been considered where the cross elasticities are fuel specific (as shown in the following tables). The elasticity values have been estimated using a "least squared error" approach. An initial forecast was produced with all elasticities set at 0. The model errors from this initial forecast were then minimised by adjusting the elasticity parameter values. This was done using a linear least squares optimisation in Matlab[4].

Price signals can induce some fuel switching immediately (eg. a boiler switching from gas to coal) while some switching is available only over time (eg. new houses being built with heat pumps as opposed to gas heating). However, we have not modelled a lag parameter in the new approach. The current model allows price effects to lag up to one year, but this is a long term forecasting exercise so whether a price signal affects demand this year or next year is not so relevant when we are looking at producing a forecast out to 2040. Quantifying the short term versus long term (two year plus) demand effect may be a useful research project using the least squared errors approach and we may re-visit this lag effect in a subsequent model update.

The fuel conservation elasticity parameters from the current model no longer needs to be included in the new approach, since the stage one econometric equations now include an "Aggregate Price" variable.

The mathematical description of the new approach is contained in the appendices (7.2).

[4] An additional non-linear optimisation was also performed in Excel with additional constraints. This tended to give similar results in terms of the parameter estimates. The MATLAB approach was retained for simplicity.

4.4.2 Results

The least squares optimisation produced the following results.

Market share cross/price elasticities

Residential

	Elec	Gas	LPG
Elec		0.01	0.00
Gas		0.00	0.04
LPG			

Commercial

	Elec	Gas	Diesel	LPG
Elec		0.04	0.00	0.01
Gas		0.00	0.00	0.00
Diesel		0.00	0.00	0.00
LPG				

General Industry

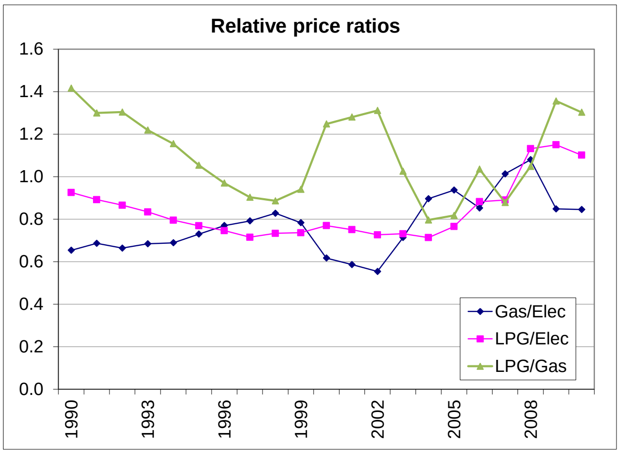
	Elec	Gas	Coal	Diesel	Fuel_(	LPG
Elec		0.00	0.08	0.00	0.00	0.00
Gas		0.00	0.09	0.00	0.00	0.00
Coal		0.00	0.00	0.00	0.12	0.13
Diesel		0.00	0.00	0.00	0.00	0.00
Fuel_Oil		0.00	0.00	0.00	0.00	0.00
LPG						

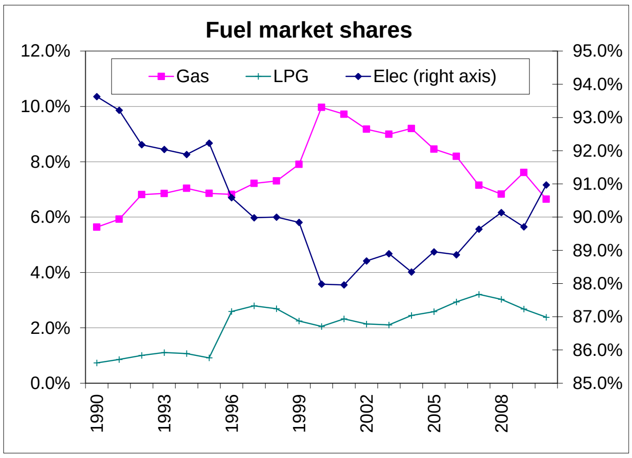
A cross elasticity of 0 means that the fuels cannot be substituted. An elasticity value of 0.01 means that a 100% increase in the price of fuel B relative to fuel A results in a 1% increase in the demand for fuel A (and an equal decrease in fuel B demand in absolute terms)[5].

The optimised parameter values reflect the patterns in the historical data and we must be weary of coincidental results or of patterns which may change in the future. In saying that, the parameters estimated above do appear to reflect realistic fuel switching potential. When implementing this approach in SADEM in the future we would still need to apply some qualitative judgement around the estimates.

The relationship between relative fuel prices and market shares can be illustrated in the following charts for the Residential sector. Between 2002 and 2008 the price of gas rose relative to the electricity price. This is consistent with an increase in the electricity market share over the same period, and a fall in the gas market share.

Residential price ratio and market share trends





[5] Note that the elasticities are defined with respect to the fuels on the vertical axis, so the 0.01 for residential elec/gas is the percent change in electricity demand from a 100% percentage change in the relative price between these fuels (price gas / price electricity). The resulting percent change in gas will be a negative sign, but will be a much higher percentage since electricity demand (PJ) is much higher than gas.

When evaluating model accuracy at fuel and sector level, the proposed model is superior to the current model (see following table). The greatest improvements have been made in the General Industry model, especially when assessing the MAPE for the 2006 "back-forecasts"[6].

Diagnostics[7] for the four large fuel groups

Current model

MAPE of modelled history, 1990-2010

	Elec	Gas	Coal	Diesel	Total
Light Industry	2.50%	4.93%	10.55%	6.56%	2.08%
Commercial	1.66%	4.30%	0.00%	18.31%	2.03%
Residential	2.08%	6.23%	0.00%	0.00%	1.95%
Total excl HI	**1.24%**	**3.68%**	**10.55%**	**6.28%**	**1.20%**

MAPE from 2006 "back-forecast" (2006-2010)

	Elec	Gas	Coal	Diesel	Total
Light Industry	6.32%	12.83%	22.08%	23.80%	12.39%
Commercial	4.10%	14.71%	0.00%	29.40%	5.07%
Residential	3.92%	28.49%	0.00%	0.00%	5.70%

Correlation in residuals

	Elec	Gas	Coal	Diesel	Total
Light Industry	-0.22	-0.44	-0.21	0.14	-0.17
Commercial	-0.05	-0.06	0.00	-0.43	-0.24
Residential	-0.14	0.14	0.00	0.00	-0.08
Total excl HI	**-0.29**	**-0.18**	**-0.21**	**-0.10**	**0.07**

Proposed model

MAPE of modelled history, 1990-2010

	Elec	Gas	Coal	Diesel	Total
Light Industry	2.15%	3.77%	10.41%	4.38%	1.36%
Commercial	1.68%	3.90%	na	16.21%	1.85%
Residential	1.43%	6.93%	na	na	1.34%
Total excl H	**1.03%**	**3.30%**	**10.38%**	**4.46%**	**0.66%**

MAPE from 2006 back-forecast (model errors 2006-2010)

	Elec	Gas	Coal	Diesel	Total
Light Industry	4.97%	3.81%	7.15%	7.41%	3.03%
Commercial	2.40%	12.03%	na	18.19%	1.77%
Residential	1.84%	15.44%	na	na	2.78%

Correlation in residuals

	Elec	Gas	Coal	Diesel	Total
Light Industry	-0.18	-0.44	-0.09	0.24	0.02
Commercial	0.38	-0.14	na	-0.33	-0.07
Residential	0.18	0.07	na	na	0.03
Total excl HI	**-0.22**	**-0.25**	**-0.09**	**-0.13**	**-0.02**

The following charts decompose the General Industry 2006 back-forecast errors, showing how much of the variance was attributable to the stage one econometric model (and therefore errors in the GDP/Price/Household forecasts) and how much was due to the market share allocations to the fuels. These highlight the inadequacies in the current model and the improvements made with the proposed model.

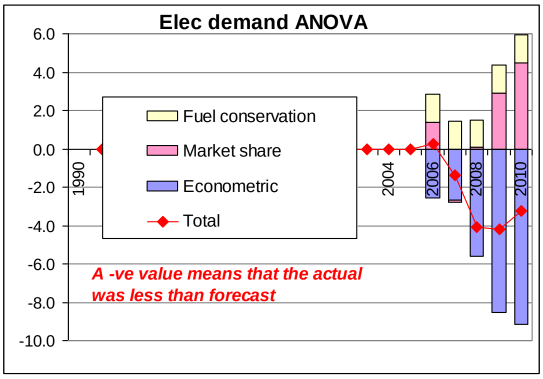
There are some additional diagnostic charts in the appendices section 7.4 also (residual plots and "back-forecast" error analysis).

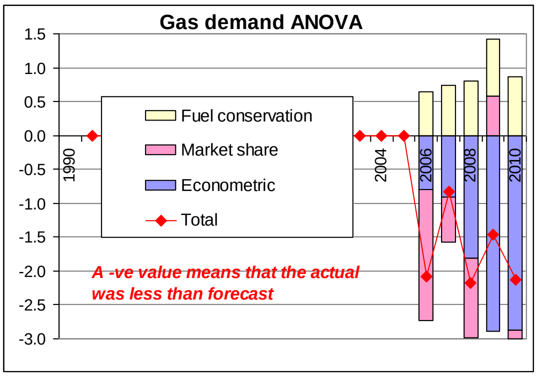
[6] Forecasts were made using 2006 as the start year, and then the 2006-2010 forecasts were compared to actual values in those years by using the "Mean absolute percent error" (MAPE).

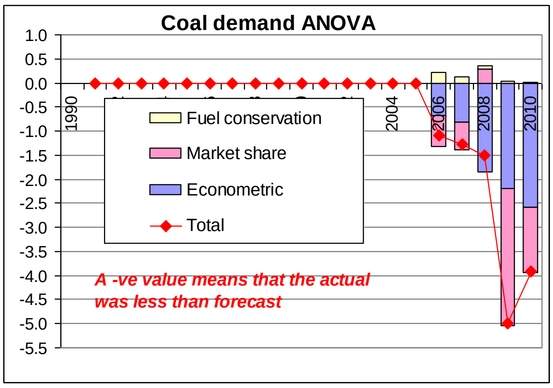
[7] Note that the Total MAPE is not equal to the sum of the individual fuels because the fuel errors are not perfectly correlated. For example, a large positive error in electricity in year X may coincide with a large negative error in gas, resulting in a relatively low error value for Total energy demand in that year.

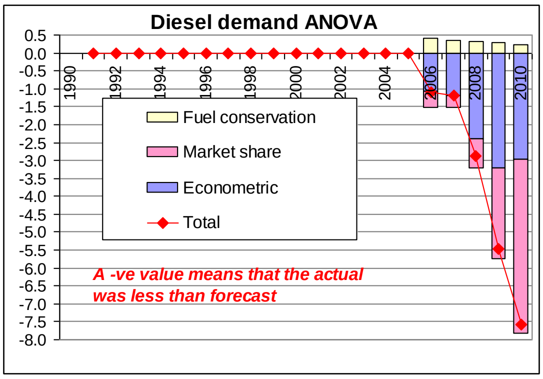
General Industry model back-forecast error analysis

Current model

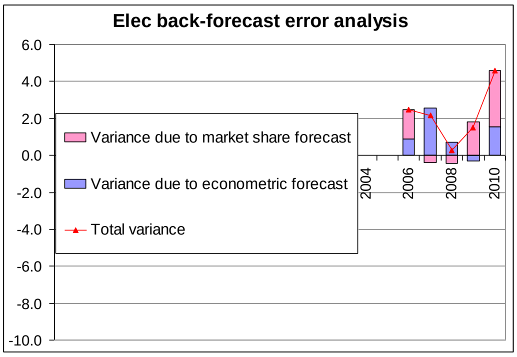


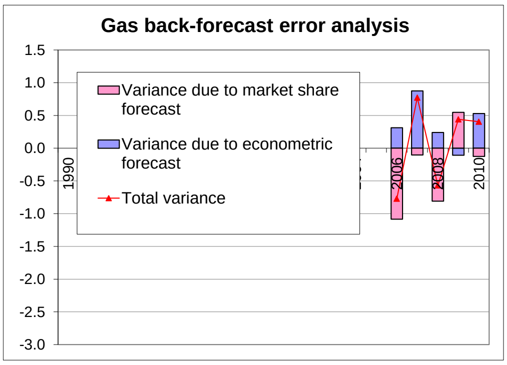


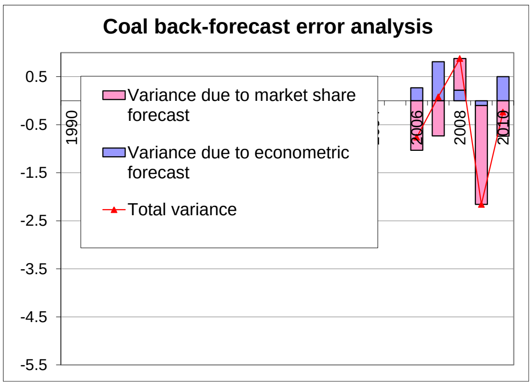


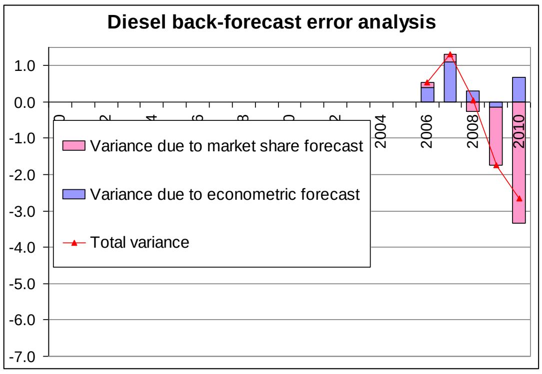


Proposed model









4.4.3 Recommendations

The current stage two forecast approach has been rejected in favour of the proposed model. The proposed model has more design appeal:

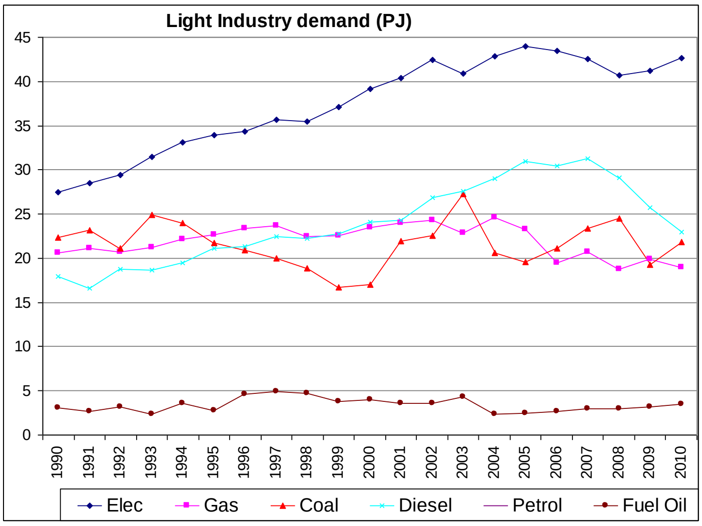
- the ability to estimate market share elasticity parameters between each fuel,
- avoiding the estimation of a "fuel conservation" elasticity parameter (perhaps offsetting the added complexity introduced from the above point), and
- more mathematical rigour applied to the method of estimating the elasticity parameters.

The proposed model also has superior accuracy diagnostics.

5 Electricity demand forecasting for 2012 GPAs

The models outlined in the previous section work well for forecasting an energy "system", taking into account the inter-relationships between the fuels. This model design is very useful for producing MED's Energy Outlook forecasts, where we want to examine the influence of drivers such as carbon price, fuel price, GDP, etc on demand for each of the fuels. However, from 2012 MED will also be responsible for providing national electricity demand forecasts as part of the "Grid Planning Assumptions" (GPAs). The GPA's will be used as a basis for evaluating grid upgrade proposals from Transpower. As a result we expect additional scrutiny on MED's electricity demand forecast.

Some of the fuel groups (e.g. General Industrial coal) exhibit a lot of annual volatility in the historical data (see chart). The fuels are multiplied by their respective efficiencies, then summed, to provide an effective energy data series. Therefore, the effective energy data series, and the resulting forecasts, will be influenced by volatility in the underlying fuels.



The electricity demand forecast is based on a two stage process: the first stage forecasts effective total energy demand (for all fuels), and the second stage allocates demand across fuels based on market shares. This means that volatility in other (non-electricity) fuels affect the electricity forecast via the stage one forecast. Electricity has the dominant market share in all sectors, so will be the main driver of effective energy trends, however, the other fuel series will be influencing the electricity forecast in some way.

Therefore, if we were to focus purely on electricity, the model design may be different. For example, the Electricity Authority and Transpower forecast electricity without taking into account the inter-relationships between the various fuel groups – they regress electricity demand on the most significant explanatory variables (GDP, Price, Population, Number of Households).

Several options have been considered for producing electricity demand forecasts:

1) use the MED forecast produced for the Energy Outlook,

2) use an alternative "electricity focused" MED forecast (similar approach to the current EA or Transpower forecasts),

3) use the EA or Transpower electricity forecasts,

4) use a weighted average of the above three forecasts.

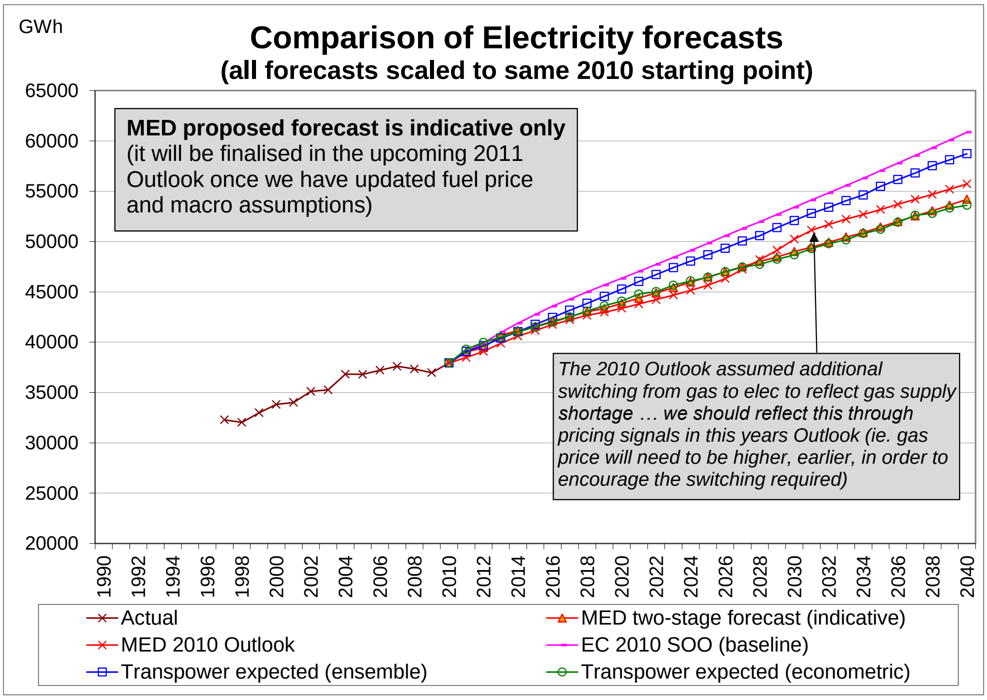
Option 1 has the disadvantages already mentioned around the volatility of other fuels, however it has the advantage of considering how all the fuels interact in an energy system.

Options 2 and 3 have the inverse attributes (ie. the advantages of not being influenced by the volatility of alternative fuel series, however the disadvantage of not reflecting the effect of substitute fuel groups).

Option 4 merits further consideration. When producing the GPA forecasts MED could consider the range of demand forecasts produced from the EA, Transpower and MED. A set of rules would be established to determine how to weight the forecasts. MED would consult on the proposed approach and take into account stakeholder feedback when finalising the electricity demand forecasts.

Transpower have recently revised their forecasts, and their econometric forecast is closely aligned with the MED two-stage forecasts (refer to following chart). However, the MED two-stage forecasts are purely indicative at this stage, they will be finalised in the 2011 Outlook once we have updated fuel price and macroeconomic assumptions.

MED will also need to consider how best to reflect uncertainty in the forecasts. The Outlook Reference Scenario could be considered a "central" forecast. The Outlook sensitivity scenarios are designed to test more extreme outcomes, and do not explicitly consider the probability of these extreme outcomes occurring. The GPA "P90" forecast may require a different approach which can be considered at a later stage when MED consults on the GPA demand forecasts.



6 Conclusions and recommendations

The first question to address is whether to maintain the current two-stage forecasting approach (stage one = effective energy, stage two = market shares for individual fuels). A more bottom-up approach, where each fuel was forecast individually in a set of simultaneous equations, would have its advantages, such as allowing for the unique trends and relationships at a fuel demand (as opposed to energy demand) level. However, this simultaneous equation approach was tested by NZIER and was not feasible. The current two stage approach is far simpler and can be improved, and therefore that is the recommendation.

> *Recommendation 1: maintain the current two stage forecasting process*
>
> *(stage 1 = effective energy, stage 2 = individual fuels based on market shares)*

Section 4 shows evidence that the current stage one econometric equations for total effective energy can be improved, especially for the General Industry and Residential sectors. The proposed models have been chosen based on the evaluation principles outlined in section 4.

> *Recommendation 2: reject the current econometric models and re-specify as follows:*
>
> *Residential demand = Numbers of Households * Demand per household, where*
>
> *Demand per household = f(GDP per household, Energy Price, Constant)*
>
> *Commercial demand forecast is a weighted average of following forecasts:*
>
> *Log Commercial demand = f(log Commercial GDP, log Commercial demand t-1, Constant)*
>
> *Commercial demand annual %Δ = f(Commercial GDP annual %Δ)*
>
> *General Industrial demand annual %Δ = f(Industrial GDP annual %Δ, Energy price annual %Δ)*

Applying a single elasticity value for all cross fuel substitution doesn't always make sense. For example, the current model allows for substitution between petrol (direct use, not transport) and electricity for residential consumers. It is more likely that Fuels such as gas, coal and fuel oil could be substitutable, in industrial boilers for example. Therefore the recommendation is to identify the fuel cross-elasticities separately, for each sector, in a matrix as shown in section 4.4.2.

Recommendation 3: replace the current market share elasticity parameter with separate elasticity values for each fuel, based on the relative prices between the fuels.

The fuel conservation price elasticity parameter can be omitted from the new model specification if we instead use the "Aggregate Price" indicator in the stage one forecast. The current model has a qualitative estimate of the elasticity parameter, whereas this new method would allow for a more statistically robust estimate. Section 3 showed that "Aggregate price" was significant for Residential and Industrial consumers only.

Recommendation 4: remove the current "fuel conservation" price elasticity parameter, and instead introduce the "Aggregate price" indicator variable into the stage one forecast for Residential and General Industry.

Electricity demand forecasts are also required for the 2012 GPAs. MED needs to consider how appropriate the Energy Outlook forecasts are for this purpose, and should also consider alternative electricity forecasts (e.g. EA and Transpower).

Recommendation 5: consider alternative electricity-specific forecasts (as well as the MED Outlook forecast) when determining the GPA demand forecasts

NZIER's assessment of the recommendations:

1. Agree
2. Agree
3. Agree
4. Agree
5. Agree

7 Appendices

7.1 The current demand models in SADEM

These models have different exogenous drivers and different parameters, however the basic construction of each model is identical. Outlined below is the sequence of equations used to produce a final demand forecast in one of these sectors.

The first step is to forecast the "effective" energy demand which is the net petajoules (PJ) of energy consumed (net PJ of fuel consumed takes into consideration the "efficiency" of each fuel). The effective demand forecast is based on an econometric relationship with an exogenous driver and an autoregressive parameter is also used due to the strong autocorrelation in the historical series.

(1) $Effective\_energy_{s,t} = \exp\{\beta_{1,s} * \ln(Exog_{s,t}) + \beta_{2,s} * \ln(Effective\_energy_{s,t-1}) + Constant_s\}$

where $Exog_{s,t}$ is the exogenous driver for sector s in year t,

exp is the natural exponential function,

and ln is the natural log.

The sectors (s) are Residential, Commercial and General Industry. The following table shows the exogenous drivers for each.

Table 1 Demand model drivers

Sector	Exogenous driver	$\beta_{1,s}$	$\beta_{2,s}$	$Constant_s$
Residential	Household numbers	.62	.38	-.65
Commercial	GDP	.38	.48	-.97
General Industry	GDP	.35	.18	.6

The remaining equations calculate how this effective energy demand is broken down into demand for the alternative fuels. This is where we introduce the prices for each fuel type and allow for switching between fuels based on relative fuel prices.

(2) $Unadj\_mkt\_share_{f,s,t} = Base\_mkt\_share_{f,s} * (Price_{f,s,t}\hat{}Mkt\_elasticity_s / Price_{f,s,base}\hat{}Mkt\_elasticity_s)$

where $Unadj\_mkt\_share_{f,s,t}$ is the unadjusted market share for fuel f, sector s and year t,

$Base\_mkt\_share_{f,s}$ is the market share in the base year, in this case 2008, and

$Mkt\_elasticity_s$ is the elasticity parameter reflecting the degree of fuel switching in response to relative price changes.

At this point when we sum the market shares across the fuels we will get a number less than 1 if all fuel prices have increased relative to their base years. Since equation (2) is focused only on fuel switching, we need to make a pro-rata adjustment so that the market shares sum to 1. This is outlined in equation (3) which also introduces a lag parameter, Mkt_lag_s, which has a value between 0 and 1.

$$(3)\ Adj\_mkt\_share_{f,s,t} = (1-Mkt\_lag_s) * (Unadj\_mkt\_share_{f,s,t} / \Sigma Unadj\_mkt\_share_{s,t}) + Mkt\_lag_s * Adj\_mkt\_share_{f,s,t-1}$$

We can then apply the market share percentages in (3) to the effective energy demand in (1) to get a preliminary demand for each fuel:

$$(4)\ Prelim\_demand_{f,s,t} = Adj\_mkt\_share_{f,s,t} * Effective\_energy_{s,t} / Efficiency_f$$

where $Efficiency_f$ is the efficiency with which fuel (f) can be converted to energy.

The final demand equation introduces a "fuel conservation" effect via the price elasticity parameter "$Price\_elasticity_s$". This elasticity parameter allows total fuel demand to reduce in response to increasing prices (as opposed to the parameter $Mkt\_elasticity_s$ which was just concerned with relative market shares of the fuels). Equation (5) also introduces another lag parameter, $Price\_lag_s$.

$$(5)\ Final\_demand_{f,s,t} = Prelim\_demand_{f,s,t} * \{(Price_{f,s,t}/Price_{f,s,base})\hat{}Price\_elasticity_s\} * \{(Final\_demand_{f,s,t-1} / Prelim\_demand_{f,s,t-1})\hat{}\ Price\_lag_s\}$$

The following table shows the elasticity and lag parameter values for each sector.

Table 2 Demand model elasticities

Sector	$Mkt\_elasticity_s$	Mkt_lag_s	$Price\_elasticity_s$	$Price\_lag_s$
Residential	-0.5	0.2	0.0	0.2
Commercial	-0.5	0.5	-0.01	0.5
General Industry	-0.5	0.5	-0.05	0.5

Omitted from the above equations are some additional calculations relating to the direct use of gas. If total gas demand is greater than total production then the demand for gas can be scaled back so that gas supply and demand are in equilibrium. If gas is scaled back then we assume there will be offsetting increases in coal and electricity demand (these assumptions differ for each sector as shown in the below table). In the Reference Scenario we assume the gas demand is scaled back by 20% from 2027.

Table 3 Redistribution of gas

Fuel	Specific Industry	General Industry	Commercial	Residential
Electricity	70%	80%	90%	95%
Coal	30%	20%	10%	5%

7.1.1 Estimating the elasticity and fuel switching parameters

These were initially based on a literature search providing generic elasticities and fuel switching parameters, over several years of modelling these have been revised based on fine tuning and calibration of the model outputs. The sub-models are not very sensitive to these variables and because of the dominance of electricity (particularly in the residential and commercial sub-models) these variables do not significantly influence the results.

7.1.2 Exogenous data

GDP

The central GDP forecast for the next 5 years is sourced from The Treasury, and thereafter is based on a long-term productivity rate multiplied by population. The model uses a GDP index normalised to 1000 based on GDP production with 1983 as the base year.

Household numbers

Population and household number projections are sourced from Statistics NZ. The 2010 Reference Scenario uses the Medium Fertility, Medium Mortality and Medium Migration series.

Oil price

The Reference Scenario assumes that oil prices will follow the New York Mercantile Exchange (NYMEX) futures price in the near term, trending towards the International Energy Agency's (IEA) World Energy Outlook (WEO) mid-case projection. For the 2010 modelling the WEO long-term oil price was US$115/bbl (real) by 2030.

7.1.3 Autoregressive term in the econometric demand models

The Demand(t-1) explanatory variable in the econometric equations helps to reduce autocorrelation in the errors. By expanding out the equation below we can see that the Demand (t-1) parameter effectively puts weight on previous GDP forecasts as well as increasing the constant parameter value.

$$D_t = \beta_0 + \beta_1 GDP_t + \beta_2 D_{t-1}$$

$$\begin{aligned} D_{t+1} &= \beta_0 + \beta_1 GDP_{t+1} + \beta_2 D_t \\ &= \beta_0 + \beta_1 GDP_{t+1} + \beta_2(\beta_0 + \beta_1 GDP_t + \beta_2 D_{t-1}) \\ &= \beta_0(1+\beta_2) + \beta_1 GDP_{t+1} + \beta_2\beta_1 GDP_t + \beta_2^2 D_{t-1} \end{aligned}$$

$$\begin{aligned} D_{t+2} &= \beta_0 + \beta_1 GDP_{t+2} + \beta_2 D_{t+1} \\ &= \beta_0 + \beta_1 GDP_{t+2} + \beta_2\{\beta_0(1+\beta_2) + \beta_1 GDP_{t+1} + \beta_2\beta_1 GDP_t + \beta_2^2 D_{t-1}\} \\ &= \beta_0 (1+\beta_2+\beta_2^2) + \beta_1 GDP_{t+2} + \beta_2\beta_1 GDP_{t+1} + \beta_2^2\beta_1 GDP_t + \beta_2^3 D_{t-1} \end{aligned}$$

This is a known value

and so on……

7.2 Mathematical description of the proposed demand models

The following equations show how the final fuel forecasts are produced for the Residential model. The Commercial and General Industry approach is the same.

Equations 1a to 1c describe the price ratio calculations.

(1a) $Price\%\Delta\_Elec\_Gas_t = (Price\_Gas_t / Price\_Elec_t) \,/\, (Price\_Gas_{t-1} / Price\_Elec_{t-1}) - 1$

(1b) $Price\%\Delta\_Elec\_LPG_t = (Price\_LPG_t / Price\_Elec_t) \,/\, (Price\_LPG_{t-1} / Price\_Elec_{t-1}) - 1$

(1c) $Price\%\Delta\_Gas\_LPG_t = (Price\_LPG_t / Price\_Gas_t) \,/\, (Price\_LPG_{t-1} / Price\_Gas_{t-1}) - 1$

Equations 2a-2c describe the fuel switching calculations.

(2a) $Demand\Delta\_Elec_t = Demand\_Elec_{t-1} * Price\%\Delta\_Elec\_Gas_t * \beta_{E,G} + Demand\_Elec_{t-1} * Price\%\Delta\_Elec\_LPG_t * \beta_{E,L}$

(2b) $Demand\Delta\_Gas_t = Demand\_Gas_{t-1} * Price\%\Delta\_Gas\_LPG_t * \beta_{G,L} - (Demand\_Elec_{t-1} * Price\%\Delta\_Elec\_Gas_t * \beta_{E,G})$

(2c) $Demand\Delta\_LPG_t = -1 * (Demand\_Elec_{t-1} * Price\%\Delta\_Elec\_LPG_t * \beta_{E,L} + Demand\_Gas_{t-1} * Price\%\Delta\_Gas\_LPG_t * \beta_{G,L})$

Where $\beta_{E,G}$ is the electricity vs gas elasticity parameter estimated from the least squares optimisation (0.01), $\beta_{E,L}$ is the electricity vs LPG elasticity parameter (0.00) and $\beta_{G,L}$ is the gas vs LPG elasticity parameter (0.04). Note that the sum across 2a-2c will always be zero.

The final forecast for residential electricity, gas and LPG is then:

(3a) $Demand\_Elec_t = S1\_Energy\_Forecast_t * Mkt\_share_{E,t-1} + Demand\Delta\_Elec_t$

(3b) $Demand\_Gas_t = S1\_Energy\_Forecast_t * Mkt\_share_{G,t-1} + Demand\Delta\_Gas_t$

(3c) $Demand\_LPG_t = S1\_Energy\_Forecast_t * Mkt\_share_{L,t-1} + Demand\Delta\_LPG_t$

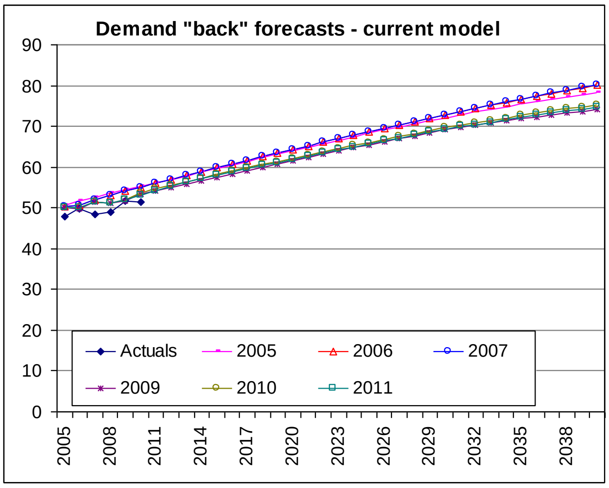
Where $S1\_Energy\_Forecast_t$ is the stage one econometric forecast for effective energy.

7.3 Additional diagnostics for stage one econometric forecasts

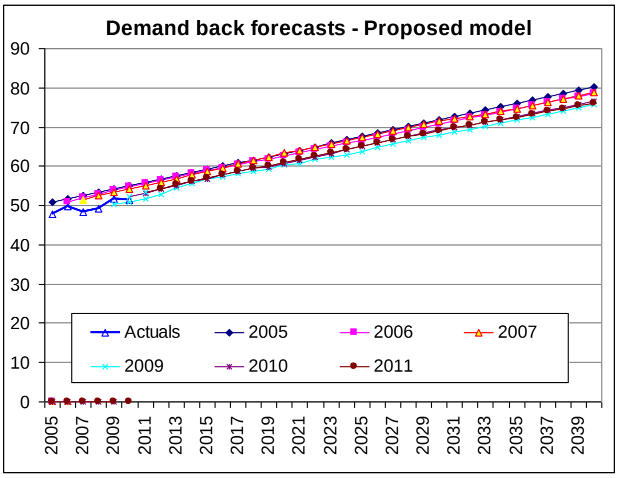
7.3.1 Residential

Stability of forecasts over time

Current model



Proposed model



Stability of parameter estimates over time

Current model

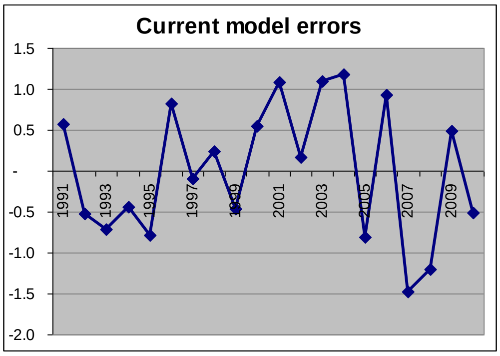
	Demand (t-1)	HH	Constant
2005	0.18	1.08	-12.10
2007	0.08	1.14	-12.57
2009	0.30	0.77	-8.29
2011	0.22	0.86	-9.26

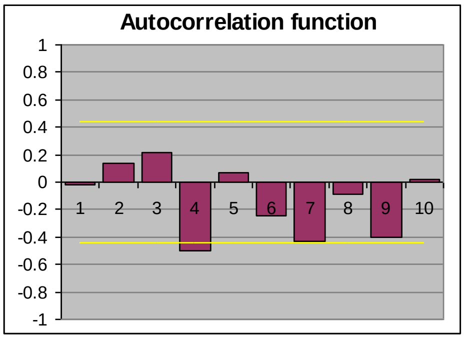
Proposed model

	Aggregate price	GDP p HH	Constant
2005	-29.83	0.11	25,489
2007	-61.67	0.12	25,930
2009	-115.96	0.15	25,591
2011	-48.95	0.10	26,862

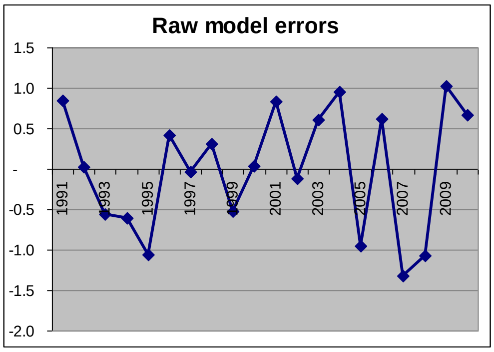
Residual plots

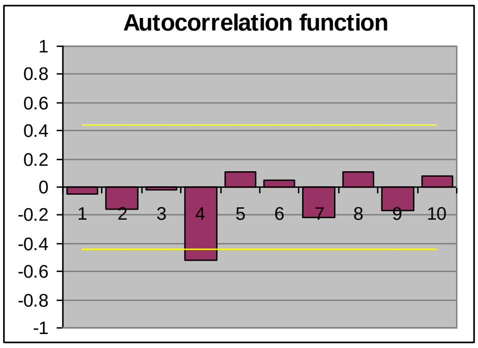
Residual plots: current model



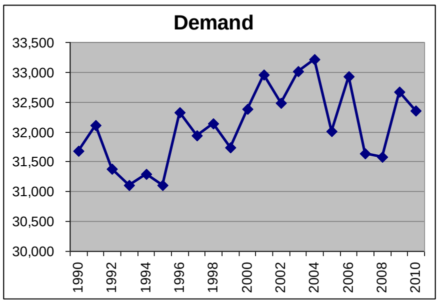
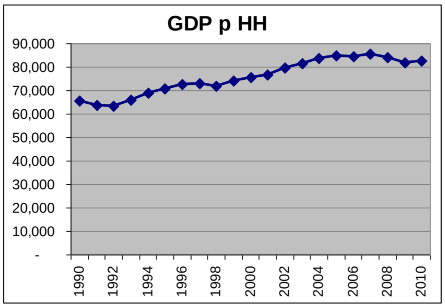
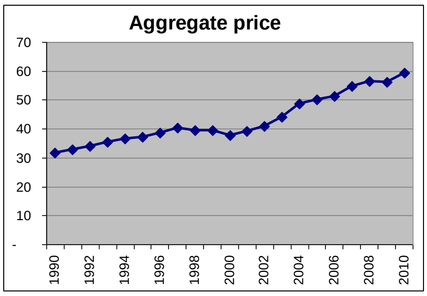
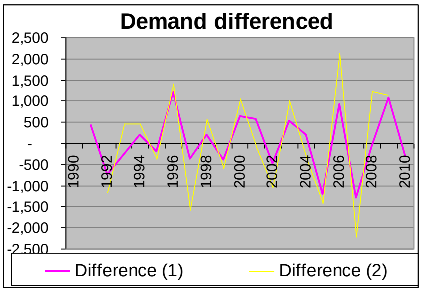
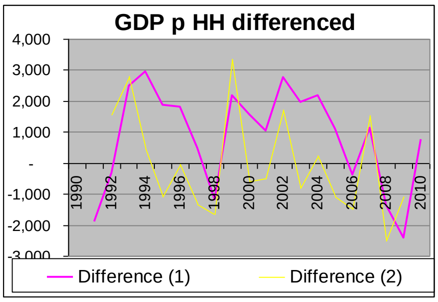
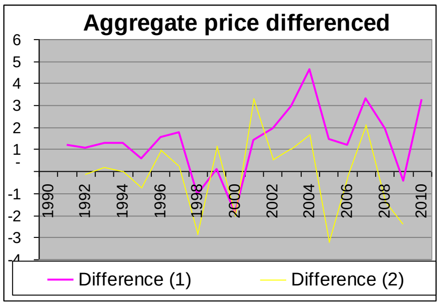
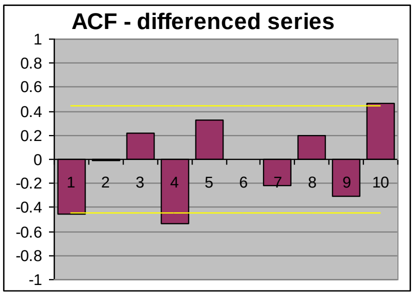
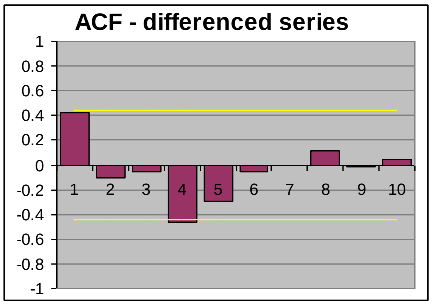
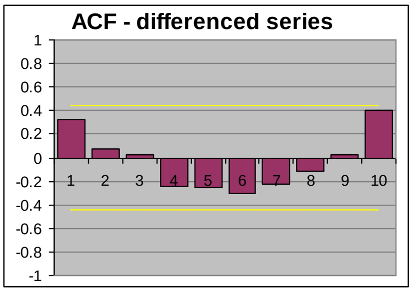


Residual plots: proposed model





Proposed model: data trends and stationarity

Demand per household	GDP per household	Aggregate price
		
		
		

ADF unit root test statistics						
Current model			Proposed model			
Diff order	Current Ln Demand	Current Ln HH	Diff order	Demand per HH	GDP p HH	Aggregate price
1	-6.75	-1.27	1	-7.03	-3.15	-3.14
5% cv	-3.00	-3.00	5% cv	-1.95	-3.00	-3.00
2		-3.86				
5% cv		-1.95				

The augmented Dickey Fuller (ADF) unit root test, combined with analysis of the time series plots, shows that all the time series in the proposed model are all I(1). Therefore, MED have proceeded with the proposed model on the assumption that all the variables can be co-integrated. The residuals from the resulting econometric model appear to be stationary and show no signs of autocorrelation.

However, the ADF test shows that the current model has differing orders of integration, with log demand I(1) and log households I(2).

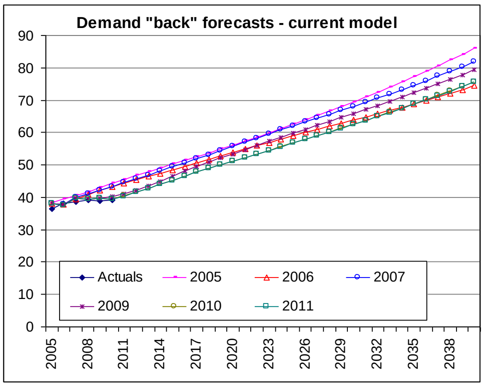
We also tested the proposed model with a reduced data range of 1996-2010, and the F statistic was only 1.35 (ie. model not significant). The 2040 demand forecast was 1.4PJ lower with this model.

GNE (as opposed to GDP) is considered a better proxy for household income, however GDP per household was a superior variable in terms of the model diagnostics.

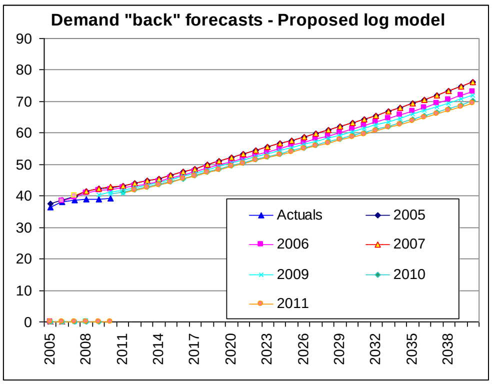
7.3.2 Commercial

Stability of forecasts over time

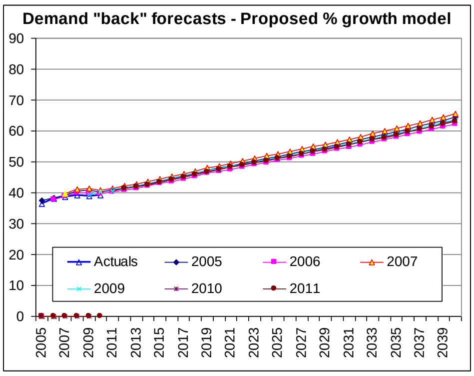
C1: Current model



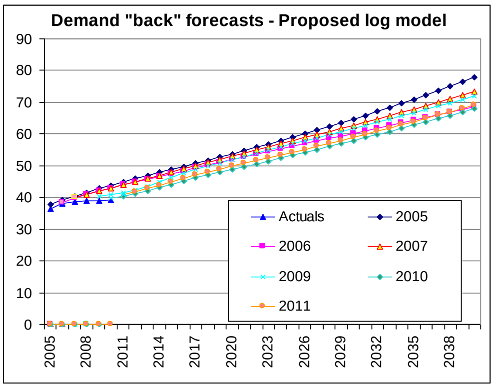
C2: Proposed model (log)



C4: Proposed model (% growth model)



C3: Proposed model (log, GNE)



Stability of parameter estimates over time

C1: Current model

	Demand (t-1)	GDP	Constant
2005	0.66	0.37	-1.49
2007	0.67	0.36	-1.47
2009	0.65	0.37	-1.50
2011	0.62	0.39	-1.54

C2: Proposed model (log)

	Demand t-1	GDP: Commerc	Constant
2005	0.63	0.34	-1.23
2007	0.63	0.34	-1.23
2009	0.58	0.37	-1.24
2011	0.53	0.39	-1.27

C3: Proposed model (log GNE)

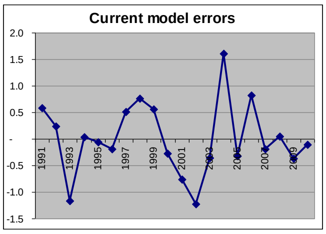
	Demand t-1	GNE ($m)	Constant
2005	0.61	0.36	-2.85
2007	0.61	0.36	-2.82
2009	0.57	0.38	-2.88
2011	0.56	0.38	-2.92

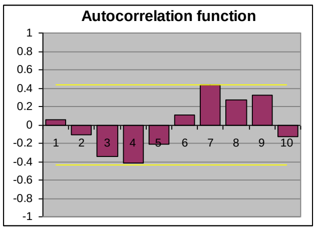
C4: Proposed model (%growth)

	GDP: Commerc
2005	0.72
2007	0.73
2009	0.70
2011	0.70

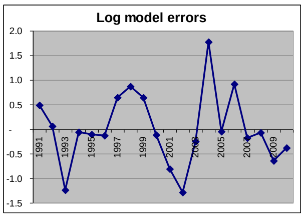
Residual plots

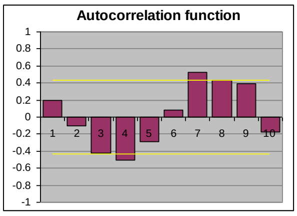
C1: Current model



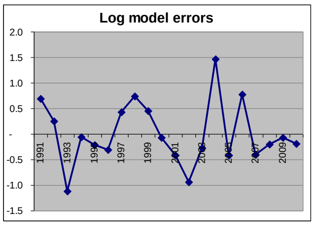


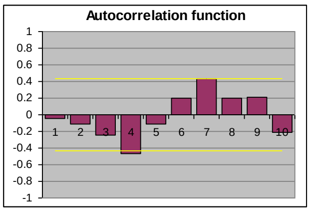
C2: Proposed model (log)



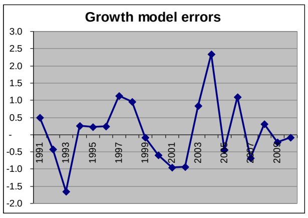


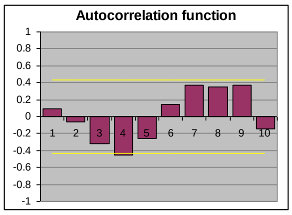
C3: Proposed model (log GNE)





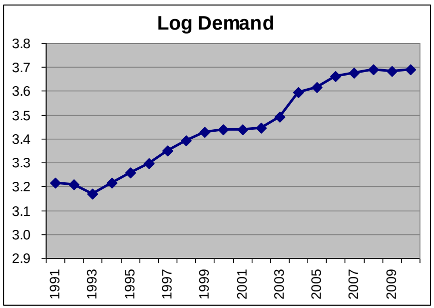
C4: Proposed model (%growth)

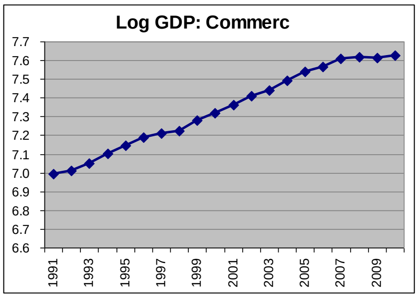


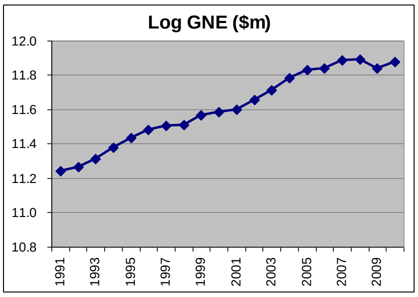


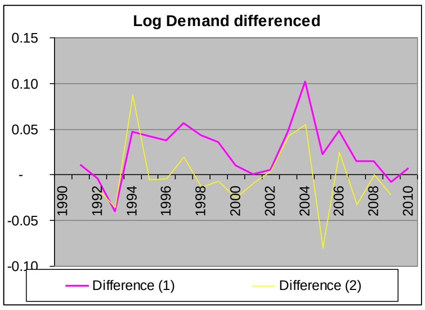
Proposed models C2 and C3: data trends and stationarity

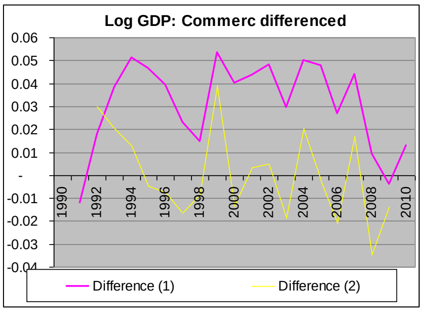
Demand log	Commercial GDP log (model C2)	GNE log (model C3)

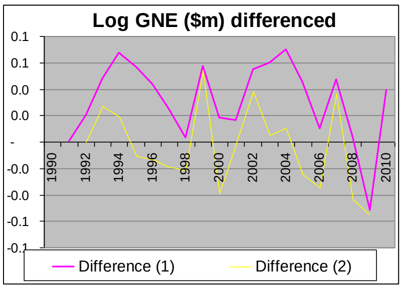


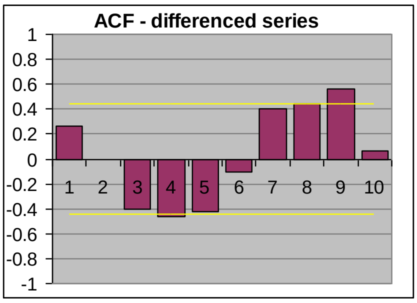


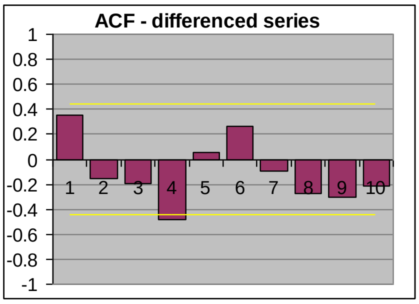


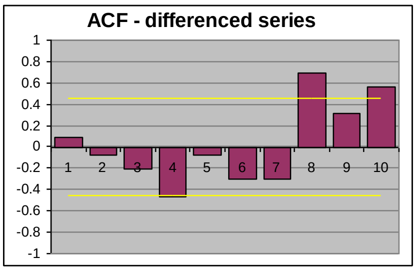


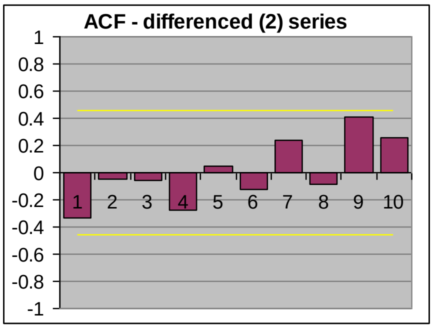


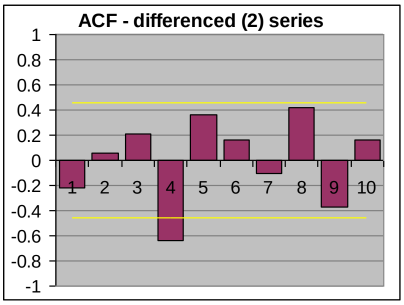


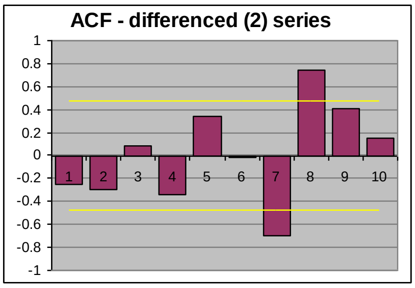




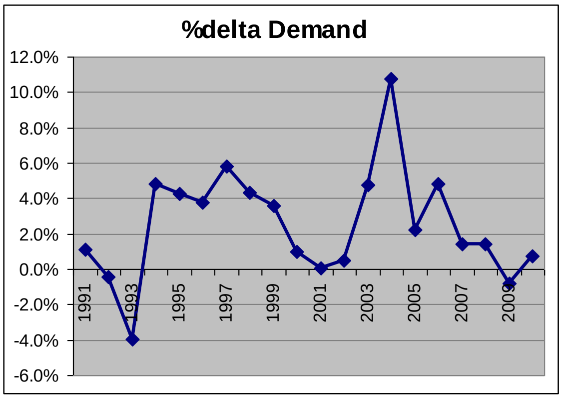
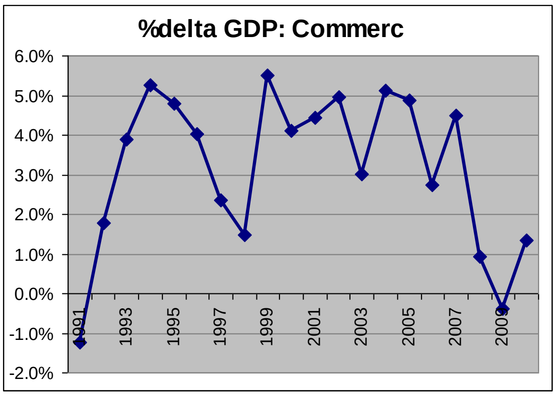
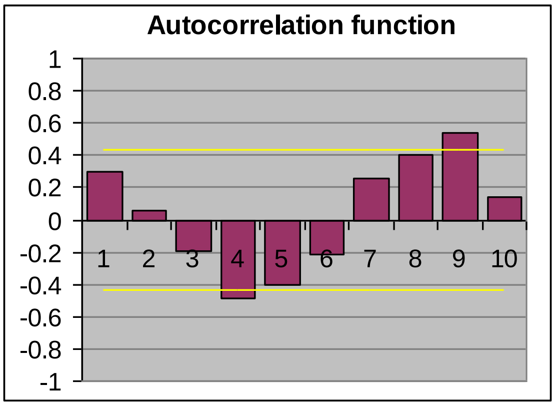
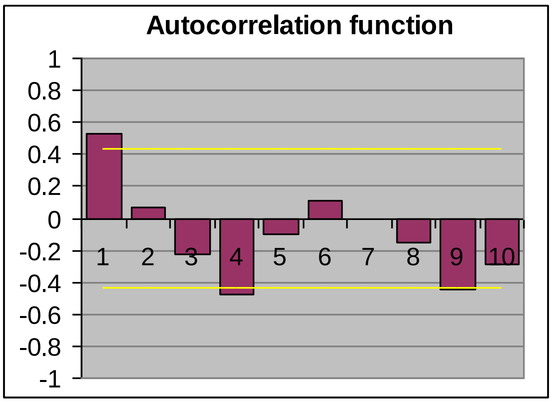








Proposed model C4: data trends and stationarity

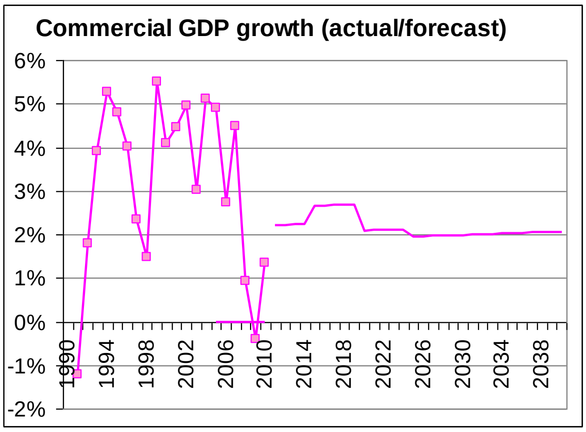
Demand % growth	GDP % growth (Commercial)
	
	

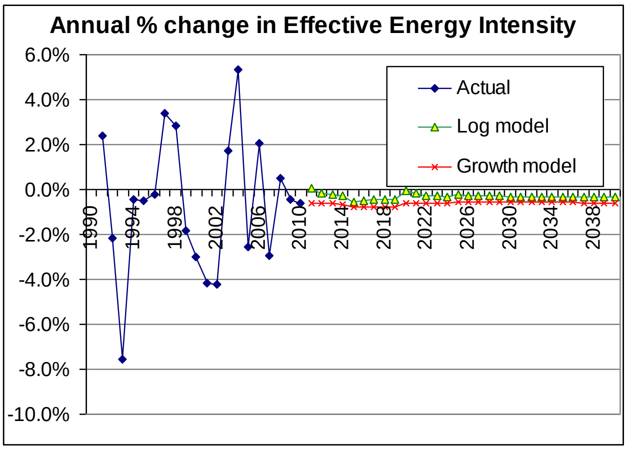
ADF unit root test statistics

Diff order	Log Demand	Log GDP: Commerc	Log GNE ($m)		Diff order	%delta Demand	%delta GDP: Commerc
1	-3.03	-3.27	-3.26		0	-3.05	-3.28
5% cv	-3.00	-3.00	-3.00		5% cv	-3.00	-3.00

The ADF tests show that the growth data series are all I(0), while the log series are all I(1).

Exogenous forecast and Energy intensity

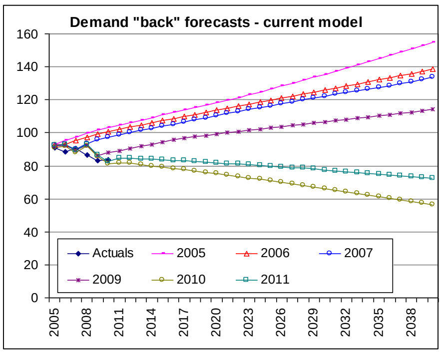
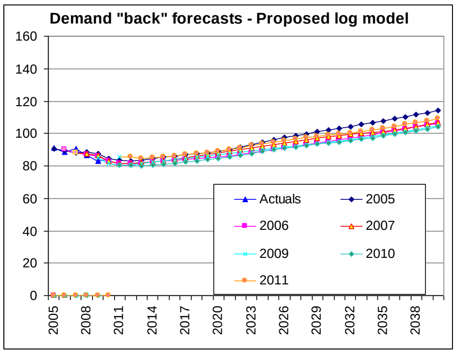
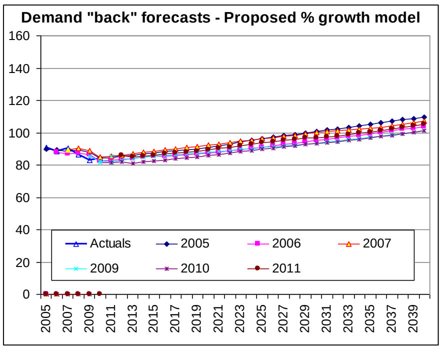




Annual intensity avg % change historical = -.7%, forecast = -.3% log, -.6% growth

7.3.3 General Industry

Stability of forecasts over time

Current model	I2: Proposed model (log)	I3: Proposed model (% growth)
		

Stability of parameter estimates over time

Current model

	Demand (t-1)	GDP	Constant
2005	0.32	0.46	-0.29
2007	0.51	0.28	0.16
2009	0.72	0.11	0.44
2011	0.92	-0.03	0.57

I2: Proposed model (log)

	Aggregate price	GDP: Ind or Prim	Constant
2005	-0.20	0.42	-0.02
2007	-0.14	0.40	-0.17
2009	-0.14	0.49	-0.38
2011	-0.15	0.53	-0.46

I3: Proposed model (% growth)

	Aggregate price	GDP: Ind or Prim
2005	-0.328	0.69
2007	-0.207	0.64
2009	-0.221	0.65
2011	-0.201	0.69

Residual plots

<table>
<tr><th>Current model</th><th>I2: Proposed model (log)</th><th>I3: Proposed model (% growth)</th></tr>
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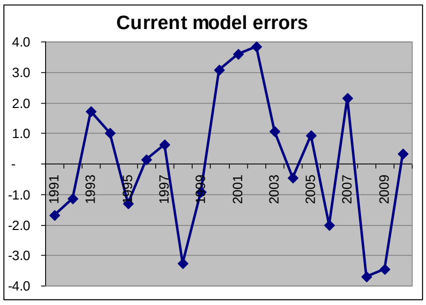
<td>
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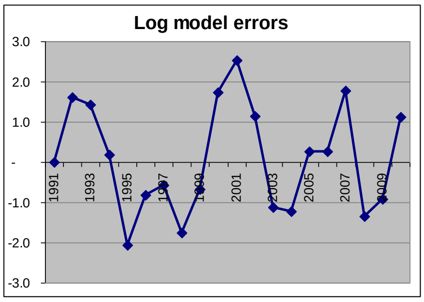
<td>
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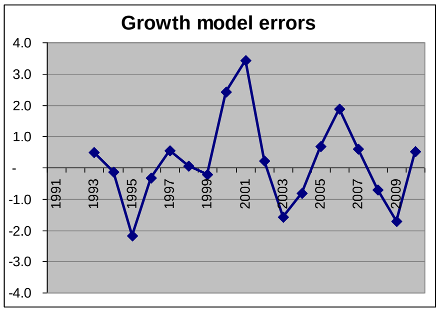
<td>
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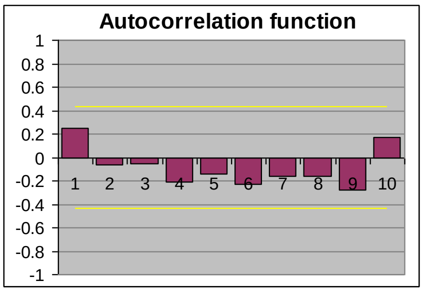
<td>
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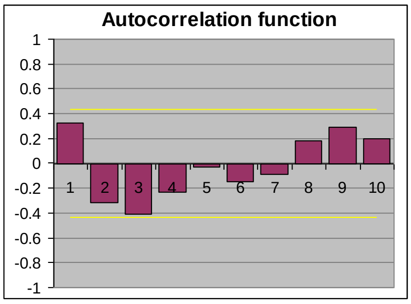
<td>
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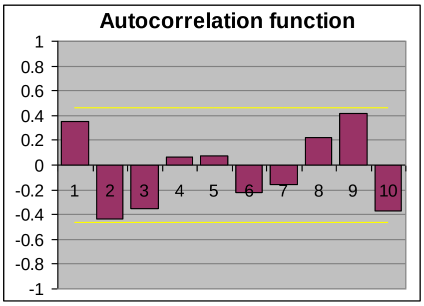
<td>
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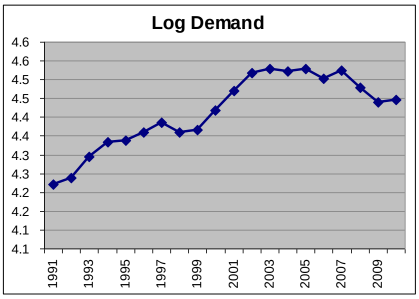
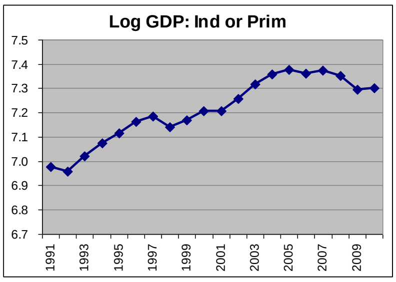
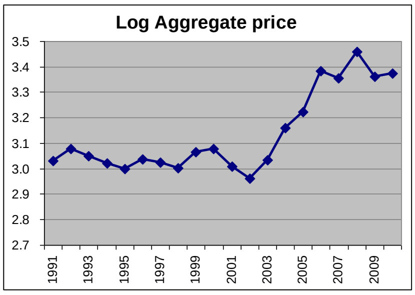
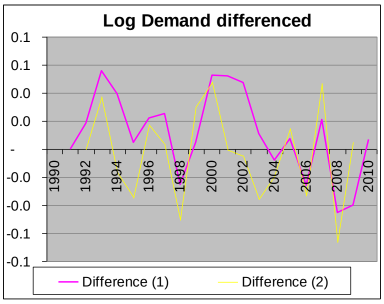
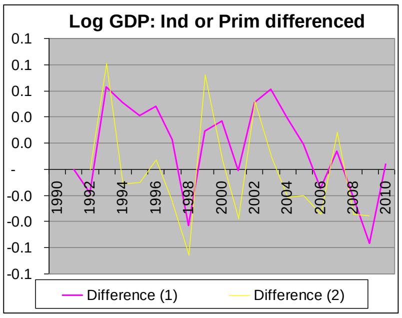
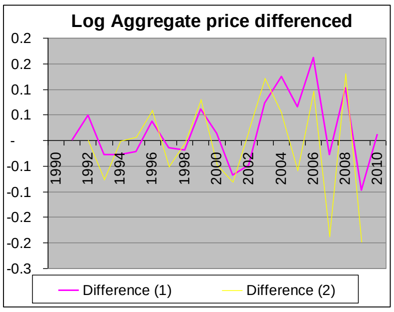
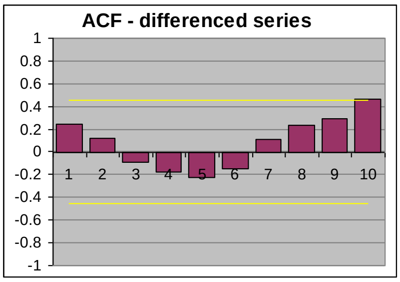
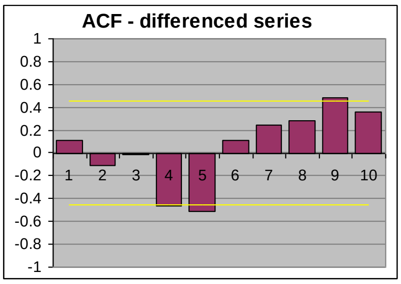
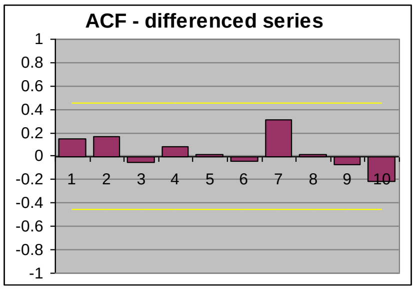
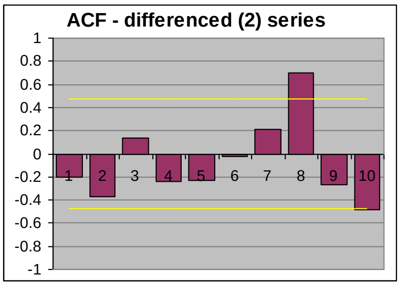
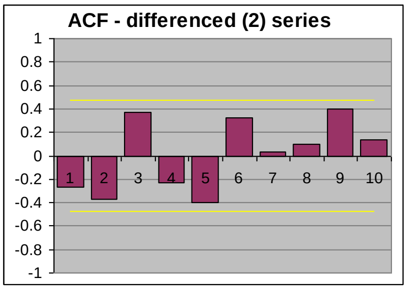
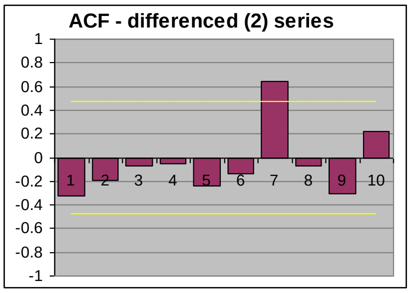
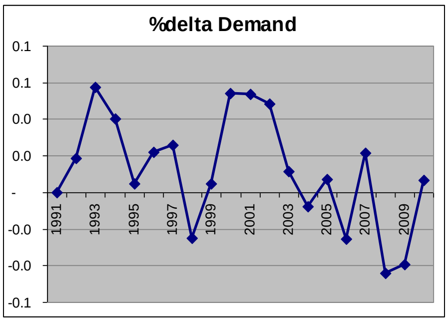
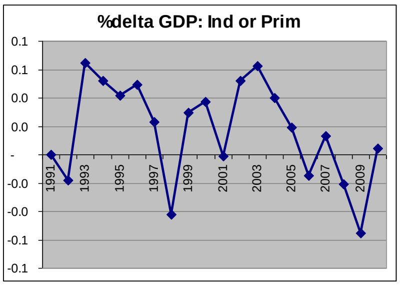
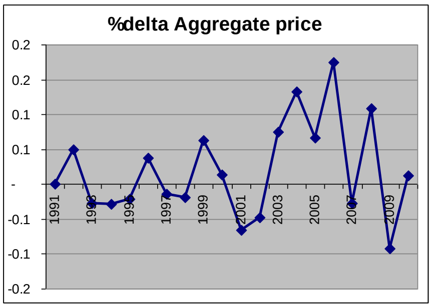
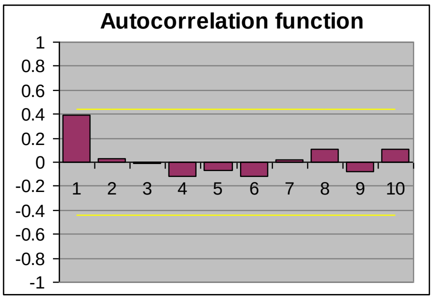
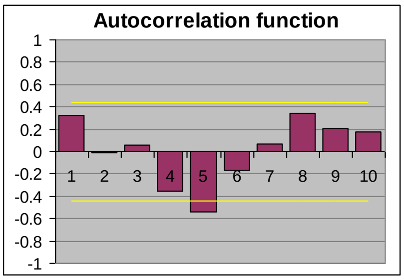
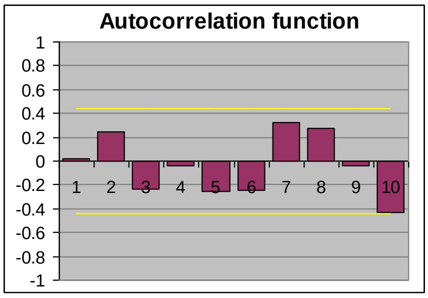
Using GDP gives a poorer model fit however, there is less autocorrelation in the series (as shown in the Current model errors).

Proposed model I2: data trends and stationarity

Demand log	GDP log (Industrial)	Aggregate price log
		
		
		
		

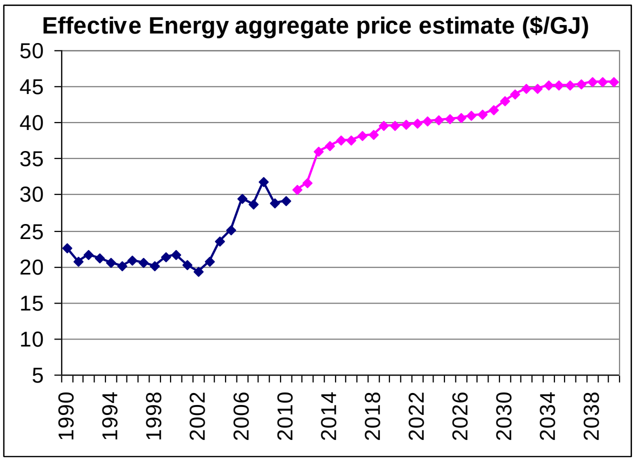
Proposed model I3: data trends and stationarity

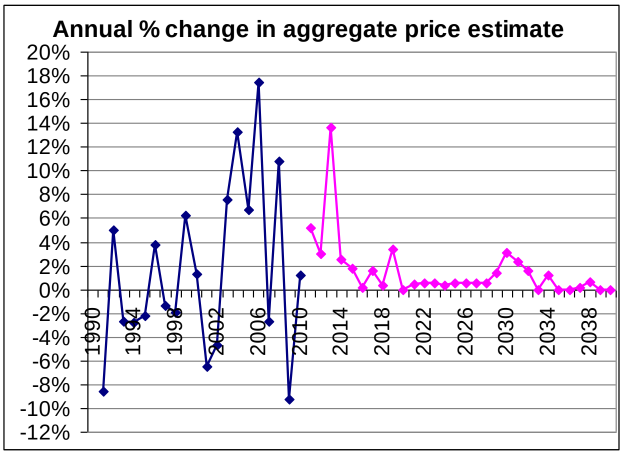
Demand % growth	GDP % growth (Industrial)	Aggregate price % growth
		
		

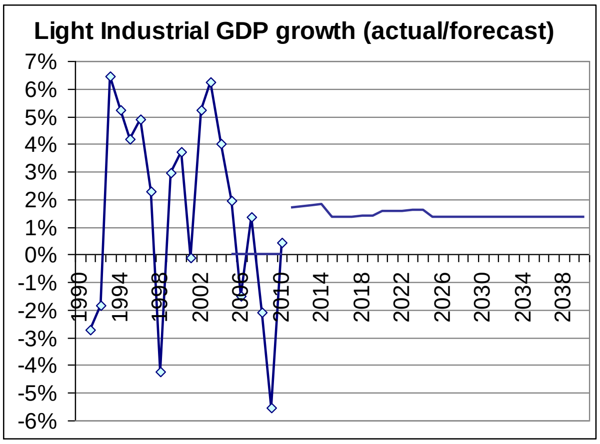
ADF unit root test statistics								
Diff order	Demand % delta	GDP: Industrial % delta	Aggregate price % delta		Diff orde	Log Demand	Log GDP: Industrial	Log Aggregate price
0	-2.85	-2.56	-3.78		1	-2.52	-2.56	-3.87
5% cv	-1.95	-1.95	-3.00		5% cv	-1.95	-1.95	-1.95

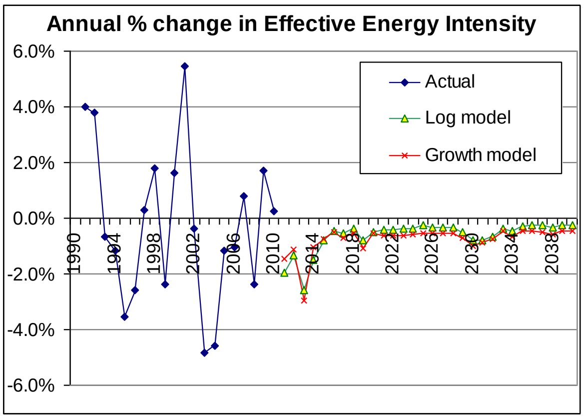
The ADF tests show that the growth data series are all I(0), while the log series are all I(1).

Exogenous forecasts and Energy intensity





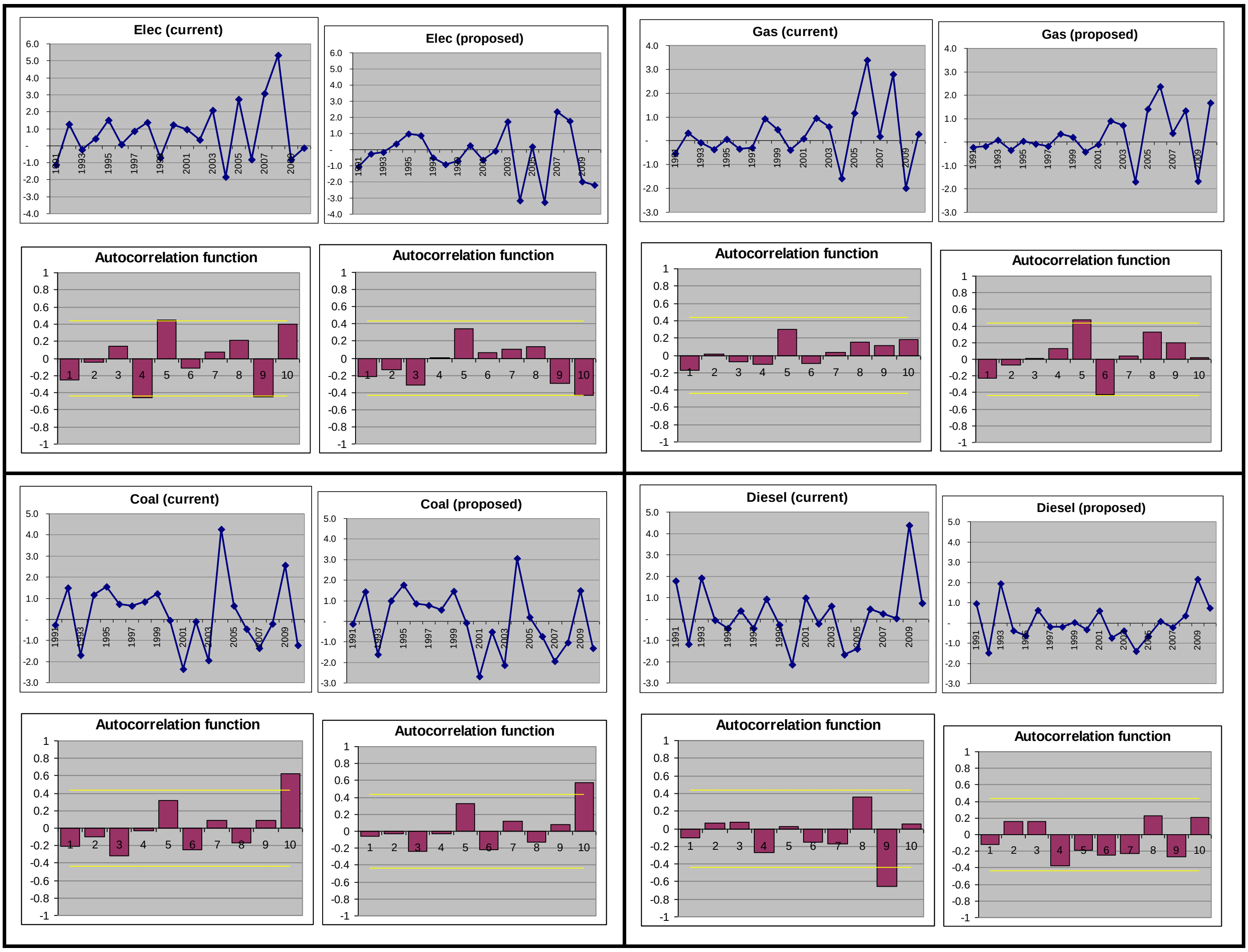




Annual intensity avg % change historical = -.3%, however between 1990 and 2001 when prices were flat, intensity increased by +.6% pa, while between 2002 and 2010 when prices were rising, intensity fell by -1.4% pa. Forecast log model = -.6% pa while growth model is -.7%, reflecting ongoing price rises (2011 to 2019 the rates are -1% and -1.1% respectively).

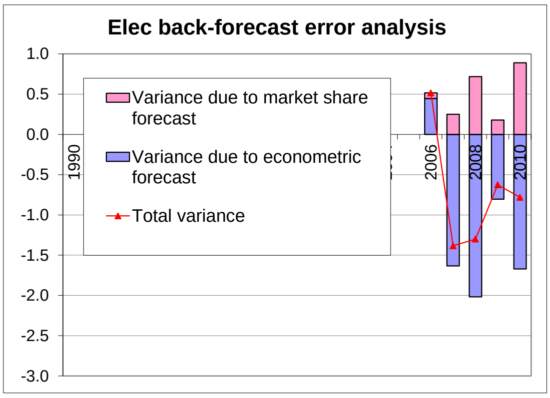
7.4 Additional diagnostics for Stage two forecasts

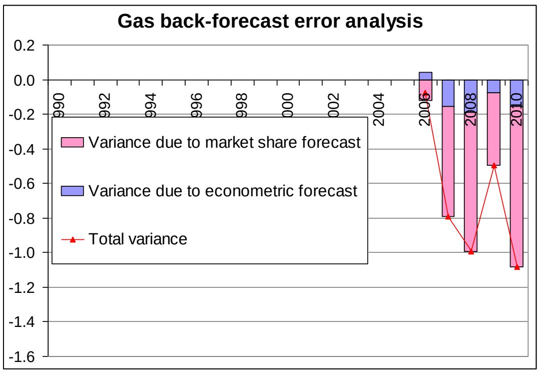
Residual plots for the four large fuel groups (sum across all sectors excluding Specific Industry)

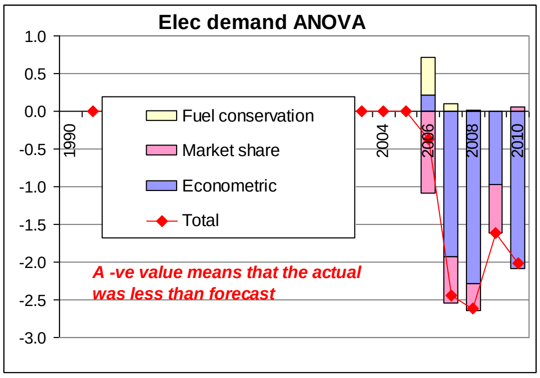


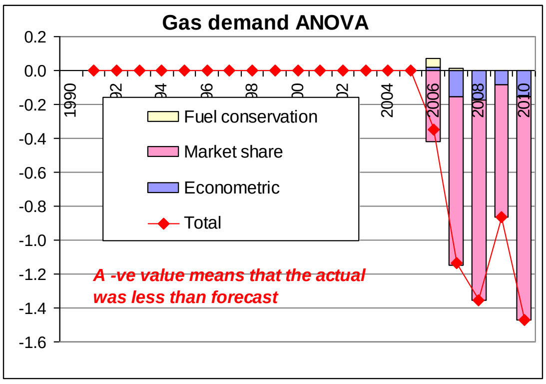
Residential model back-forecast error analysis

Proposed model	Current model



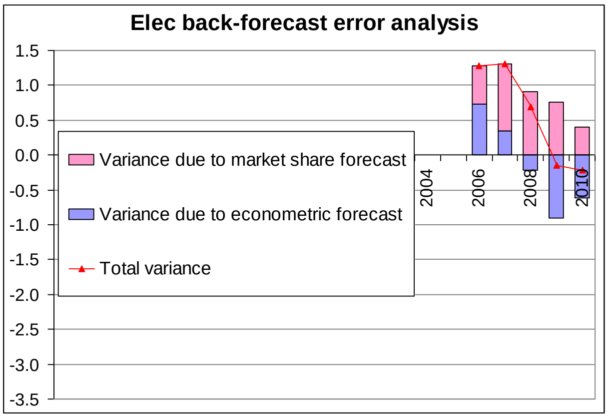


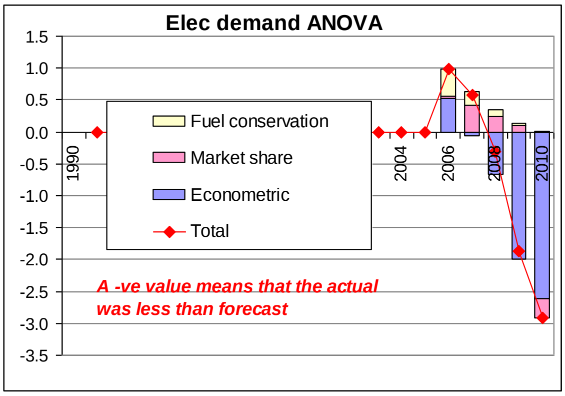


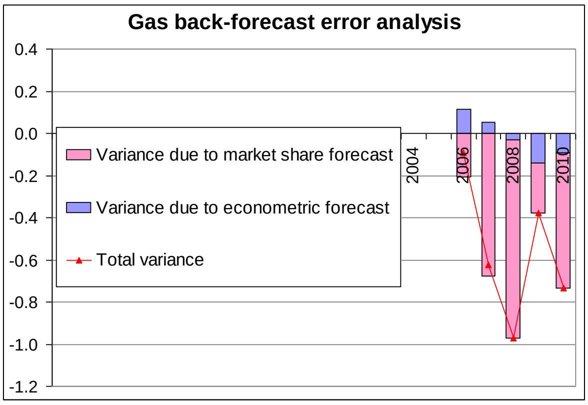


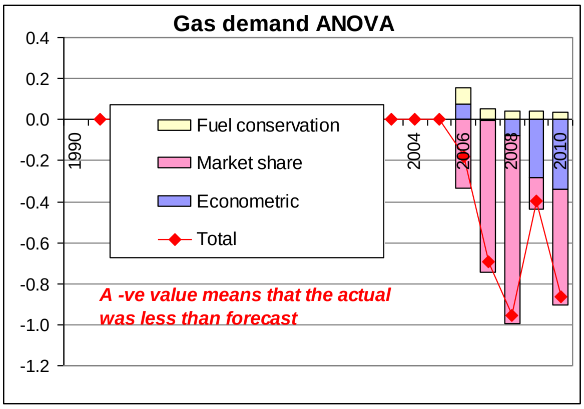
Commercial model back-forecast error analysis

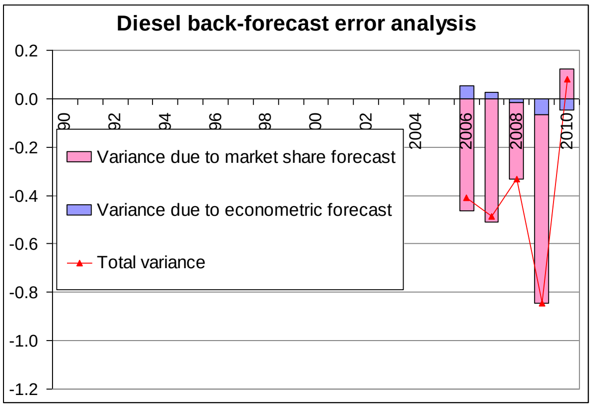
Proposed model	Current model

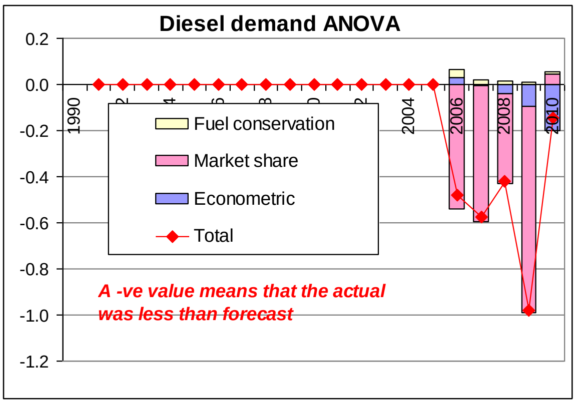




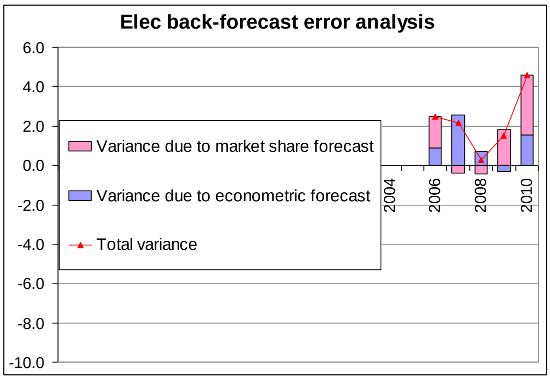
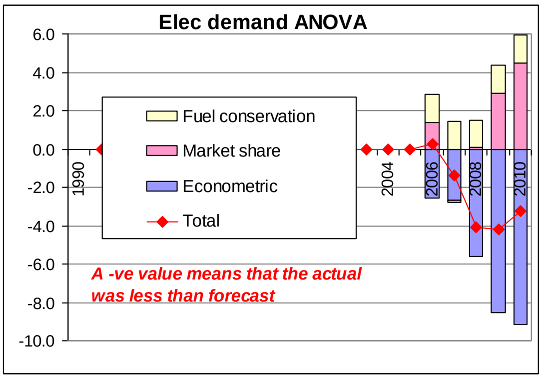
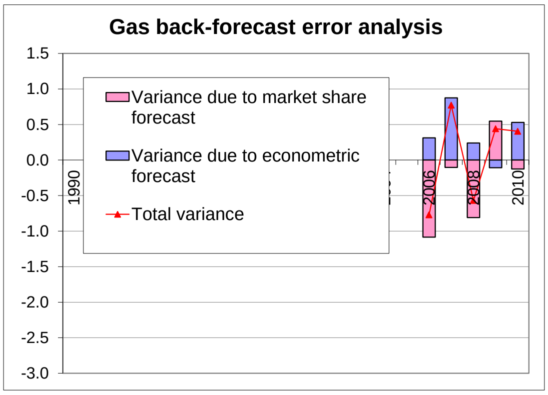
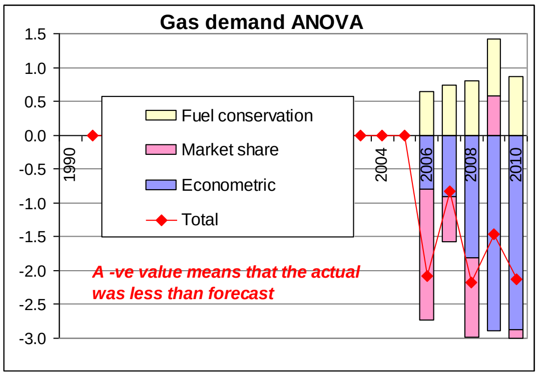
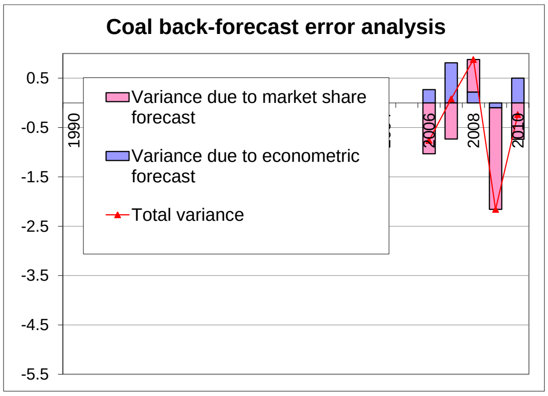
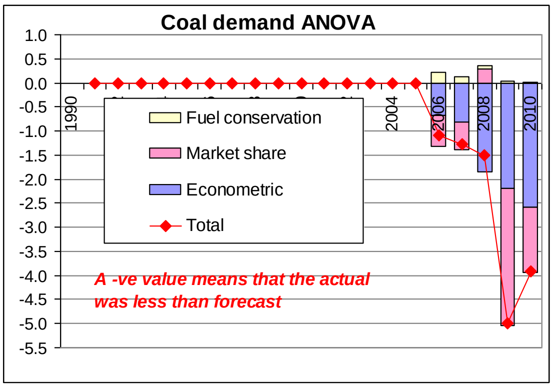
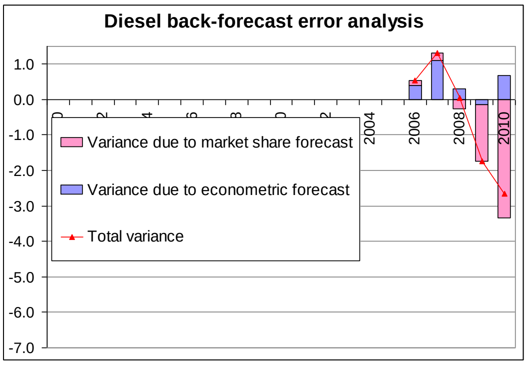
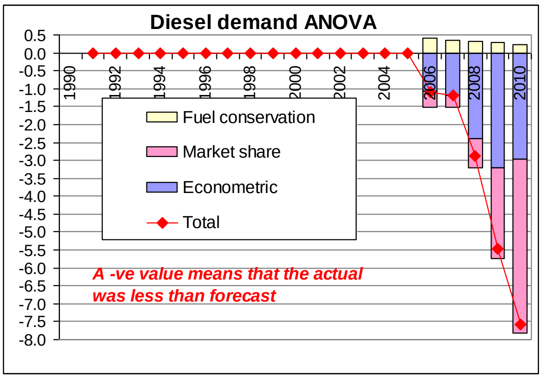








General Industry model back-forecast error analysis

Proposed model	Current model
	
	
	
	

7.5 Terms of reference for engaging NZIER

NZIER are required to provide a "review of the review". They are required to comment on the review document and its contents, as well as what could be missing from the document. NZIER will have full access to the models and analysis that contribute to the document. The key components to consider in the NZIER review are:

7.5.1 Review process and diagnostics

Comment on the general review process. Is the analysis of the current model sound, and are the appropriate diagnostic statistics used?

7.5.2 Theoretical justification for modelling approach

Do the current or proposed modelling approaches contradict any fundamental economic or statistical theory? Would theory suggest an alternative approach(es) to those considered here?

7.5.3 Practical justification for modelling approach

Factors such as data quality or software availability may limit the modelling approaches that can be considered. Does a simpler modelling approach merit consideration given these limiting factors (ie. will more complicated approaches truly add value)? Will the forecasting process be simple to manage on an ongoing basis and easy to understand for new staff?

7.5.4 Fitness for purpose

Do the forecasts satisfy the requirements of both the Energy Outlook and the Transpower Grid Planning Assumptions?

7.5.5 Evaluation of the forecast equations and parameters

Are the equations mathematically correct, do they reflect the intended purpose, and are the parameter estimates robust?

7.5.6 Exogenous variable forecasts

What are the appropriate GDP and household forecasts MED should use for these models?

7.5.7 NZIER recommendations

Does NZIER agree with MED's conclusions in this document or would they recommend some further changes (or even a completely different approach)?

7.5.8 Deliverables

Stage One

MED has produced the attached draft document (v1.0 30th June 2011) outlining the review process and the preferred modelling approach. NZIER are required to review this draft document and provide feedback to MED by 12-July, commenting on the general approach and highlight any important factors that should immediately be considered. This initial feedback from NZIER may be in the form of an email followed up by a meeting on the 13th July. NZIER will not be required to comment on 7.5.5 at this first stage since MED has not finalised the equations or parameters.

Stage Two

This stage involves MED finalising the demand equations and parameter estimates (incorporating relevant NZIER feedback from stage one) and producing a final version of this document. NZIER will complete the review in full by a mutually agreed date, delivering a document which covers off all the Terms of Reference. The NZIER document will be released on the MED website in conjunction with the attached document (final version).

7.6 NZIER report

The NZIER report is available on the MED website alongside this document.