APPENDIX 15

Review of demand and energy forecasting methodologies
Frontier Economics

Assessment of Energex's energy consumption and system demand forecasting procedures

A REPORT PREPARED FOR ENERGEX

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Tables

Executive summary

Frontier Economics (Frontier) was engaged by Energex in 2013 to undertake reviews of Energex's electricity consumption and peak demand forecasting processes as part of Energex's preparation for its submission to the Australian Energy Regulator (AER) for the 2015-16 to 2019-20 distribution determination. Frontier assessed Energex's models against the criteria outlined by the AER for assessing best practice forecasting methodology and made a number of recommendations for aligning Energex's forecasting procedures more closely with the AER's principles of best forecasting practice. .

At the end of May 2014, Frontier was asked by Energex to re-assess two of the models reviewed in the earlier review process following Energex's implementation of Frontier's recommendations. The models in question are the econometric models for forecasting electricity consumption per customer and for forecasting the summer system peak demand. This present report summarises our assessment of these two models against the AER criteria. Our overall assessment of the two models is provided below.

Electricity consumption model

The electricity consumption model has been developed in a professional manner and it is very well documented. In our view, it meets all of the AER criteria, with a few exceptions, the main ones being: (i) there is little discussion of the impact of government policies on the forecasts, and it appears that only PV generation has been taken into account; (ii) the income variable is specified as year-on-year changes to overcome a non-stationarity issue; however, intuitively one wouldn't expect changes in income to be a driver of the level of consumption, and (iii) there is no discussion on how the projections of the economic drivers obtained from external sources have been validated.

We understand that Energex has an active continuous improvement program in place for its forecasting models, and Energex has undertaken to address these issues in future refinements of its forecasting methodology.

Subject to the above provisos, it is our view that Energex's electricity consumption forecasting model meets AER's criteria for good forecasting methodology.

Peak system demand model

The peak system demand model has also been developed in a professional manner, but it is not quite as well documented. The files provided contain sufficient information to reproduce some but not all of Energex's forecasts. Most notably, no information is provided on how the forecasts for the low and high economic scenarios are obtained. In addition, although the number of and types of diagnostic and validation tests conducted is satisfactory; in most cases, there is insufficient detail on the results of the tests to make an independent assessment of the test outcomes.

With respect to model specification our main concern is that the economic drivers only appear in the model as interactions with the temperature variables. This makes it hard to assess the impact of the economic drivers on peak demand, and it could lead to biased estimates of the coefficients.

Finally, there is no discussion on how the projections of the economic drivers obtained from external sources have been validated. We have been assured that Energex will address the above issues in the future development of the peak system demand model.

Subject to the above provisos, it is our view that Energex's peak system demand forecasting model meets AER's criteria for good forecasting methodology.

1 Background

Frontier Economics (Frontier) was engaged by Energex Limited (Energex) between September and December 2013 to review a number of Energex's models and procedures for forecasting electricity consumption and peak demand as part of its preparation for its submission to the Australian Energy Regulator (AER) for the 2015-16 to 2019-20 distribution determination.

The results of Frontier's reviews were presented to Energex in two reports which included a number of recommendations for aligning Energex's forecasting procedures more closely with the AER's principles of best forecasting practice.

At the end of May 2014, Frontier was asked by Energex to re-assess two of the models reviewed in the earlier review process following Energex's implementation of Frontier's recommendations. The models in question are the econometric models for forecasting electricity consumption per customer and for forecasting the summer system peak demand.

For each of the two models we were provided with a Word document setting out details of the model's specification and the development process, as well as an Excel file with input data and the results of model estimations and diagnostic testing.

In the next two sections we provide a summary of our assessment of these two models against AER's principles of good forecasting practice.

2 Model for forecasting average daily consumption per customer

2.1 Model description

The model for forecasting average daily consumption per customer is an econometric model with monthly data on the average daily electricity consumption per customer as the dependent variable, and an electricity price, an income, and several weather variables as the independent variables. The model also includes a variable for non-working days and dummy variables for the GFC and the 2011 floods. Electricity consumption is taken to be the sum of the energy supplied from the network and estimates of solar PV generation.

The model is estimated using monthly data from April 2008 to January 2014. The package used to estimate the model is EViews, and EViews' comprehensive diagnostic tools have been used to develop the final form of the model. The residual term in the model is specified as having an ARMA(1,1) structure in the light of diagnostic testing.

The final model has incorporated all the suggestions made in our earlier review in regard to the drivers to be included in the model. Most of the variables enter the model in levels. However, the electricity price variable enters the model as logarithms, and the income variable is specified as the annual change in gross state income per capita. This is a somewhat unusual combination of specifications for the economic variables, but it seems to be the outcome of a statistical evaluation process.

2.2 Model assessment

Our assessment of the electricity consumption model against AER's criteria for a good forecasting methodology is summarised in Table 1.

Table 1: Assessment of consumption model against AER's criteria

Elements of good forecasting methodology	As evidenced by	Assessment
Accuracy and unbiasedness	1) careful management of data (e.g. removal of outliers) 2) model selection (e.g. choosing a parsimonious model based on sound theoretical grounds) 3) weather normalisation 4) consistency of forecasts at different levels of aggregation (e.g. in forecasting peak demand, consistency between spatial forecasts and system level forecasts)	1) data management has been done to a professional standard 2) the diagnostic tools in EViews have been used to determine the final form of the model 3) variables for heating/cooling degree days, rainfall and humidity are included to capture the impact of weather on consumption. This is an appropriate way of undertaking weather normalisation within the model, rather than as a preliminary step 4) data to develop a more disaggregated model are not available; hence this type of consistency check is not possible
Transparency and repeatability	5) good documentation, including documentation of the use of judgment, which ensures consistency and minimises subjectivity in forecasts	5) the process undertaken to develop the model is well documented, and the Excel file contains all the information necessary to replicate the model. More detail could have been provided on steps taken to validate the economic projections obtained from external sources
Incorporation of key drivers	6) including economic growth, population growth, growth in the number of households, temperature and weather related data (where appropriate), and growth in the numbers of air conditioning and heating systems 7) incorporating anticipated impacts of public policies	6) drivers for economic activity and price are included and have been specified to match the customer class being modelled. Several weather variables are also included. The specification of the income variable as year-on-year changes overcomes a non-stationarity issue, but intuitively one wouldn't expect changes in income to be a driver of the level of consumption 7) adjustments are made for PV generation. The PV projections appear consistent with AEMO's PV projections. Insufficient information has been provided to enable us to assess what, if any, adjustments made for changes in energy efficiency, electric vehicles, or policy changes
Use of	8) comparison of input	8) the most recent data from the ABS

Elements of good forecasting methodology	As evidenced by	Assessment
consistent and most recent input information	information with publicly available sources	and NIEIR are used for the economic variables. There is no evidence of comparisons for projections of these drivers against other publicly available sources
Model validation and testing	9) assessment of statistical significance of explanatory variables and goodness of fit 10) in-sample and out-of sample forecasting performance of the models [e.g. use of statistical measures such as the Mean Absolute Percentage Error (MAPE) or Root Mean Square Error (RMSE)] 11) diagnostic checking of the models	9) the model fits the data well (adjR^2 = 0.90), coefficients have the expected sign and are generally statistically significant 10) a cross-validation check had been done by re-estimating the model on a smaller dataset and 'forecasting' the last two months of observations. The MAPE is 2.4% which is acceptable 11) the model passes most of the standard econometric diagnostic tests. Where a diagnostic test indicates a concern, the approach to dealing with the concern is generally professional and sensible

Note: The criteria of AER's good forecasting methodology are based on material in AER (Nov 2011), "Draft Distribution Determination Aurora Energy Pty Ltd 2012-13 to 2016-17"; AER (Jun 2010), "Victorian electricity distribution network service providers Distribution determination 2011-2015 (Draft decision)".

3 Model for summer peak system demand

3.1 Model description

In broad terms, Energex's peak demand forecasting methodology consists of the following main steps:

1. **estimate an econometric model** for daily maximum demand as a function of GSP, price, temperature variables and calendar effects
2. **make projections** of drivers in the model over the forecast horizon
3. **carry out simulations** to obtain an empirical distribution for system peak demand for each year in the forecast horizon and each of three economic scenarios
4. **derive probability of exceedance (POE) forecasts** for each year in the forecast horizon from the corresponding empirical distribution for system peak demand.

This is a familiar approach in the electricity industry to forecasting peak demand.

All explanatory variables enter the model in levels. The raw daily maximum demand variable has been modified to include estimates of the impact of photovoltaic solar cell generation (PV).

The dataset used to estimate the model consists of daily maximum demand data for the summers of 2000/2001 to 2013/2014, where the summer season is defined as the months December to February. Days when the average temperature at Amberley weather station is less than 23.5^{o}C are removed from the estimation sample as being too mild to provide useful information on weather sensitivity. The EViews package has been used to estimate the model, and EViews' comprehensive set of diagnostic tools has been used to develop the final form of the model.

3.2 Model assessment

Our assessment of the peak system demand model against AER's criteria for a good forecasting methodology is summarised in Table 2.

Table 2: Assessment of consumption model against AER's criteria

Elements of good forecasting methodology	As evidenced by	Assessment
Accuracy and unbiasedness	1) careful management of data (e.g. removal of outliers) 2) model selection (e.g. choosing a parsimonious model based on sound theoretical grounds) 3) weather normalisation 4) consistency of forecasts at different levels of aggregation (e.g. in forecasting peak demand, consistency between spatial forecasts and system level forecasts)	1) data management has been done to a professional standard 2) the diagnostic tools in EViews have been used to determine the final form of the model 3) variables for daily min and max temperatures are included in the model, and simulation is used to obtain weather normalised POE10 and POE50 forecasts 4) an alternative model based on annual peak data is used as a comparator. Forecasts from the two approaches are claimed to be similar
Transparency and repeatability	5) good documentation, including documentation of the use of judgment, which ensures consistency and minimises subjectivity in forecasts	5) the process undertaken to develop the model is reasonably well documented but there are gaps. It would be possible to reproduce the econometric estimation results but there is not enough information to reproduce forecasts for the high and low economic scenarios
Incorporation of key drivers	6) including economic growth, population growth, growth in the number of households, temperature and weather related data (where appropriate), and growth in the numbers of air conditioning and heating systems 7) incorporating anticipated impacts of public policies	6) GSP and electricity price are the economic drivers. Min and max temperature and calendar effects are also included. The economic variables are interacted with the temperature variables which confounds the impact of these variables possibly leading to biased estimates 7) adjustments are made for PV generation and electric vehicles, as well as for some major new loads. No adjustments are made for changes in energy efficiency or other policy changes.
Use of consistent and most recent input information	8) comparison of input information with publicly available sources	8) the most recent data from AEMO and the Reserve Bank are used for the economic variables. There is no evidence of comparisons of the projections of these drivers against

Elements of good forecasting methodology	As evidenced by	Assessment
		other publicly available sources
Model validation and testing	9) assessment of statistical significance of explanatory variables and goodness of fit 10) in-sample and out-of sample forecasting performance of the models [e.g. use of statistical measures such as the Mean Absolute Percentage Error (MAPE) or Root Mean Square Error (RMSE)] 11) diagnostic checking of the models	9) the model fits the data well (adjR^2 = 0.87), coefficients are statistically highly significant and have the expected sign. Some of the coefficients can't be interpreted directly since the variables appear as interactions with other variables 10) a cross-validation check has been done by re-estimation model on a randomly selected 70% sub-sample of the data. Estimates and forecasts were compared with the full model and deemed to be satisfactory. No details have been provided to confirm this assessment 11) the model passes most of the standard econometric diagnostic tests. However, the Durbin-Watson statistic is statistically significant, which suggests that serial correlation or some type of model misspecification is present. The results of a number of tests are noted but not fully documented, and hence their interpretations can't be validated

Note: The criteria of AER's good forecasting methodology are based on material in AER (Nov 2011), "Draft Distribution Determination Aurora Energy Pty Ltd 2012-13 to 2016-17"; AER (Jun 2010), "Victorian electricity distribution network service providers Distribution determination 2011-2015 (Draft decision)".

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