Review of TransGrid's Load Forecasting Methods

Final Report

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1. Executive summary

1.1 Project background

TransGrid develops forecasts of annual energy and seasonal maximum demand. These forecasts are published in TransGrid's Annual Planning Reports (APRs) and in the National Electricity Market Management Company (NEMMCO) annual Statement of Opportunities (SOO). The forecasts are used in several ways by TransGrid, the New South Wales (NSW) Jurisdictional Planning Body (JPB), other JPBs, NEMMCO planners, and other market participants.

TransGrid's forecasts use information developed by the National Institute for Economic and Industrial Research (NIEIR) on behalf of NEMMCO. NEMMCO engages NIEIR to prepare a number of key background documents, including an Economic Outlook for the NEM states and Projections of Non-scheduled Generation for each of the NEM regions. Use of the NIEIR reports ensures that the TransGrid load forecasts are produced with assumptions consistent with those used for the rest of the NEM.

1.1.1 Goal of the study

The objective of this study is to assess whether the load forecasting procedures used by TransGrid are in accordance with internationally recognised good or "best" practices. In particular TransGrid wants to ensure that the load forecasting processes can be relied upon to produce a realistic expectation of demand forecast.

1.1.2 Methods

This report is based on review of documents prepared by TransGrid describing the forecasting methods, together with discussions with TransGrid forecasting staff to clarify these procedures.

1.2 Key findings

TransGrid's long-term load forecasting processes and methods use internationally recognized good practices, and can be relied upon to produce a realistic expectation of demand forecast. The overall approaches used in developing the forecasts process are sound, and combine good technical methods with good judgment and experience. The review did not include cross-checking of calculations or auditing of compliance with stated procedures . Nevertheless, KEMA has had open discussions with the forecasters, and has understood enough of the processes to be confident that TransGrid's forecasters are using good methods in good faith. .

1.3 Strengths of TransGrid's forecasting procedures

Key positive features of TransGrid's methods include the following:

1.3.1 Overall analytic approaches

TransGrid's primary forecasts are based on a set of "top-down" models, which forecast energy and peak demand for the NSW region as a whole.   These models use advanced econometric methods, and a model forecasting structure that has been established by recognized experts in energy demand forecasting. TransGrid also conducts extensive diagnostic testing of model forms and specifications. These approaches are good practices.

TransGrid also develops a "bottom-up" forecast by summing the forecasts provided by the Distribution Network Service Providers (DNSPs), with corrections for line losses and diversity. The process of reconciling the two sets of forecasts improves and validates both. This validation and reconciliation is good practice.

1.3.2 Very large stable loads

The top-down model handles very large customers such as smelters individually, projecting future use based on historical use and explicit plans known for each customer. This approach is standard and good practice.

1.3.3 Demand-side participation

NEMMCO and the Load Forecasting Reference Group (LFRG) have established a consistent way of handling DSP across the JPBs. NEMMCO provides estimates of DSP for each JPB based on a survey of retail elecricity suppliers. TransGrid uses the NEMMCO DSP estimate as an adjustment to its forecast.

1.3.4 Renewable and embedded generation

TransGrid's forecasts use estimates of renewable and embedded generation are developed by NIEIR together with Greenworld Energy, on behalf of NEMMCO. These estimates are based on detailed accounting of existing units and effects of government policy on expansion of renewables production and capacity. This systematic accounting appears to have been done thoroughly and carefully.

1.3.5 Weather sensitivity

The TransGrid top-down approach involves explicit modeling of weather sensitivity, and projection of increasing weather sensitivity reflecting growth in air conditioning loads. TransGrid has given considerable attention to these modeling steps, testing alternative model specifications. The overall structure and the attention given the details represent good practice. Care with the weather-sensitive load is important given that air conditioning is the main source of the divergence between the 10 percent and 50 percent POE forecasts for any given year, and growth in air conditioning is a key source of uncertainty regarding even the base 50 percent POE forecast.

TransGrid's top-down models use as inputs some economic indicators from NIEIR's macroeconomic model, as well as forecasts of embedded generation provided by NIEIR. NIEIR' Institute Multipurpose (IMP) model model is a large econometric model of the Australian economy that captures inter-relationships among national and state economic indicators, energy demand, and energy prices. The model has been developed and refined over the past 20 years, and is used by NIEIR in a variety of applications. Assessment of the model itself was beyond the scope of this evaluation. However, use of such an integrated and highly developed modeling system represents an advanced forecasting approach.

1.3.6 Empirical Model Performance

Both the energy and demand models exhibit good performance based on out-of-sample tests. Models were re-estimated excluding the data from the most recent 5 years. The re-fitted models were then evaluated using the actual conditions of those years as inputs. Results were compared with actual energy and peak demand.

The Mean Absolute Percent Error (MAPE) from these out-of-sample estimates was 0.6 percent for energy and less than 1.2 percent for peak demand. Thus, the overall forecasting process provides results that are close to actual observed loads. This performance indicates that the forecasting processes can be relied upon to produce a realistic expectation of demand forecast.

Actual observed loads also fell generally between the estimated 10% and 90% POE bands. Thus, the model predictions appear to be in line with the intended meanings of the POE levels, and the method performance is reliable.

1.3.7 Improvements since last review

TransGrid's 2007 forecasts incorporate several improvements since KEMA's 2005 review.

1.3.7.1 Air conditioner saturation

The assumed model of air conditioning growth now incorporates a flattening in later years, consistent with air conditioning use achieving its maximum likely percent in the population. The previous report recommended a change along these lines. This change constitutes an improvement in good practice.

1.3.7.2 Energy quantity modeled

Energy in the 2007 forecasts is directly modeled at three points: generation, send-out, and network delivery. By contrast, in the previous work, energy sales to end users was modeled directly, and the other three energy quantities were determined by adjustments to the projected sales. This change represents an improvement in practice.

1.3.7.3 Weather correction of peak demand

In previous years, TransGrid constructed a base peak demand forecast for a 50% POE temperature condition. This base forecast was then adjusted to 10% and 90% POE conditions using a weather model. TransGrid's current method directly models the 10% and 90% POE peak demand levels. This approach more directly captures the extreme condition behavior represented by the POE levels. Thus, this change represents an improvement to the procedures that is expected to increase the reliability of the estimates.

1.3.7.4 Use of Normal Distribution to Determine Percentiles

The previous forecasts used the observed percentiles from the ordered values based on 50 historical years. The 2007 forecasts use a normal distribution, which provides smoother and more stable estimates of the percentiles. This change represents an improvement to the procedures that is expected to increase the reliability of the estimates.

1.3.7.5 Backcast Validation

Previous forecasts have constructed backcast estimates for a single year, and have not adjusted the backcasts to the actual economic and weather conditions. TransGrids current methods backcast several years, using the actual conditions for the backcast years. This approach was recommended in the prior review and is an improvement to the practice.

1.4 Potential Improvements

Even the best forecasting models and processes can be refined. TransGrid has adopted some improvements in response to the 2005 methods review KEMA performed for NEMMCO, and has also developed some other improvements not suggested in that review. Following are some additional steps that may be worth consideration in future models. As always, adopting such changes would require investigation of their effect on the process, and the potential costs of developing these refinements must be balanced against the likely improvement.

It must be stressed that these suggestions are not meant to imply that the current methods are deficient. To the contrary, as noted, the current methods represent good practice and can be relied upon to produce a reasonable expectation of demand forecast. These suggestions are offered in the interests of the ongoing improvement and refinement that has characterized TransGrid's forecasts.

1.4.1 Air conditioning sensitivity model

The future growth in air conditioning is one of the greatest sources of uncertainty in the TransGrid forecasts. The modification to the assumed growth pattern since the 2005 review is a definite improvement. Further improvement may be possible by explicitly modeling the growth trajectory. As noted in the prior review, weather sensitivity in each year is already estimated by TransGrid. This sensitivity itself could be directly modeled, assuming a smooth relationship with a roughly S-shaped pattern. The form of this smooth relationship could be chosen based on analysis of historic data from other areas where the air conditioning levels appear to have stabilized.

1.4.2 Using weather-normalized average demand in the peak demand models

In the current form of the models, the average demand used as a driver in the peak demand model is the actual average demand for the year. However, the peak demands used as the dependent variable are all adjusted to a particular percentile or POE level for each year. The effects of warm and mild actual average demand more or less average out, but there could be some distortions to the relationship between average and peak demand introduced by these ups and downs in the time series. It may be more appropriate and provide a more stable estimate to use weather-normalized average demand as a predictor. The modeling process already produces weather-normalized energy.

1.4.3 Selection of degree-day bases for weather modeling

TransGrid selects the bases for calculating heating and cooling degree-days by trying different bases and choosing the one with the best overall results. This approach can be made more systematic, to be consistent with a formal estimation process.

2. Introduction

2.1 Project background

TransGrid develops forecasts of annual energy and seasonal maximum demand. These forecasts are published in TransGrid's Annual Planning Reports (APRs) and in the National Electricity Market Management Company (NEMMCO) annual Statement of Opportunities (SOO). The forecasts are used in several ways by TransGrid, the New South Wales (NSW) Jurisdictional Planning Body (JPB), other JPBs, NEMMCO planners, and other market participants.

TransGrid's forecasts use information developed by the National Institute for Economic and Industrial Research (NIEIR) on behalf of NEMMCO. NEMMCO engages NIEIR to prepare a number of key background documents, including an Economic Outlook for the NEM states and Projections of Non-scheduled Generation for each of the NEM regions. Use of the NIEIR reports ensures that the TransGrid load forecasts are produced with assumptions consistent with those used for the rest of the NEM.

2.1.1 Goal of the study

The objective of this study is to assess whether the load forecasting procedures used by TransGrid are in accordance with internationally recognised good or "best" practices. In particular TransGrid wants to ensure that the load forecasting processes can be relied upon to produce a realistic expectation of demand forecast.

The general conclusion of this review, discussed further below, is that the methods are indeed consistent with good practice, and can be so relied upon. Before describing specific findings, we discuss what this assessment means.

The statement that the methods are good practice does not imply that there is no room for improvement or that no change should be made to the models. There are always multiple reasonable ways to develop a model. Which approaches work best can change over time as conditions change, and new approaches may be suggested by other modelers. TransGrid is continually refining its methods and exploring opportunities for improvement. This ongoing refinement is itself good practice.

Likewise, the statement that the methods can be relied on to produce a realistic expectation of demand forecast is not a guarantee that future years' actual energy consumption and peak demand will always fall within the upper and lower Probability of Exceedence (POE) bands. By definition, the POE bands are expected to include the actual values only 80% of the time; 10 percent of the time the actual value is expected to be higher, 10% of the time it is expected to be lower.

The statement that the methods can be relied on to produce realistic expectation of demand forecast also does not guarantee that future actual consumption and peak demand will necessarily be close to the forecasts calculated for economic and weather conditions similar to those of the actual year. The projections assume certain structure in the relationship between the model drivers on the one hand and energy and demand on the other. These structures and relationships appear to be reasonably specified and reasonably stable based on general industry practice and the observed model performance. Nonetheless, a disruption to the economy or a major shift in trends of behavior, technology, or practice could render the estimated models less accurate.

This caveat applies to any forecasting system, and is not a weakness of TransGrid's. So long as there are no major disruptions to the underlying structures and relationships that form the basis for these projections, these methods can be relied on to produce a realistic expectation of demand forecast

2.1.2 Project approach

This review is based on review of documents prepared by TransGrid describing the forecasting methods, together with discussions with TransGrid forecasting staff to clarify details of the process. In addition, KEMA's previous review of the forecasting processes for NEMMCO as a whole was also referenced.

Specific information used as the basis for the findings in this report are :

- Review of the TransGrid's draft 2007 APRs, and related reports prepared by the forecasters;
- Interviews with TransGrid forecasting staff conducted in June 2007; and
- Materials compiled and findings developed in KEMA's 2005 review of the NEMMCO forecasting processes.

This review was designed to be done at a high level. Process documentation and reports were reviewed and discussed with their authors for clarification. The review has focused on the key structural elements and drivers.

The intent of the forecasts is understood to be to provide fair, credible, realistic, and useful information to planners, both within NEMMCO and among the market participants. The quality of TransGrid's forecast procedures are assessed in terms of this general objective.

2.2 Organization of the report

A brief description of TransGrid's methods is provided in Section 3. Section 4 presents key findings related to the methods. Section 5 offers some suggestions for further improvements.

3. Summary of forecasting methods

3.1 Overview

The summary provided below describes salient features of TransGrid's forecasting process. The intent is to offer sufficient detail to provide a basis and context for the findings that follow.

3.1.1 Forecasts Reviewed

The outlook period for each year's APR is 10 years forward. Thus, the 2007 APR and JPB SOO include forecasts for each year 2008 through 2017. For each year, the annual energy consumption and maximum seasonal demand under "average" and "extreme" weather conditions are provided.

The extreme conditions are defined by 90 percent and 10 percent probability of exceedence, indicating conditions that will be exceeded on average 9 years in 10 or 1 year in 10, respectively. The base or average condition is equated with a 50 percent POE. The emphasis of this review is on the maximum demand (MD) forecast and in particular on the 50 percent and 10 percent POE forecasts of maximum demand.

3.1.2 Top-down and Bottom-up Forecasts

The NSW forecasts are developed on two bases:

- **Top-Down:** These forecasts are developed for the state planning area as a whole, using econometric modeling.
- **Bottom-Up:** These forecasts are developed by summing forecasts for individual or connection points within the state, prepared by the DNSPs.

The "top-down" approach provides the primary forecast that appears in TransGrid's APR and in the SOO. Incorporated in TransGrid's top-down forecasts are some component forecasts and assumptions developed by the NIEIR on behalf of NEMMCO. NEMMCO engages NIEIR to prepare a number of key background documents, including an Economic Outlook for the NEM states and Projections of Non-scheduled Generation for each of the NEM regions.

The TransGrid forecasts include only scheduled generation. Embedded generation less than 30 MW and wind generation are not scheduled by NEMMCO. Embedded generation consists of units connected directly to the distribution network, with no connection to the transmission network. Typically, these are small generators, such as distributed generation and co-generation.

3.1.3 Embedded and Unscheduled Generation

Unscheduled generation is handled in the TransGrid forecast by first forecasting the whole region's energy and demand without regard to how much of it will be served by scheduled versus unscheduled generation. Estimates provided by NIEIR of energy and peak demand served by unscheduled generation are then subtracted from the regional totals to yield the scheduled generation requirements.

That is, the unscheduled generators, small embedded and wind sources, are treated as negative loads for purposes of the load forecast. These generation amounts are subtracted from the total load at end-use customers (adjusted for line losses) to arrive at the total load that must be served by the transmission network. (Larger embedded generators are scheduled, and are treated as generation, rather than negative load.)

NEMMCO collects data on historical and projected embedded generation from the DNSPs, and forwards this information to TransGrid and NIEIR for development of aggregate estimates.

3.1.4 Demand-side participation

Demand-Side Participation (DSP) is defined in the SOO glossary as "The situation where customers reduce their electricity consumption in response to a change in market conditions, such as the spot price." TransGrid uses NEMMCO estimates of DSP contribution to peak demand reduction in the TransGrid region.

NEMMCO obtains information on historic and projected DSP activity within the region from the retailers. They are asked to separate the DSP into DSP committed (very high probability of being available at times of high demand) and non-committed (not committed but may be available at times of high demand). The information may be provided on an aggregate basis to protect the confidentiality of retailers' arrangements with individual customers.

TransGrid's load forecasts are developed for a hypothetical condition of no short-term demand-side participation.

3.2 Inputs Used by TransGrid for Forecasts in the APR

3.2.1 NIEIR forecasts prepared for NEMMCO

NIEIR prepares three reports for NEMMCO that are used by TransGrid and the other the JPBs in preparing their projections. These reports are referred to in this report by the following short titles.

- Economic outlook
- Embedded generation
- Greenhouse policy

3.2.1.1 Economic outlook: the economic outlook for the NEM states to 2016-17

This report provides projections of economic indicators by state. These indicators are developed from NIEIR's Institute Multipurpose model (IMP model). The energy and demand models are integral components of that structure. Also included in the modeling system are:

- A national component addressing the macroeconomic environment and industry structure
- A state economic environment model, which projects state level industry output, capital stocks, major projects, household numbers, population growth
- A model of energy production investment and prices.

3.2.1.2 Embedded generation: projections of cogeneration and renewable generation in the NEM

This report provides explicit projections of embedded generation capacity and output, taking into account existing and planned cogeneration facilities, and the renewable generation additions required to meet current legislative mandates.

3.2.1.3 Greenhouse policy: impact of greenhouse policy on electricity demand

This report describes current and planned programs to reduce greenhouse gases within Australia and internationally, and their likely impact on demand and energy prices through the forecast period.

3.3 TransGrid forecasting methods

3.3.1 Forecast components

TransGrid's forecasts project future load (energy and demand) to be served by the transmission network based on analysis of the historic load served. The primary mechanism for the forecast is econometric modeling of the bulk of the load. However, to establish a consistent historic series, the following components are added and subtracted to the total historic TransGrid load.

- Very large stable loads are subtracted from the historic totals and forecast individually.
- Loads that have been served by unscheduled generation (mostly wind) and embedded generation are added to the scheduled load, so that the model of consumption or peak demand is not skewed by changing composition of how that demand is served.
- The Tweed River area has recently been added to the TransGrid network. Historic load data used for the projections include this area.
- Estimates of historic DSP are added back to the total, and the forecasts developed assume no future DSP.

After the bulk of the load is forecast, the projected large stable loads are added and projected unscheduled embedded generation are subtracted. Projected DSP is not subtracted from future loads; any DSP that does occur will supply a component of this projection.

TransGrid's econometric modeling uses advanced time series analysis methods, and a model forecasting structure that has been established by recognized experts in energy demand forecasting. This approach first models energy or average demand as a function of economic drivers. A separate model relating peak demand to average demand then determines the peak forecasts.

As noted above, future changes for very large customers are considered individually, and are separate from the econometric modeling. Forecasts of embedded generation and wind are provided by NIEIR, under contract to NEMMCO.

TransGrid uses NIEIR's forecasts of economic indicators, also provided by NIEIR under contract to NEMMCO. This review does not address the quality of the NIEIR forecasts. These forecasts have been reviewed previously as part of an assessment of the overall NEMMCO forecast process.

The energy and peak demand model are described below.

3.3.2 Energy model

Energy Quantity Modeled

Energy consumption can be measured and forecast at four levels:

1. Energy generated,
2. Energy sent out: differs from energy generated by generator transformer losses and in-plant electricity use
3. Energy delivered to the transmission network (DNSPS): differs from energy sent out by transmission losses
4. Energy delivered to end users: differs from energy delivered to the transmission network by distribution losses and embedded generation.

In previous years, TransGrid's energy forecast model was based on the last of these, sales to end users. The other three were then estimated by applying adjustments for the associated losses between successive steps in the delivery chain. However, use of end-user sales data as the basis for modeling was problematic for two reasons:

1. The data are reported only on an annual basis, whereas other data used in the analysis are available monthly.
2. There is typically a lag of up to a year in reporting these data.

To address these limitations, the forecasts for TransGrid's 2007 APR took a different approach. Each of the three energy quantities other than final sales to end users was modeled directly. These quantities are reliably and consistently available.

Thus three models are fit with the same predictor variables and model structure. The three models have identical structure, but fit each of the three different energy terms as the dependent variable. Each of these variables is expresssed in per capita form in the models.

Predictor Variables

Predictor variable included in the energy models are:

- Lagged electricity consumption;
- Real electricity price;
- Relative gas price;
- Real income (using a gross state product measure as proxy);
- Real mortgage interest rate;
- Heating days (winter) temperature variable (degrees Celsius days);

- Cooling days (summer) temperature variable (degrees Celsius days); and
- Number of working days in the month
- Monthly dummy variables.

Projections Produced

The primary projections of scheduled energy provided in the APR were produced using the energy sent out model. In Table A3.1 of the 2007 APR, the output from all 3 energy models is shown

Energy Model Structure

The energy model fit is an “error correction model.” This model provides estimates of both the long-run response of consumption to the economic drivers, and the short-run responses to changes in these drivers over the last few periods. The model estimation uses “cointegration” techniques, which address non-stationarity of a time series. TransGrid explored various versions of the model, and selected the appropriate form based consideration of both model statistical diagnostics and historical model performance.

The model forecasts of energy delivered to the network may be translated into energy delivered to end users. This translation involves:

- Applying population projections,
- Assuming distribution loss factors remain at recent historic levels,
- Assuming particular increases in directly served loads, and
- Assuming embedded generation increases consistent with recent increases in renewable energy generation.

3.3.3 Peak demand model

Peak demand is modeled by time series analysis as a function of previous period average demand previous period peak demand, and increments in average and peak demand for the last few periods. The average demand used in the model is based on the energy generated for the season, divided by the number of hours in the season. Energy generated rather than one of the other energy quantities is used because the peak demand of interest to the forecast is the peak generation required. The appropriate energy driver is the corresponding average demand at the generator.

The only additional predictor in the model is a trend variable for air conditioning levels. The value of this variable follows and ‘S’ shaped pattern over time: the trend is zero until the summer of 1991-92, increases linearly with a shallow slope after that, rises more steeply over several years, then falls to a shallow slope again for the last couple years of the projection period. The flattening slope reflects the recognition that high levels of air conditioning saturation are beginning to be reached in NSW, so that growth in this consumption driver will not continue at recently observed levels. This ‘S’-shaped curve for air conditioning growth is an improvement over the model previously reviewed, which did not include the flattening air conditioning growth.

3.3.3.1 Daily temperature model

Before fitting the peak demand model, all peak demand values are normalized to standard weather conditions. This normalization uses a weather model, fit separately for each season, Summer and Winter.TransGrid has explored what temperature variable, weather station, and lag structure provides the best fit for each season, and uses the following variables (Table 1).

Table 1: TransGrid temperature variables

	Summer	Winter
Weather Station	Paramatta North	Observatory Hill
Temperature Variable	min-max midpoint for current day	midpoint of current day max, next morning min
Weighting		
current day	85%	65%
day - 1	15%	25%
day - 2	0%	10%

A number of weather models were explored prior to producing the 2007 APR. The weather model that was ultimately used was based on daily observations for a single year (4 whole seasons) at a time. Each half hour of the day was treated as a separate variable ocurring once each day, leading to a 48 equation system. Each equation was estimated separately rather than taking advantage of any system interdependencies.

The weather model uses data from each half hour in the year ending in March. The demand for each half hour in the day is regressed on daily temperature (as described in Table 1), dummy variables representing different holidays and days of the week and cyclical seasonal patterns.

For each season, the historic peak demands are all adjusted to the demands that would be observed at 10 percent, 50 percent, and 90 percent POE levels. Further description is provided in Section 4.

3.3.3.2 Developing the POE forecasts

For each season, the series of temperature-corrected 10% POE annual maximum demands is fit in the time series model described above. The fitted model together with the energy forecasts then gives the 10 percent POE projection for each year. Corresponding modeling of the 50% and 90% POE corrected series, respectively, gives the 50% and 90% POE projections.

4. Findings

Based on this review, TransGrid's methods appear to be thorough, sound, and to have no particular bias. These methods are consistent with good electricity industry practice and can be relied upon to provide a realistic estimate of demand forecast. Following are features of TransGrid's methods that lead to these positive conclusions.

4.1 Forecast components

The separation of the load into the primary component amenable to time series analysis together with several separately treated components is appropriate and consistent with widely used good practices.

4.2 Very large stable loads

It is a good and standard practice to forecast very large loads individually as TransGrid does. These loads are best forecast based on information from the individual entities. They are less reliably handled by a general statistical model, and their idiosyncratic changes can distort such models. Thus, this approach is a good practice.

4.3 Demand-side participation

TransGrid's treatment of DSP is consistent with NEMMCO's definitions and reporting requirements. These follow a standard approach among Independent System Operators, wherein total load is measured and forecast at the levels that would exist if no DSP had occurred or will occur. DSP is then treated as a supply resource that can serve these loads. This approach is appropriate. TransGrid's approach complies with the NEMMCO convention, as is necessary and proper.

4.4 Renewable and embedded generation

TransGrid's forecasts use estimates of renewable and embedded generation developed by NIEIR together with Greenworld Energy. Other JPB forecasts use the same source. These estimates are based on detailed accounting of existing units and effects of government policy on expansion of renewables production and capacity. Based on KEMA's prior review of these estimates, this systematic accounting appears to have been done thoroughly and carefully.

4.5 Econometric modeling

TransGrid's forecasting approaches use advanced time series analysis methods, and a model forecasting structure that has been established by recognized experts in energy demand forecasting. TransGrid has done extensive work to test the time series structure of this step and apply appropriate estimation procedures. These represent established good practice steps.

The quality of the econometric modeling can be assessed from two overall perspectives:

1) The conceptual appropriateness of the modeling approach and structure

2) Statistical model diagnostics.

Each of these considerations is discussed below for the energy and peak demand models.

4.5.1 Energy Model Approach and Structure

The basic drivers used in the energy model are standard for analysis of this type, and are similar to those used in the NIEIR forecasts. The specific model structure was developed after review of key literature and testing of alternative specifications. Specific features and rationale include the following:

The model accounts for the fact that consumption at a point in time reflects both long term influences on building and equipment stock and short run influences on usage. This is good practice.

Short run effects include weather. Effects of several weather factors were explored, but only the effect of temperature was found to be important in the models. The investigation of other weather factors is a good step. The finding that terms other than temperature are relatively unimportant is consistent with experience in many other areas.

Temperature effects are represented in the form of degree-days. This is a good practice.

The appropriate base temperature for calculation of degree-days was selected by testing alternative choices and selecting the ones that gave the best overall model fit. This process corresponds to an informal maximum likelihood estimation, which is consistent with good practice.

The model begins with a basic auto-regressive/moving average (ARMA) time series structure. This structure recognizes the dependence of load at each time on load and drivers from previous time periods, and also recognizes inter-dependence of “disturbance” or residual model error from successive time periods. This starting point is good practice.

An advanced feature of the model structure is the treatment of cointegration. The cointegration analysis tests and adjusts for underlying nonstationary trends in the drivers. The treatment reviewed several approaches from the literature and applied a variety of tests to determine the best model structure.

Another good practice is the development of an appropriate weighting for temperature data used in the calculation of degree-days. The weights used are based on wealth, under the assumption that higher wealth is associated with greater presence of heating and cooling equipment. Alternative specifications could also be justified, but this approach has a reasonable basis.

4.5.2 Energy Model Diagnostics

The energy models tested all show very high R^2 values. The final model used in the 2007 APR has R^2 above 0.96. Very high R^2 is common in such models when the time period is monthly and lagged dependent variables are included as predictors. Key terms in the model, including lagged consumption, income (domestic product), seasonal terms, and degree-days generally are very well determined, with standard errors less than 20 percent of the estimate (t-statistic greater than 5).

Coefficients on current and lagged electric and gas prices were less well determined. Thus, the specific effects of price changes on consumption (i.e, price elasticities of demand) are less well estimated than is the overall forecast. Estimation of elasticities is notoriously difficult, and these qualitative results are not unusual in the industry

The ultimate test of a model is the accuracy of the forecasts. One indication of forecast accuracy is the confidence interval for the prediction. At 90% confidence, the model indicates an accuracy of around +/- 2,000 GWh out of an estimate around 66,000 GWh, or about +/-3 percent.

A second indication of forecast accuracy is the performance in out-of-sample forecasting. The current model was re-fit using only data that was available 5 years ago. The resulting model was used to forecast the past 5 actual years. Model drivers, including population, price, economic and weather data were set to their actual values for the period. Thus, the resulting variations reflect model error only, not the uncertainty in the future values of these drivers. This type of back-casting is itself good practice in model validation.

With this validation, the actual values for the 5 years all fell well within the 90 percent confidence bounds of the model prediction. The root mean square prediction error was 540 GWh, or a little less than 1 percent. The Mean Absolute Percentage Error was 0.6 percent. Thus, the model performance is very good. These good performance results indicate that the methods can be relied upon to provide a realistic expectation of demand forecast.

4.5.3 Peak Demand Model Approach and Structure

4.5.3.1 General Model Structure

The peak demand model uses a structure well established in the literature, representing good industry practice. In this structure, the forecast of annual energy (represented in the form of average demand) as well as the prior year's peak demand are key drivers of the current year peak demand. This structure ensures consistency between the energy and demand forecasts. In addition, the relationships explicitly modeled in the energy forecast are by extension carried over into the peak demand forecast. Because this more complex structure is entrained in the energy estimate used as a predictor, the peak demand model itself is straightforward.

4.5.3.2 Initial Temperature Correction

The initial step of weather-correcting the historic maximum demands is valuable and good practice. This step removes short-term weather variation from the changes in maximum demand over time, ensuring a more stable and meaningful model of future peak demands.

The process of applying the weather correction for the 2007 APR is a refinement from that used in prior years, and provides a more appropriate estimate of the 10%, 50%, and 90% POE values. For each year, this process involves the following steps.

1. A model is fit relating demand at each ½-hour interval of the modeled year to calendar and weather terms.

2. The fitted model from Step 1 is evaluated using each of the 50 historic weather years available (1957-58 to 2006-07 years starting in April and finishing in March). The result is a set of 50 estimates of what the peak demand would have been like in the modeled year if the weather had been that of the historic year.

3. The mean and standard deviation are calculated of the 49 estimates from Step 2.

4. The 10th, 50th, and 90th percentiles are calculated for the normal distribution with mean and standard deviation from Step 3. These are the temperature-adjusted historic percentiles of maximum demand for the modeled year.

This process provides an internally consistent set of projections for the 3 percentile levels of interest. These results are explicitly the peak demand levels that would be exceeded in 10%, 50%, and 90% of all years, respectively. That is, this method leads to projections that are fully consistent with the definition of the POE.

In previous years, rather than using the normal distribution, an "ordering" procedure was used. That is, the 10% highest and lowest temperature conditions were taken directly from the ordered observed annual extreme temperatures. Thus, the 5th highest and lowest observed hot (cold) day out of the 50 years would define the define the 10th and 90th percentile points for summer (winter) maximum demand. This ordering approach can lead to "lumpy" estimates, or to over- or under-stating the POE levels based on the extremes of the historically observed temperatures extremes.

The use of the normal distribution allows exact percentiles to be calculated., without this lumpiness or over- and under-statement of extremes. Other smooth distributions could also be used. However, temperatures have been found in other studies to be reasonably well characterized by the normal distribution. TransGrid reviewed the observed distribution of temperatures for consistency with the normal distribution before applying this method.

The particular weather adjustment model used was validated by testing four different models with different structure. The various models gave similar results. In particular, the differences in estimates from the different models were small compared to the difference between the 10th and 90th percentile estimates for any one model; differences between models in calculated 10th percentile points were on the order of 1 percent, while the differences between the 10th and 90th percentiles were on the order of 5 percent. Moreover, these two calculated percentiles of maximum demand bracketed the actual maximum demands observed for almost all of the 15 years for which the temperature adjusted values were calculated.

The temperature-correction models include terms for calendar effects and weather sensitivity, as well as auto-regressive terms. Durbin-Watson tests on the final models indicated no appreciable remaining serial correlation. Attention is given also to the appropriate lag terms to include for temperature responsiveness. Over all, the weather correction process is handled very thoroughly and systematically. Thus, this process can be relied upon to produce realistic outcomes.

4.5.4 Peak Demand Model Diagnostics

The model diagnostics for the peak demand model show a generally good fit. R^2 values are around 0.99. Annual average demand is a strong predictor of the winter peak (t-statistic greater than 5) but a weaker predictor of summer peak (t-statistic a little over 1). On the other hand, the air conditioning trend term is a strong predictor of summer peak, and nearly as good a predictor of winter peak.

As for the energy model, the validity of the peak demand model is shown most clearly by the model's predictive value. For summer, 90 percent confidence intervals for the maximum demand forecasts have a width of around ± 700 MW relative to a total load around 13,000 MW, or about ± 5 percent. For winter the bandwidth is about half that wide.

Out-of-sample predictions for a 5 year period results for the peak demand model show clearly the model validity. The root-mean-square error of prediction is under 200 MW for the summer, under 100 MW for the winter. Corresponding Mean Absolute Prediction Errors are 1.2% and 0.5%, respectively. Thus, the model performs very well, and can be relied upon to produce realistic outcomes.

4.5.5 Consistency between Top-Down and Bottom-Up Estimates

The forecasts developed by the DNSPs use different methods and may use some different assumptions from TransGrid's top-down estimates. The reconciliation process involves confirming some key assumptions and inputs. The process of reconciling the top-down estimate to the bottom-up derived from the DNSP estimates provides a cross-check and further validation of both sets of estimates.

The development of the bottom-up estimate also involves adjustment for loss factors and diversity factors based on historic data. These adjustments are handled systematically. Factors from the last several years are used to project the future factors, with heavier weight given to more recent years. These methods are in accordance with good practice and can be relied upon to produce realistic outcomes.

After reconciliation, the top-down and bottom-up projections showed very little divergence for the summer peak, and almost no divergence for the winter peak. Average annual growth rates based on the two methods differed by only 0.1 percentage point for winter peak demands, and 0.0 percent for summer. This close correspondence serves as further validation of the methods adopted by TransGrid, and that they can be relied upon to produce realistic expectation of demand forecast.

4.6 Changes since previous review

TransGrid's 2007 forecasts incorporate several changes since KEMA's 2005 review. These changes are noted briefly below. Details have been described in Section 3. Ways these changes contribute to enhanced good practice are discussed above in the the earlier portions of Section 4.

4.6.1 Air conditioner saturation

The assumed model of air conditioning growth now incorporates a flattening in later years, consistent with air conditioning use achieving its maximum likely percent in the population. The previous report recommended a change along these lines. This change constitutes an improvement in good practice.

4.6.2 Energy quantity modeled

Energy in the 2007 forecasts is directly modeled at three points: generation, send-out, and network delivery. By contrast, in the previous work, energy sales to end users was modeled directly, and the other three energy quantities were determined by adjustments to the projected sales. This change represents an improvement in practice. One benefit is that the energy series now used in the model has more reliable inputs. The other benefit is that projecting the 3 components separately means that the loss factors between successive stages in the delivery chain can now be estimated for future years based on the differences in the 3 projections, rather than being assumed based on past history.

4.6.3 Weather correction of peak demand

In previous years, TransGrid constructed a base peak demand forecast for a 50% POE temperature condition. This base forecast was then adjusted to 10% and 90% POE conditions using a weather model. The limitation of this approach, pointed out in the previous review, is that the relationship between peak demand and average demand tends to be different in an extremely hot or cold season than in a mild season. TransGrid's current method directly models the 10% and 90% POE peak demand levels. This approach more directly captures the extreme condition behavior represented by the POE levels. Thus, this change represents an improvement to the procedures that is expected to increase the reliability of the estimates.

4.6.4 Use of Normal Distribution to Determine Percentiles

The previous forecasts used the observed percentiles from the ordered values based on 50 historical years. The 2007 forecasts use a normal distribution, which provides smoother and more stable estimates of the percentiles. This change represents an improvement to the procedures that is expected to increase the reliability of the estimates.

4.6.5 Backcast Validation

Previous forecasts have constructed backcast estimates for a single year, and have not adjusted the backcasts to the actual economic and weather conditions. TransGrids current methods backcast several years, using the actual conditions for the backcast years. This approach was recommended in the prior review and is an improvement to the practice.

5. Potential Improvements

Even the best forecasting models and processes can be refined. TransGrid has adopted some improvements in response to the 2005 methods review KEMA performed for NEMMCO, and has also developed some other improvements not suggested in that review. Following are some additional steps that may be worth consideration in future models. As always, adopting such changes would require investigation of their effect on the process, and the potential costs of developing these refinements must be balanced against the likely improvement.

It must be stressed that these suggestions are not meant to imply that the current methods are deficient. To the contrary, as noted, the current methods represent good practice and can be relied upon to produce a reasonable expectation of demand forecast. These suggestions are offered in the interests of the ongoing improvement and refinement that has characterized TransGrid's forecasts.

5.1 Air conditioning sensitivity model

The future growth in air conditioning is one of the greatest sources of uncertainty in the TransGrid forecasts. The modification to the assumed growth pattern since the 2005 review is a definite improvement. Further improvement may be possible by explicitly modeling the growth trajectory. As noted in the prior review, weather sensitivity in each year is already estimated by TransGrid. This sensitivity itself could be directly modeled, assuming a smooth relationship with a roughly S-shaped pattern. The form of this smooth relationship could be chosen based on analysis of historic data from other areas where the air conditioning levels appear to have stabilized.

5.2 Using weather-normalized average demand in the peak demand models

In the current form of the models, the average demand used as a driver in the peak demand model is the actual average demand for the year. However, the peak demands used as the dependent variable are all adjusted to a particular percentile or POE level for each year. The effects of warm and mild actual average demand more or less average out, but there could be some distortions to the relationship between average and peak demand introduced by these ups and downs in the time series. It may be more appropriate and provide a more stable estimate to use weather-normalized average demand as a predictor. The modeling process already produces weather-normalized energy.

5.3 Selection of degree-day bases for weather modeling

TransGrid selects the bases for calculating heating and cooling degree-days by trying different bases and choosing the one with the best overall results. This approach can be made more systematic, to become explicit maximum likelihood estimation.