High level review of transmission connection point forecasts: Victoria

A REPORT PREPARED FOR THE AUSTRALIAN ENERGY MARKET OPERATOR

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Executive summary

In 2012, the Council of Australian Governments (COAG) gave AEMO responsibility for developing independent maximum demand forecasts as an independent reference for the Australian Energy Regulator's (AER's) revenue reset determinations.

AEMO commissioned ACIL Allen (ACIL) to develop methodologies for forecasting maximum demand and energy consumption at the transmission connection point (CP) level.

AEMO implemented this methodology for the first time in 2014 to produce maximum demand forecasts for transmission connection points (CPs) in New South Wales (NSW) and Tasmania (Tas). AEMO engaged Frontier Economics (Frontier) to review AEMO's implementation of the methodology for the NSW and Tas forecasts. The forecasting methodology developed further during the NSW and Tas implementation as some aspects of the original ACIL methodology required interpretation and judgment.

In 2014/15 AEMO will use the methodology developed to date to forecast maximum demand for the three remaining regions of the NEM: QLD, VIC and SA. AEMO has engaged Frontier to act as peer reviewer and advisor in this process, including:

- peer review of the models, assumptions, methodology and forecasts developed by AEMO's Connection Point Forecasting team
- provide expert advice and guidance on the data, methodology, models and forecasts, as required
- include clear identification of any issues and recommendations to address these.

This report reflects Frontier's review of AEMO's maximum demand forecasts for 61 Victorian (VIC) transmission CPs. The review and advice process included:

- a Red Flag review in which we identified key issues that should be addressed in the implementation of the methodology for forecasting maximum demand for the VIC CPs
- ongoing advice and interaction with AEMO regarding the maximum demand methodology and its implementation
- this report, which reflects a review of AEMO's VIC forecasts

The scope of Frontier's review is mainly a desktop review of AEMO's implementation of the methodology and the resulting forecasts. Frontier was not required to produce an alternative set of forecasts. The review did not involve an audit-type exercise which would include a detailed review of computer code in the R statistical package and spreadsheet formulas to ensure that no errors were made.

On the basis of our understanding of the steps in AEMO's implementation of the maximum demand forecasting methodology for the Victorian CPs, it appears that AEMO has correctly implemented the proposed methodology, subject to some modifications to address issues that arose during the implementation process or during the previous implementation of the methodology in NSW and Tas. Some of these issues relate to areas of ACIL's original methodology where judgment calls were required to interpret the recommendations.

Frontier made a number of recommendations during the prior round of CP forecasts (NSW and Tas) and we have provided some additional recommendations for this round of VIC CP forecasts. Some of these have been implemented for the current forecasts in VIC. Other recommendations involve further analysis and could not be implemented in time for the current forecasting process. The recommendations for possible improvements are yet to be tested but we will explore these and further improvements in future rounds of CP forecasts.

Our overall assessment of the implementation of the methodology is that it meets the standard of good industry practice. The proposed methodology has been implemented in a professional manner, and where issues of concern have arisen during the implementation of the methodology, all reasonable steps have been taken, within the time and resource constraints, to ensure the statistical integrity of the forecasts.

1 Introduction

1.1 Background

In 2012, the Council of Australian Governments (COAG) gave the Australian Energy Market Operator (AEMO) responsibility for developing independent demand forecasts as an independent reference for the Australian Energy Regulator's (AER) revenue reset determinations.

AEMO commissioned ACIL Allen (ACIL) to develop a methodology for forecasting maximum electricity demand at the transmission connection point (CP) level. The proposed methodology was published in a report titled 'Connection Point Forecasting: A Nationally Consistent Methodology'[1] (henceforth referred to as the ACIL Report).

In 2013-14 the maximum demand methodology was implemented for the first time to deliver maximum demand forecasts for all CPs in NSW and Tasmania. Frontier undertook an independent peer review of AEMO's implementation of the ACIL methodology in those regions. The forecasting methodology was further developed during that forecasting round as some aspects of the original ACIL methodology required interpretation and judgment.

This current review covers AEMO's maximum demand forecasts for CPs in Victoria. These forecasts enable AEMO to provide input into the upcoming revenue reset assessments for this jurisdiction by the Australian Energy Regulator (AER). AEMO has engaged Frontier to act as peer reviewer and advisor in this process. In this report we present a high level overview of the review process and an assessment of AEMO's implementation of the methodology. The review and advice process consisted of a number of steps:

- a Red Flag review in which we identified key issues that should be addressed in the implementation of ACIL's methodology for forecasting maximum demand for the Victorian CPs to ensure the statistical integrity of the resulting forecasts
- ongoing advice and interaction with AEMO regarding the maximum demand methodology and its implementation
- this report, which reflects a review of AEMO's forecasts

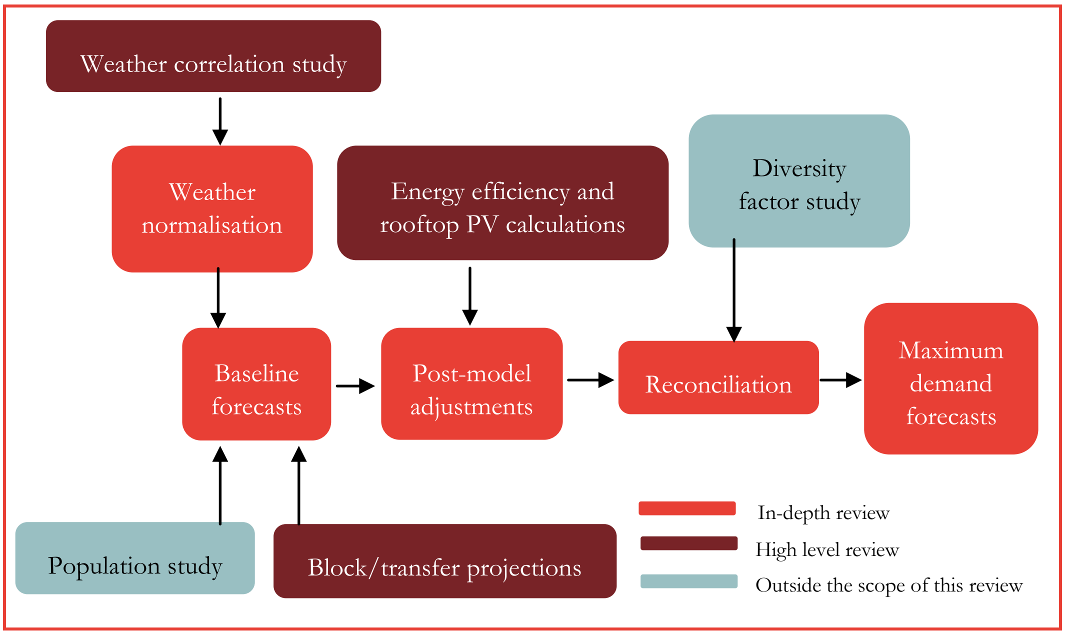
1 http://www.aemo.com.au/Electricity/Planning/Forecasting/~/media/Files/Other/planning/ConnectionPointForecastingANationallyConsistentMethodologyforForecastingMaximumElectricityDemandpdf.ashx

1.2 Scope of our review

Forecasting maximum demand at the CP level involves completing a number of interlinked steps. A simplified schematic representation of these steps is presented in Figure 1. The scope of our engagement does not involve an in-depth review of all the steps involved in deriving the forecasts. Steps that have not been reviewed in any detail are shown as 'outside the scope of this review'.

In undertaking this review, we have assumed that appropriate investigations have been undertaken to select the required inputs, and that the preparation of the data used for the modelling has been performed to a professional standard. We have also assumed that the computer code has been checked carefully and does what it is intended to do (i.e. it is outside our scope to provide quality assurance or checks on the correctness of the computer code).

Figure 1: Scope of Frontier's maximum demand methodology review



Source: Frontier Economics

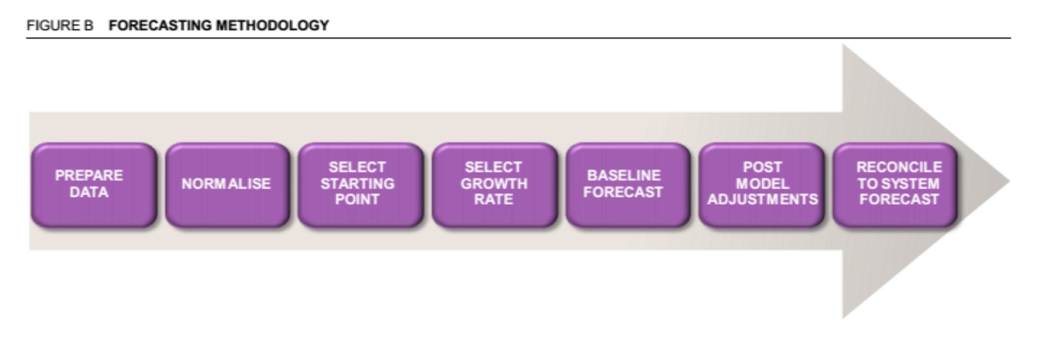
2 AEMO's maximum demand forecasting methodology

2.1 Overview

AEMO's forecasting methodology is an implementation of ACIL's proposed methodology for forecasting maximum demand at the CP level. Separate forecasts are produced for summer and for winter maximum demands.

A high level summary of ACIL's proposed methodology for forecasting maximum demand at the connection point level is presented in Figure 2. The steps involved are described in detail in the ACIL report. Some modifications were made to the proposed methodology in response to issues arising during its implementation in the prior round of forecasts (NSW and Tas) and during the current round of forecasts (VIC)

Figure 2: Overview of ACIL's proposed methodology



Source: ACIL Allen (2013), Connection Point Forecasting

AEMO's methodology consists of the following main steps:

1. Data collection and manipulation. This step consists of the collection of load and temperature data, adjustments of load data for large industrial loads and embedded generation, and the treatment of influential and missing observations.
2. Weather normalisation. This step involves specification and estimation of temperature sensitivity models for daily maximum demand, followed by a simulation exercise to determine the P50 (POE50) and P90 (POE10)[2] levels of maximum demand for each historical year.
3. Selection of a starting point for the demand forecasts. The starting point is a choice between the last point on the trend line through the P50 (POE50) and P90 (POE10) historical demands ("off the line") or the last actual observation for the POE historical demands ("off the point"). The choice depends on how well the trend line fits the data.
4. Determination of a growth rate. The growth rate is determined from either the trend line through the historical demands or anticipated population growth in the local area. In some cases a zero growth rate is assumed.
5. Calculation of baseline forecasts. This is done by applying the growth rate to the starting point.

2 Throughout this report the 90th Percentile (P90) corresponds to the 10% probability of exceedence (POE10).

6. Post-modelling adjustments for photovoltaic solar generation (PV), energy efficiency improvements (EE) and block loads and transfers.
7. Reconciliation of CP maximum demand forecasts to system maximum demand forecasts.

2.2 Worked example of a connection point forecast

Figure 4 presents an example of some of the main stages of the forecasting process for the Keilor (Jemena) 66 kV connection point (VKT2) in Victoria. The different panels of the chart represent different seasons (Summer and Winter) on the top X-axis, and different levels of the probability of exceedence (POE) of annual maximum demand on the far right Y-axis. P50 is the percentile corresponding to a POE of 50%, or POE50, and P90 is the percentile corresponding to a POE of 10%, or POE10. The legend in the chart is ordered by the stage of the process.

AEMO's implementation of ACIL's methodology begins with data cleaning, followed by weather normalisation to obtain estimates of the historical POE50 and POE10 levels of annual MD. These MDs are shown in Figure 4 as:

- '**Actual MD**' — measured maximum demand at the connection point less non-PV embedded generation and major industrial loads.
- '**Working day MD**' — the **Actual MD** excluding non-working days.[3]
- '**Simulated POE**' — the result of the weather normalisation and simulation process.

The intent of the weather normalisation process is to remove the effects of extreme weather events on maximum demand, revealing an underlying trend. Hence in Figure 4, particularly in summer, **Simulated POE** is less volatile than the **Actual MD** because the effects of varying weather have been removed.

Once the effects of weather have been accounted for, the next stage is to adjust the simulated historical P50 and P90 data for historical PV, block loads and load transfers, which results in the '**Adjusted simulated POE**' traces.[4] Figure 3

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3 In earlier reports we did not plot the 'Working day MD' line, moving from 'Actual MD' straight to 'Simulated POE'. Over the course of the review process, the possibility that the 'Simulated POE' line could be significantly driven by data cleaning has become apparent, hence the inclusion of the 'Working day MD' line.

4 Historical PV output is *added* to the historical simulations *before* establishing the growth trend. This is so that the underlying trend in MD is not affected by growing PV output over time. Once the underlying trend is established and forecasts produced, the estimated PV impact on MD in the future is later *subtracted* from the forecast. Similar adjustments to the *historical* simulations for energy efficiency (EE) are not applied as the National Electricity Forecasting Report (NEFR) assumes that EE growth is linear and is already fully reflected in the historical trend. For EE, only deviations from the established trend in the future are applied.

shows the relevant adjustments for VKT2.[5] In VKT2 these adjustments are minor so the '**Simulated POE**' and the '**Adjusted simulated POE**' traces virtually coincide.

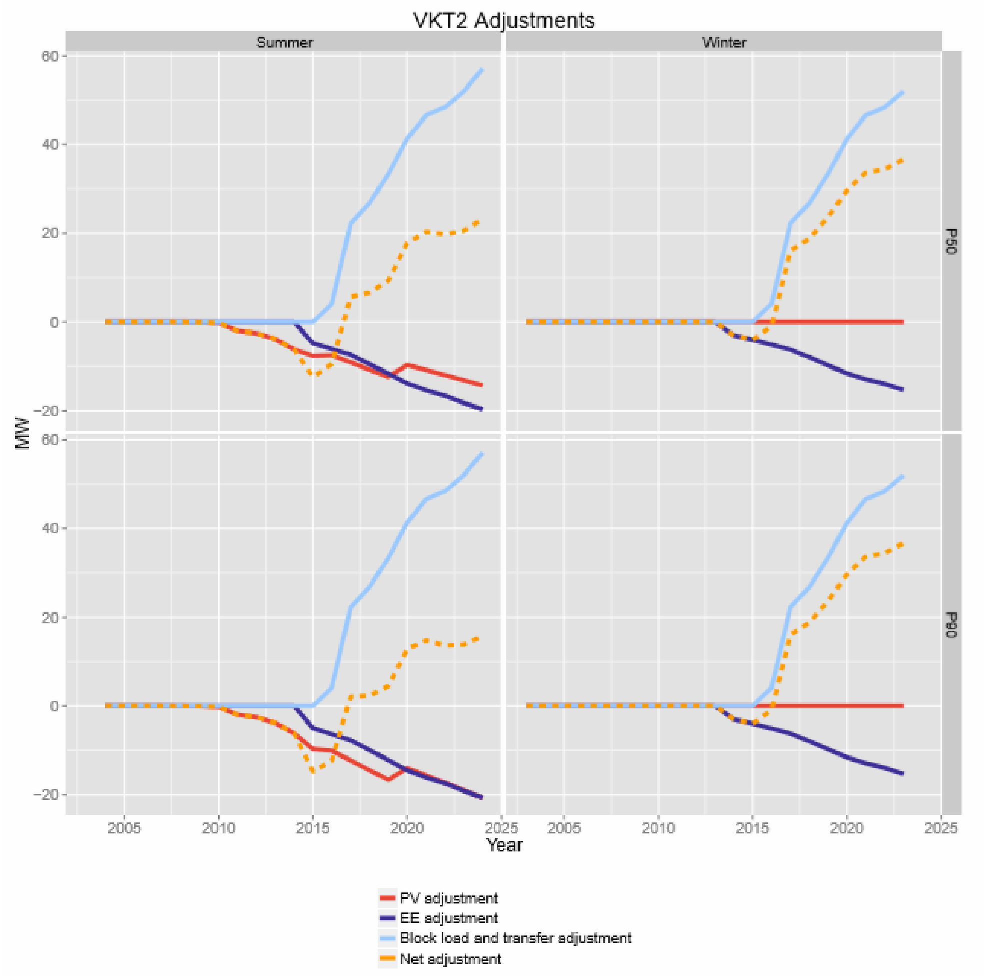
The '**Trend line**' in each panel is the linear time trend through the '**Adjusted simulated POE**', and generally provides the growth rate for the '**Baseline forecast**' line in the chart. If the trend line is a bad fit (based on statistical tests) the growth rate will be 'overruled' using either an Australian Bureau of Statistics Local Government Area (LGA) population growth rate or a zero growth rate in its place. In the instance of VKT2, statistical tests determined the trend line is a good fit, hence it is used to generate the 'Baseline forecast'.

The '**Baseline forecast**' line can start either from the last point on the 'Trend line' or from the last observed (adjusted) simulated data point. The decision on whether to start the forecasts 'off the line' or 'off the point' is based on further statistical tests and discussed in more detail in the next section. The Summer P50 panel is an example of a baseline forecast 'off the line', while the Winter P50 panel is an example 'off the point'.

The '**Adjusted baseline forecast**' reflects the '**Baseline forecast**' with adjustments made for *future* block loads and transfers, PV and energy efficiency improvements, as outlined in Figure 3.

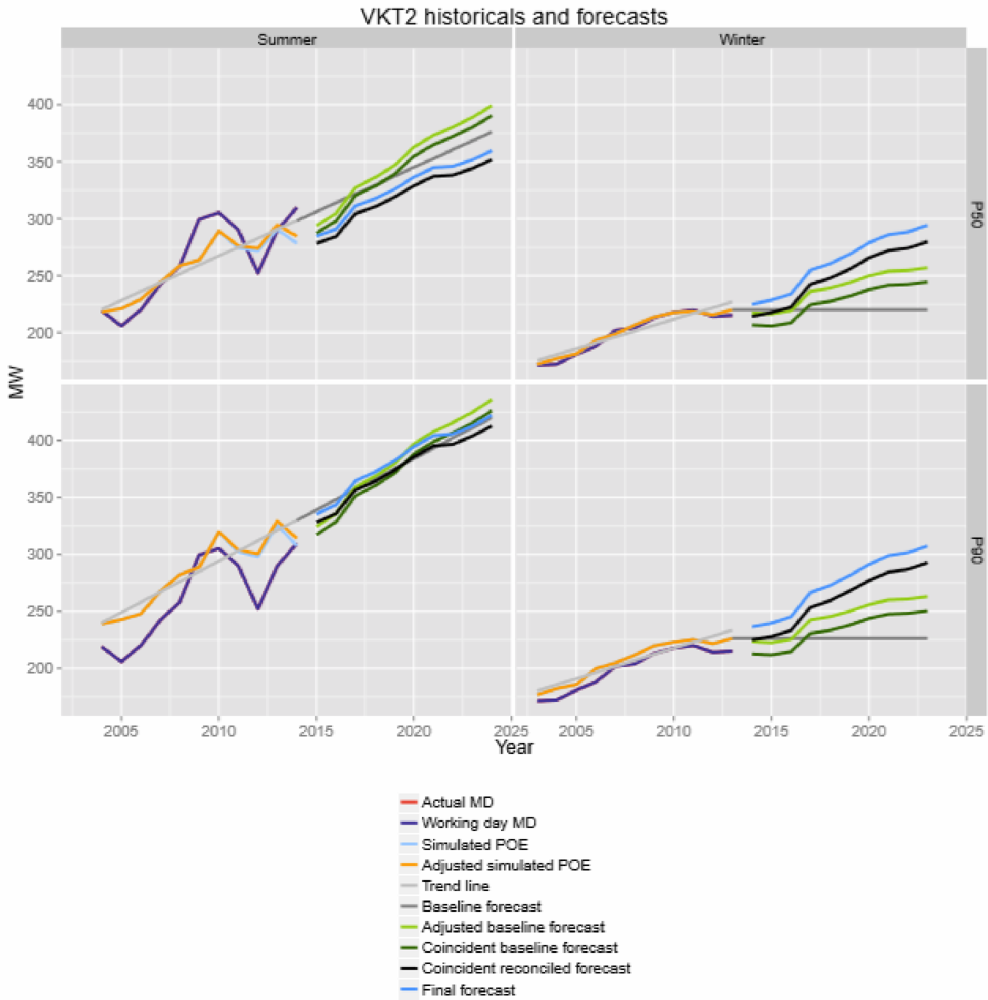
5 The adjustments at this stage don't include the major industrial load and embedded generation adjustments made prior to the weather normalisation process, which is part of the data preparation stage.

Figure 3: PV, EE and block load and transfer adjustments for VKT2



Source: Compiled from AEMO data.

Figure 4: Forecast of connection point VKT2 at each stage of the process



***Actual MD** is effectively the same as **Working day MD** for this CP (the red line is hidden by the blue line).*

***Simulated POE** is mostly the same as **Adjusted simulated POE** for this CP (the light blue line is mostly hidden by the orange line).*

Source: Compiled from AEMO data

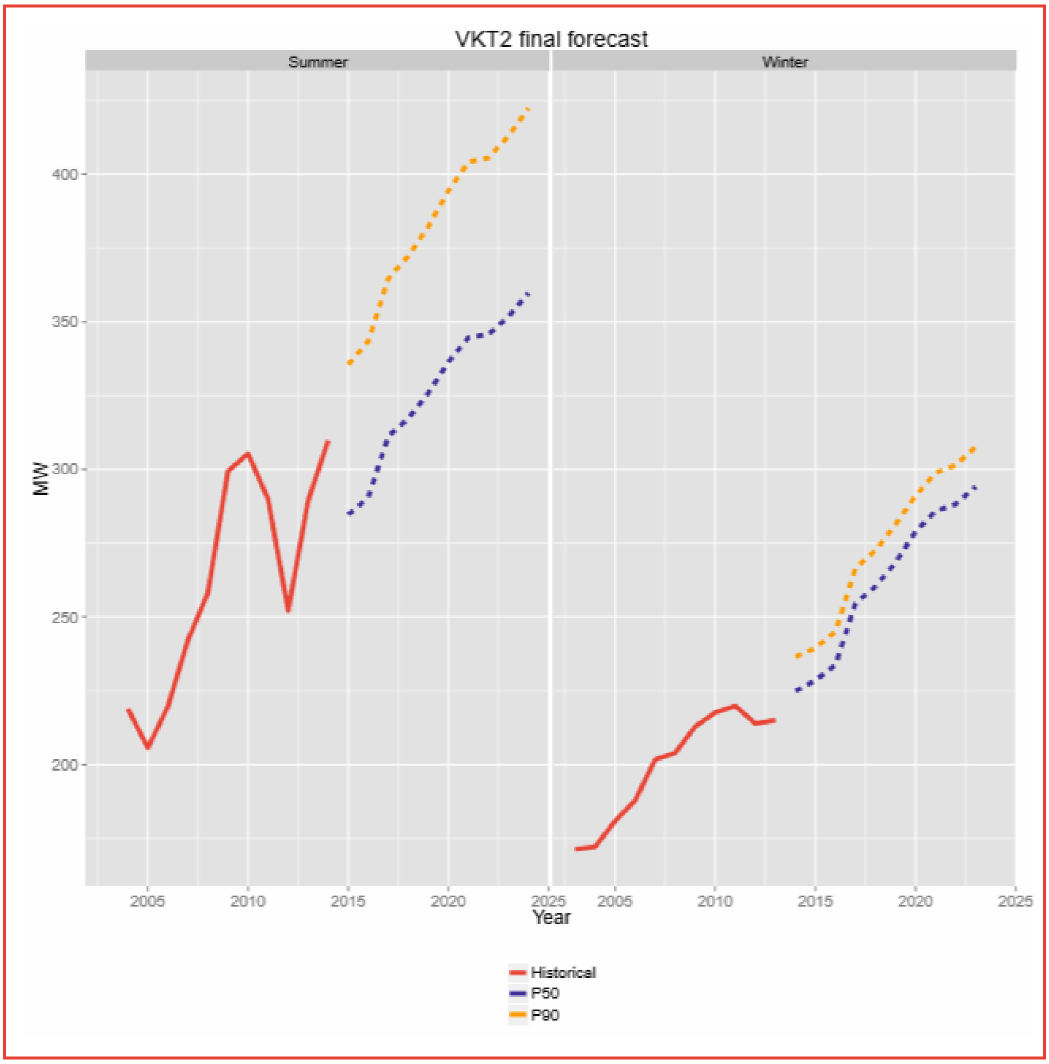
The final three stages of the forecasting process shown in the chart relate to the reconciliation process, in which the forecasts are reconciled with AEMO's system level MD forecasts produced for the National Electricity Forecasting Report (NEFR).

- For each CP, a diversity factor is used to convert the adjusted baseline forecast (which reflects a non-coincident CP peak) to forecasts of coincident maximum demand (CMD), i.e. the demand for that connection point at the time of system peak. This step is plotted as the '**Coincident baseline forecast**' line. The diversity factor will always be less than or equal to one as the coincident peak is always less than or equal to the non-coincident peak.

- The CMDs are then adjusted by a scaling factor which ensures that, in each forecast year, the sum of the scaled CMDs across connection points corresponds to the NEFR regional level forecasts. The '**Coincident reconciled forecast**' line in Figure 4 shows the result of the reconciliation stage at the time of system peak (i.e. the scaled CMDs).
- The '**Final forecast**' line shows the corresponding forecasts at the time of the CP's local peak, which is obtained by applying the diversity factor in reverse. This reflects the non-coincident peak after having adjusted for the scaling factors to ensure that the CP forecasts are consistent with the system/region forecasts.

Figure 5 shows the historical actual MD data and the final forecasts for VKT2 without the intermediate steps.

Figure 5: The final non-coincident forecast for connection point VKT2



Source: Compiled from AEMO data

3 Review of AEMO's implementation of ACIL's proposed forecasting methodology

In this section we review AEMO's implementation of the forecasting methodology outlined in the ACIL Report. Table 1 provides a summary of the main steps in ACIL's proposed methology, where further decisions were required during AEMO's implementation of the methodology, and Frontier's recommendations. It also indicates some areas where additional analysis is required to refine the methodology.

In the following sections we expand on some of the more complex conceptual issues arising in the implementation of ACIL's proposed methodology, including areas that may require further refinement for future implementations.

Table 1: Summary of methodology steps and recommendations

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Data preparation	Prior to undertaking any regression modelling, daily maximum demand and weather data should be modified to: • remove known block load and transfers, as these are exogenous • remove weekends and public holidays • remove 'mild' days and potentially misclassified days (which appear as outliers).	Embedded generation is added to the demand data; large industrial load is netted out for weather normalisation. Offsetting adjustments are made later. The range of days to be excluded as 'public holidays' requires some judgment. AEMO's original definition of 'public holidays' applied in the draft forecasts for VIC CPs meant that data from 23rd December to 2nd January were excluded. Closer inspection of individual connection points revealed that this should be extended further to avoid the inclusion of days with low MD due to ongoing holiday activity. The threshold temperature for a "mild day" (to exclude data) is also subjective.	Frontier has not inspected the files providing details of the removal of major industrial load or the addition of embedded generation. We understand that in some cases data was not available, and AEMO has made judgment calls on appropriate block load/transfer adjustments. A detailed inspection of the CP VBL6 revealed that the week before Christmas and the week after New Year's Day had particularly low MDs so that these days appeared as outliers in the temperature regressions. This led to negative skewness in the regression residuals and increased the standard error of the regressions, thereby resulting in higher baseline forecasts. Additionally, this inspection revealed that the rule for excluding 'mild temperature' days was set quite low for this particular connection point, prompting a review of temperature-based exclusion rules. We expect that the simulation results would be less sensitive to these changes/assumptions if data pooling were adopted for the weather normalisation (discussed below). **As a general rule, there is a risk of bias where data is excluded on the basis of a demand threshold.** One exception to this rule is using a threshold as a proxy for a dummy variable for load switching. For example, a connection point load may appear to have two 'states', high load and low load, based on whether agricultural refrigeration is occurring at the time. In this instance, excluding data based on a demand threshold is acceptable. ***This approach generally appears reasonable and appropriate.***

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Weather normalisation	Undertake the following steps to weather normalise the maximum demand: • for each historical year, estimate a model of daily maximum demand as a function of temperatures • for each historical year, use this relationship to simulate a distribution of hypothetical historical annual peak demands under different weather scenarios and random influences • determine the POE50 and POE10 levels of peak demand for each year from these distributions	Exact specification of the model for maximum demand as a function of temperature Implementation of the simulation exercise to obtain a distribution of maximum demand for temperature sensitive CPs Simulation methodology for CPs that are not temperature sensitive	**Weather normalisation:** The recommended methodology for estimating demand-temperature models resulted in most Victorian CPs being judged 'temperature sensitive'. Although not particularly problematic in this round of forecasts, in the previous round of CP forecasts (NSW and TAS) Frontier recommended pooling observations across years when estimating its maximum demand-temperature models in order to more effectively use the available data. AEMO did not implement the pooling approach in the Victorian forecasts because most CPs were judged temperature sensitive anyway (suggesting no problem with the data in this instance). Nevertheless, we recommend that this be considered in future implementations as an improvement in methodology. We expect that this would produce less volatile simulated P50 and P90 traces, and hence better estimates of the corresponding trend lines. It might also address the sensitivity of some results to assumptions in the data preparation step evident in the review of VBL6 (above). ***Frontier recommends that further analysis be undertaken to consider data pooling for weather normalisation in future forecasts*** **Weather simulations:** The distribution for maximum demand produced by AEMO's simulation procedure should be inspected to confirm that, on average, about 50% of the historical actual MDs do lie above the P50 levels, and about 10% lie above the P90 (POE10) levels. Comparisons of the Victorian historical actual versus the simulations suggest that the Victorian simulations are lower than expected. ***Frontier recommends reviewing the weather simulation results against historical actual data.***

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Estimate historical trends	Regression is used to fit linear trends through the historical POE50 and POE10 values	Prior to estimating the trends, AEMO adjusts historical POE values for block loads and load transfers, and adds PV load.	The adjustments are not mentioned explicitly in the ACIL Report, but are required to ensure that the estimated trend lines reflect underlying demand at the consumer level. During the Red Flag review we identified that the historical solar PV load was not being correctly added back in the data. This resulted in (a) the underlying trends for many CPs were lower than they should be, and (b) potential incorrect rejection of linear trends. AEMO corrected this in the final forecasts. ***The final approach appears reasonable and appropriate***
Select starting point for projecting forecasts	The starting point for forecasting is based in the last year for which actual data are available. ACIL recommends that, depending on how far the last observed point deviates from the trend line, the forecasts should start either: • “off the point”: taking the most recent weather normalised observation, or • “off the line”: taking the corresponding point on the fitted time trend line through the weather normalised data.	The decision for selecting the starting point is based on whether ‘the point is close to the line’, however no formal approach was prescribed in the ACIL methodology. During the review of the NSW/Tas CP forecasts, Frontier recommended a statistical test to determine whether the trend model is “well specified”, in which case “off the line” should be used as the starting point.	From a statistical point of view, “off the point” should only be used as the starting point if the linear time trend regression model is not well specified, and hence does not provide a good indication of future maximum demand. AEMO adopted and correctly applied the statistical test recommended by Frontier. Some problems were identified with the starting points in earlier draft forecasts which were corrected for by AEMO in the final forecasts. For example: - an inconsistency between the starting point and solar PV adjustments which effectively resulted in ‘double counting’ of these adjustments (and forecasts which were too low); - incorrectly starting “off the point” in some cases where the statistical tests accepted the linear trend and the last point was not an outlier ***The recommended approach was implemented by AEMO in the final forecasts***

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Determine a growth rate	ACIL proposes that two approaches be investigated to determine the growth rate: (i) fitting a linear time trend regression model through the historical POE50 and POE10 series; and (ii) estimating a regression model with regional population as the driver. The approach with the better fit to the data is used to determine the future growth rate, provided that the estimated growth rate seems reasonable. If the growth rate does not seem reasonable, a zero growth rate is assumed.	Some trends in the historical data are nonlinear. When this is the case, it is inappropriate to use a linear trend line to determine the growth rate.	In the prior round (NSW and Tas) Frontier provided a statistical test to determine when use of the linear time trend model for producing forecasts was inappropriate due to nonlinearity. In cases where the statistical test rejected the use of the linear trend model for producing the forecasts, Frontier recommended using judgement to determine an appropriate alternative trend to use. Reasonable alternatives include the local area population growth rate (as a proxy for customer numbers), an upper limit of 4 per cent (as suggested by ACIL, since greater than 4 per cent is unusual) or a lower limit of zero percent growth rate. AEMO also used judgement to manually override a linear trend if this was less than zero or more than 4 per cent. On average, these manual adjustments to the **baseline** growth trends results in very small changes to the annual weighted average growth across all CPs. As a result of the reconciliation process, the average growth rates across CPs in the final forecasts are not affected by these adjustments. However, the relative growth rates between CPs will be affected. ***The recommended approach was implemented by AEMO in the final forecasts***
Baseline forecasts	Apply the selected growth rate to the selected starting point to produce baseline forecasts	Prior to applying the growth rate, adjustments were made to the starting point for PV and block loads to reverse the adjustments made in a previous step	AEMO's initial approach led to 'double counting' of the PV adjustment and some load transfer adjustments being applied incorrectly when starting "off the point". Frontier recommended changes to the procedure to overcome these issues, which AEMO implemented for the final forecasts. ***The recommended approach was implemented by AEMO in the final forecasts***

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Post-model adjustments	Where necessary, make post model adjustments to take into account factors that are known, but not yet incorporated into the trend forecasts. These factors include: • new large block loads and load transfers • demand side management initiatives • impact of government policies driving factors such as energy efficiency and the uptake of solar PV	ACIL does not appear to make specific recommendations for post-model adjustments, but discusses general principles and identifies complications/difficulties. We generally agree with ACIL. These adjustments mostly require expert judgment to estimate deviations from existing trends. AEMO has applied an approach consistent with the NEFR 2014, though decisions were required to allocate/ pro-rate adjustments to the CP level. In some cases there is a switch from a day time to a night time as a result of increasing PV. The timing of this switch was not always the same for the POE50 and P90 (POE10) forecasts, which led to complications in adjusting for PV by POE level	**Energy efficiency** The complications that ACIL identify (in estimating EE) are dealt with in AEMO's NEFR, including estimation of the impact on maximum demand. We understand that the approach applied by AEMO for adjusting the CP forecasting for EE is based on a pro-rata adjustment of the NEFR EE estimate for the state (based on customers per CP for building EE and residential customers per CP for appliance EE). Frontier compared the sum of all the P50 (POE50) and P90 (POE10) EE forecasts across CPs against the corresponding forecast for EE in the 2014 NEFR, and found them to be consistent. We understand that the EE MD in the 2014 NEFR reflects the incremental EE (i.e. the deviation from trend), which is the correct approach. ***This approach appears reasonable and appropriate*** We note that the P90 (POE10) estimates for EE are larger than the P50 (POE50) estimates. This implicitly assumes that EE is positively correlated with demand (i.e. there is more EE likely when demand is higher). This will narrow the range between the final P50 (POE50) and P90 (POE10) MD forecasts.

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
			Solar PV AEMO determines the PV forecast at CP level as a pro-rata allocation of the NEFR system level PV estimate based on the residential customers per CP. ***This approach appears reasonable and appropriate*** The switch from day peak to night peak due to increasing PV potentially leads to the P90 (POE10) MD forecast falling below the P50 (POE50) MD baseline forecast. These anomalies are partly overcome in the reconciliation process. In the previous round of forecasting (NSW and Tas) Frontier recommended an approach to overcoming these anomalies in the baseline forecasts by applying the same time of day for the P50 and P90 solar PV adjustments. This meant that the sum of the P50 solar PV adjustments applied to the Vic CPs was higher than the NEFR 2014 Victorian P50 solar PV adjustment. ***This approach was implemented by AEMO in the final forecasts. AEMO changed the P50 time of MD to match the P90 time in Victoria. It would also be possible to change the P90 time to match the P50 time.*** Theoretical statistical analysis showed that the current approach to combining percentiles from the maximum demand and PV distributions is only valid under certain assumptions. In general, it is not valid to add the percentile values from different distributions, and this could lead to biases in the calculations, particularly at the P90 (POE10) level. ***Frontier recommends that further analysis be undertaken to address this issue in future implementations***

Step	ACIL approach (summarised)	Further decisions during implementation	Resolution/recommendation and notes
Reconciliation with system forecasts	Scale the individual connection point forecasts so that the totals of the CP forecasts match the system level (regional) forecasts.	How to calculate appropriate diversity factors for each connection point Decide which CPs should be exempted from the re-scaling because its forecasts are considered reliable	AEMO estimates the diversity factor for each CP by averaging the annual diversity factors for the latest five years. The switch from day peak to night peak due to increasing PV is also likely to affect the relationship between maximum demand and coincident maximum demand, and hence the diversity factor. ***Frontier will work with AEMO to address this issue in future implementations*** The scaling factors for the VIC CPs have negative trends in summer and positive trends in winter over time. In some cases, the adjustment become quite material; for example for Summer P50 the ratio between the system forecasts and the sum of the CP forecasts falls from 97% to 90%. This is because the regional forecasts grow at an average of just 0.1% per annum in summer compared with average CP baseline forecast growth of 1.4% per annum and adjusted forecast growth of 0.9% per annum. This means that the final reconciled forecasts for Victorian CPs in Summer will tend to show low growth (in aggregate) due to the reconciliation process and the slow growth in the regional forecasts, irrespective of the trends at the CP level. The source of this discrepancy should be investigated. ***Frontier will work with AEMO to address this issue in future implementations*** The scaling factor for P90 (POE10) is always considerably larger than for P50 (POE50). There is no theoretical reason why this should be the case. It suggests that the simulated spread of MDs due to weather conditions is larger in the system level forecasts than in the CP forecasts. The reason for this most likely lies in the different approaches used to develop the weather simulations. The reconciliation exercise overcomes the discrepancy between the approaches to some extent, but the source of the discrepancy should be investigated. ***Frontier will work with AEMO to address this issue in future implementations***

3.1 Weather normalisation

ACIL's approach to weather normalising maximum demand consists of two main steps:

- estimating a regression model to determine the temperature sensitivity of the daily maximum demands in a season
- using this model to simulate the annual maximum demands under many different weather scenarios. The simulations also incorporate a random term that varies from simulation to simulation. The random term encapsulates unobserved idiosyncratic factors that impact maximum demand.

The simulation step results in a distribution of hypothetical annual maximum demands for each historical year. The maximum demand for each year at any level of POE can be obtained from the corresponding percentile of this distribution. The default temperature model selected by AEMO is shown in Figure 6.

Figure 6: 'Max min' temperature sensitivity model

$$MD_d = \beta_0 + \beta_1 maxtemp_d + \beta_2 mintemp_d + \varepsilon$$

where

MD_d is the daily maximum demand for day d

$maxtemp_d$ is the maximum daily temperature for day d

$mintemp_d$ is the minimum daily temperature for day d

Source: Adapted from the ACIL Report

A recurring issue from the weather normalisation process in these connection point forecasts is that, for many CPs that are temperature sensitive, the weather normalised demands, i.e. the simulated historical POE50 and POE10 demands, are quite volatile from year to year. Since the main aim of weather normalisation is to produce like-with-like comparisons of demand over time by eliminating the impact of weather on demand, it is likely that the observed volatility in the weather normalised demand is to some extent due to the small sample sizes used to estimate the temperature sensitivity models.

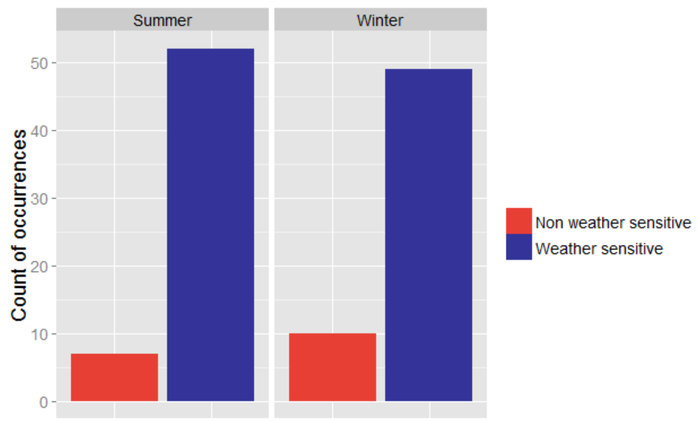
Frontier suggested that the issue of volatile simulated demand could be addressed by pooling the data across years when estimating the temperature sensitivity models.[6] Using a sample that covers several years has the following benefits:

- it increases the range of temperatures included in the estimation which leads to more precise estimates of the coefficients. The increased spread of temperatures also overcomes the problem that in mild years it is difficult to obtain statistically significant coefficients because the weather was too mild to evoke much demand response. Both of these factors will result in less instances of a CP being deemed to be not temperature sensitive.
- it increases the sample size, which further improves the precision of the estimates.
- it smoothes the estimated temperature sensitivity coefficients over time, which will result in less volatile weather normalised demands. This should also benefit the step where a trend line is fitted through the POE50 and POE10 historical maximum demands.

AEMO investigated the pooling of data in the previous round of forecasts for NSW and Tas. In earlier forecasting processes, it was not applied to the final forecasts, partly due to time constraints and partly to adhere to the published methodology for this round of forecasts. In this round of forecasting for Victoria there were fewer temperature insensitive connection points so this was less of an issue in this regard (Figure 7). For the reasons outlined above, Frontier recommends that further analysis should be undertaken to address this issue in future implementations, and we understand that AEMO is considering this.

6 The pooled model recommended by Frontier includes yearly dummy variables to capture differences in the average level of demand from year to year. But determining the best approach to pooling the data across years requires further investigation.

Figure 7: Temperature sensitivity of Victorian CPs



Temperature sensitivity is only applicable to 59 Victorian CPs. This is not relevant to two new CPs, which are based on future load transfers from existing CPs

Source: Frontier Economics analysis of data provided by AEMO

3.2 Historical trends in MDs and starting points for the forecasts

ACIL's methodology to determine growth rates includes fitting a linear trend line through the historical weather normalised MD data. If a linear trend fits the data well, then it would be appropriate to obtain the forecasts for future MDs by extrapolating the linear trend line, referred to as forecasting 'off the line'.

For a number of CPs it appears that the time trend is non-linear or that there is a structural break in the series. If there is a non-linear trend in the data, or a structural break, then it is inappropriate to forecast 'off the line'. It is also inappropriate to use growth rate implied by the trend line in the forecast. There is indeed an argument that in such cases it is preferable to start the forecasts 'off the point', i.e. to use the last weather normalised observation as the starting point for producing the forecasts.

ACIL's approach to choosing between these two options relies on how far apart the two values are, with a preference for starting 'off the point' if the values are far apart. However, ACIL provided only limited guidance as to when these values are 'far apart'. Unfortunately, the sample sizes involved are too small, typically only 8 observations, to undertake a detailed investigation of non-linear trends and structural breaks. Instead Frontier has recommended the following two simple statistical tests to assist in deciding between the two starting point options:

- **Test for linear trend.** Include a quadratic term in the time trend model and test whether the coefficient on the quadratic term is statistically significant.

- **Test for outlier**. Test whether the last weather normalised observation is an outlier for the linear trend model by testing the significance of the 'external' or 'jacknifed' studentised residual. This can be done by including a dummy variable in the linear trend regression, with the dummy variable equal to one for the last year and zero for other years, and testing whether or not the coefficient on the dummy variable is statistically significant.

Frontier recommended that the 'off the line' starting point be used only in cases where the above tests accepted linear trend and rejected the outlier. If either the trend was found to non-linear or the last point to be an outlier, then the forecasts should be starting 'off the point'. In this case, subjective judgement should be used to decide whether the appropriate growth rate is the population growth rate in the area where the CP was located, or a zero growth rate.

AEMO has adopted Frontier's recommendation. Table 2 summarises the number of instances when the tests determined that the forecasts should be taken 'off the line' versus 'off the point' in Victoria. Forecasts for two future CPs (BTS66 and DPTS) have a starting point in 2017/2018 based on future load transfers from existing CPs (not off the point or the line).

Table 2: Starting points used for CPs

Starting point	VIC	
	Summer	Winter
Off the line	38	29
Off the point	21	30
New CPs (based on future load transfers from existing CPs)	2	2
Total number of CPs	**61**	**61**

Source: Frontier Economics analysis of data provided by AEMO

3.3 Issues related to solar PV

Shift in the timing of maximum demand

The increased adoption of solar PV generation is predicted to lead to a change in the time of the MD in Victoria from afternoon to evening in the later years of the forecasts (for example in P50 for Summer). ACIL's methodology does not take explicit account of the time at which MD occurs. However, a shift in the timing of MD impacts on several aspects of the methodology. For example, the diversity factor used to convert the MD into coincident maximum demand at the time of system peak can be expected to be quite different for a day peak compared to a night peak. Similarly, the appropriate adjustment made for the contribution of PV will be different depending on whether the peak is a day time or a night time peak.

ACIL's methodology is essentially a static methodology with respect to the timing of MD. This works satisfactorily in jurisdictions and eras when the time of day at which MD occurs stays fairly constant from year to year. Winter MDs tend to fit this situation. Summer MDs tend to be less static, they can occur across a range of hours of the day. Hence time of day effects have some influence in determining the level of MD.

The shift from having MD during the day versus at night amplifies this issue. In a previous forecasting exercise for NSW and Tasmanian CPs, AEMO found that for quite a number of CPs, applying ACIL's methodology produced baseline forecasts for the P90 (POE10) MDs that are lower than the P50 (POE50) MD forecasts. These anomalies disappear in most cases in the reconciliation process. However, the underlying issue is still present.

In the NSW and Tasmania CP review, Frontier recommended an approach to addressing these anomalies in the baseline forecasts that involved estimating the solar PV output for the same MD time of day in the P50 scenario as the P90 (POE10). This approach overcomes the problem of the baseline P50 (POE50) forecasts exceeding the P90 (POE10) forecasts. AEMO have implemented this approach in the Victorian CP forecasts by changing the P50 time of MD to match the P90 time of MD.

Adjusting for PV by POE level

The current approach to adjusting forecasts for the impact of PV generation at the P50 (POE50) and P90 (POE10) levels is to subtract the forecast P50 (POE50) level of solar PV generation from the P50 (POE50) adjusted forecast MD, and to subtract the forecast P90 (POE10) level of PV generation from the P90 (POE10) adjusted forecast MD. Statistical analysis shows that this approach is only valid under the extreme assumption that PV and adjusted MD are perfectly correlated.[7] While the approach is valid at the POE50 level under fairly broad conditions, in general it is not valid to do this for other POE levels, and it could produce quite misleading results at the P90 (POE10) level.[8]

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7 This result holds if both PV and adjusted MD are normally distributed. If they are not normally distributed, the analysis becomes considerably more complicated and it is unlikely that general results can be established.

8 For example, at the POE50 level the approach is valid if the distributions involved are symmetrical. However, this does not generalise to other POE levels.

Developing an approach to adjusting for PV, when both the PV and adjusted MD forecasts are assumed to be random variables, that is statistically valid under more general conditions is a fairly complex task that requires further analysis.

We note, however, that AEMO's current approach is consistent with the approach adopted in the 2014 NEFR, which appears to apply a P90 (POE10) level of PV generation to P90 (POE10) MD. In contrast, the 2013 NEFR applied P50 (POE50) PV generation to P90 (POE10) MD.

4 Assessment of AEMO's forecasting procedure

On the basis of our review of AEMO's implementation of the maximum demand forecasting methodology for the Victorian CPs, Frontier confirms that AEMO has correctly implemented ACIL's proposed methodology, subject to some modifications to address issues that arose during the implementation process.

Our overall assessment of the implementation of the methodology is that it meets the standard of good industry practice. ACIL's proposed methodology has been implemented in a professional manner, and where issues of concern have arisen during the implementation of the methodology, all reasonable steps have been taken, within the time and resource constraints, to ensure the statistical integrity of the forecasts.

FRONTIER ECONOMICS | MELBOURNE | SYDNEY
Frontier Economics Pty Ltd 395 Collins Street Melbourne Victoria 3000
Tel: +61 (0)3 9620 4488 Fax: +61 (0)3 9620 4499 www.frontier-economics.com
ACN: 087 553 124 ABN: 13 087 553 124