High level review of transmission connection point forecasts: VIC

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) in 2013 to develop the original methodologies for forecasting maximum demand (MD) at the transmission connection point (CP) level.

AEMO engaged Frontier Economics (Frontier) to review AEMO's implementation of the methodology for New South Wales (NSW) and Tasmanian (TAS) forecasts in 2014, and again in 2014/15 to review AEMO's implementation of the methodology to forecast maximum demand for Victoria (VIC), South Australia (SA) and Queensland (QLD). AEMO has now engaged Frontier to peer review the new VIC forecasts for 2015.

The methodology has been refined and improved during each round of CP forecasts. This report reflects Frontier's review of revisions to the original methodology and AEMO's application of the revised methodology to produce maximum demand forecasts for 76 VIC transmission CPs.[1, 2] The review and advice process included:

- Identification of key issues with implementation of the methodology for the VIC CPs, in particular in relation to the choice of horizons for cubic forecasts
- This report, which reflects a review of AEMO's VIC 2015 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.

Based on the scope of the review undertaken, in our opinion the maximum demand forecasting methodology that was applied for the VIC CP forecasts is robust and reflects appropriate improvements on the original ACIL methodology. On the basis of our understanding of the steps in AEMO's implementation of the methodology for the VIC CPs, AEMO has implemented the revised methodology correctly. This includes recommendations made by

1 The total number of CPs at the time of Frontier's review. We understand that AEMO revised the number of CPs before publishing the forecasts.

2 The 2015 forecasts are split by busbar in some instances. AEMO developed forecast for 71 CPs. For the remaining 5 large industrial load CPs, AEMO used forecasts from the 2015 National Electricity Forecasting Report.

Frontier during prior rounds of CP forecasts (NSW and TAS, VIC (2014), QLD and SA).

On the basis of our review of AEMO's implementation of the maximum demand forecasting methodology for the VIC CPs, Frontier confirms that (a) the revised methodology adapted for the CP forecasts is reasonable and appropriate and (b) AEMO has correctly implemented this revised methodology to the best of our knowledge.

Our overall assessment of the methodology and implementation is that it meets the standard of good industry practice. The 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 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 the original methodologies for forecasting maximum demand (MD) and energy consumption at the transmission connection point (CP) level.

AEMO engaged Frontier Economics (Frontier) to review AEMO's implementation of the methodology for New South Wales (NSW) and Tasmanian (TAS) forecasts in 2014, and again in 2014/15 to review AEMO's implementation of the methodology to forecast maximum demand for Victoria (VIC), South Australia (SA) and Queensland (QLD).

AEMO has engaged Frontier to act as peer reviewer for the 2015 VIC CP forecasts. This report reflects Frontier's review of revisions to the original methodology and AEMO's application of the revised methodology to produce maximum demand forecasts for 76 VIC transmission CPs.[3, 4] The review and advice process included:

- Identification of key issues with implementation of the methodology for the VIC CPs, in particular in relation to the choice of horizons for cubic forecasts
- This report, which reflects a review of AEMO's VIC 2015 forecasts.

1.2 Scope of our review

The scope of Frontier's role is to provide advice to AEMO on the maximum demand forecasting methodology (and potential improvements to the original methodology) and to review AEMO's implementation of the methodology and the resulting forecasts.

A simplified schematic representation of the steps involved in the forecasting methodology is presented in Figure 1. The scope of our engagement does not

3 The total number of CPs at the time of Frontier's review. We understand that AEMO revised the number of CPs before publishing the forecasts.

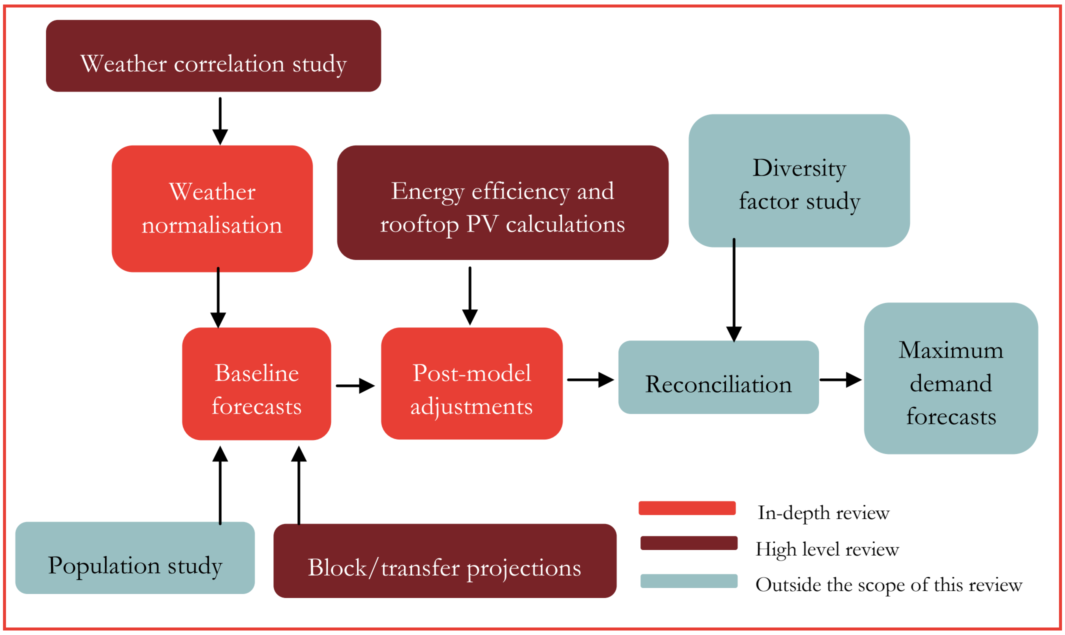
4 The 2015 forecasts are split by busbar in some instances. AEMO developed forecast for 71 CPs. For the remaining 5 large industrial load CPs, AEMO used forecasts from the 2015 National Electricity Forecasting Report.

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'. This includes AEMO's reconciliation and final forecasts for Vic 2015.

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.

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

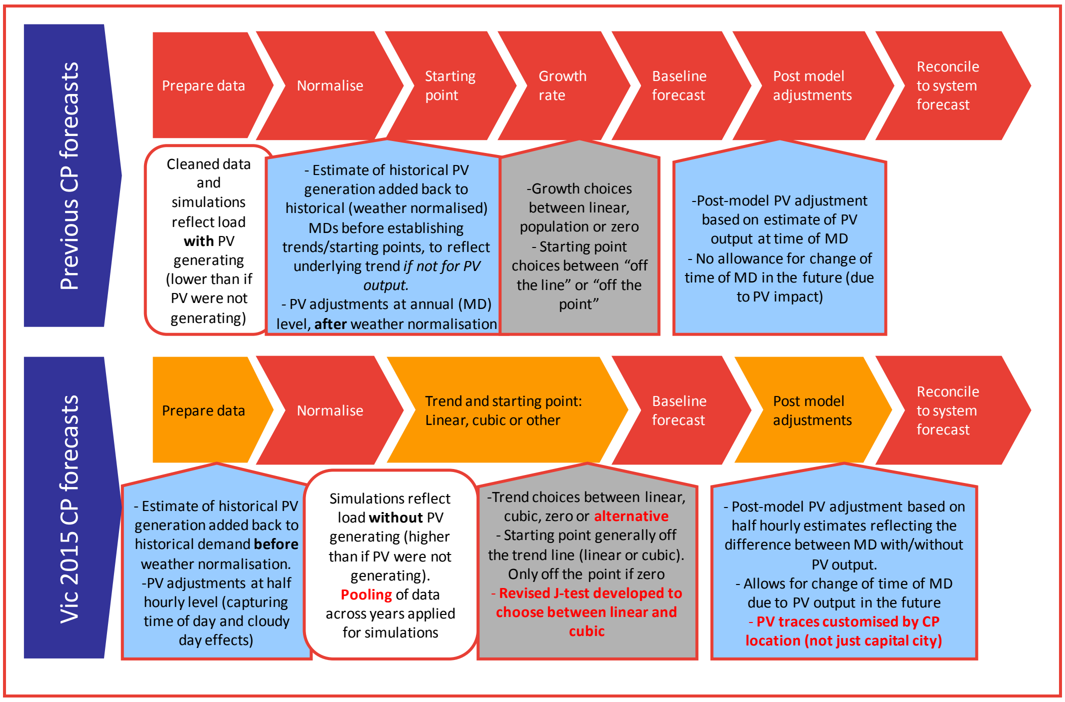
2.1 Overview

The methodology adopted by AEMO for the 2015 VIC CP forecasts is an improvement on the original methodology proposed by ACIL for forecasting maximum demand at the CP level and implemented in the 2014 VIC forecasts.

A high level summary of the previous methodology for forecasting maximum demand at the CP level is shown in the upper half of Figure 2. The lower half of Figure 2 shows the revised methodology adopted for the VIC CP forecasts in 2015, highlighting the key changes from the previous methodology.

The steps involved in the previous approach are described in detail in the ACIL report. For the VIC 2015 forecasts some modifications were made to ACIL's proposed methodology in response to issues arising during its implementation in the previous rounds of forecasts (NSW, TAS, VIC (2014), SA and QLD). These steps and changes are discussed in more detail below. In all cases, any changes to the methodology and implementation were discussed in detail between AEMO and Frontier Economics.

Figure 2: Summary of original/revised methodology and key changes



Source: Frontier Economics

AEMO's current 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.
  - Under the original methodology, no adjustment was made for historical PV at this stage. A single PV adjustment was applied for each year/season after weather normalisation/simulation based on an estimate of PV output at the time of system MD.
  - Under the updated methodology, estimates of historical PV output are added back to the historical half hourly level demand, prior to weather normalisation. If the PV adjustments can be estimated accurately, this would better reflect the underlying trend in customer demand for each half hour (in the absence of PV).

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)[5] levels of maximum demand for each historical year.
  - Under the original methodology, the weather normalised POE50 and POE10 MD levels reflected estimates of MD when PV was generating. To estimate the underlying trend for MD at the consumer level, it was necessary to add back estimates of historical PV output to the annual historical non-coincident MDs.
  - Under the revised methodology the simulations reflect MD in the absence of solar PV generation (i.e. as if PV were not generating). Adjusting for estimates of historical PV for each half hour ideally should improve estimates of the underlying MD trends.
- On Frontier's recommendation, AEMO has also adopted and implemented "pooling" of data across years for the VIC 2015 forecasts, with year dummy variables included in the model to allow for different levels of MD in individual years.
  - AEMO previously tested the pooling approach during the SA CP forecasts, though this was not applied in the final SA forecasts.
  - AEMO previously applied the pooling approach for the 2015 NSW and QLD CP forecasts.

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

3. **Selection of a starting point for the demand forecasts and determination of a growth rate**

- Under the original methodology, only linear trends were considered and decisions were made about the slope of the linear trend (growth rate) and the starting point.
  - The **starting point** was a choice between the last point on the linear trend line through the POE50 and POE10 historical demands ("off the line"), or the last actual observation for the POE historical demands ("off the point"). The choice depended on how well the trend line fit the data.
  - The **growth rate** was determined from either the linear trend line through the historical POE demands or anticipated population growth in the local area. In some cases a zero growth rate was assumed.
- The methodology was refined in previous forecast rounds because it became evident that for some CPs the time trend was non-linear or there was a structural break in the series. Hence the methodology was extended to allow for non-linear (cubic) trends. AEMO's default for extrapolating demand into the future is to use a linear trend. Alternatively, AEMO uses a cubic trend with a horizon value if the linear trend is not a satisfactory fit to the historical data.[6] The choice between the linear and the cubic trends was originally based on two statistical tests, developed with Frontier's assistance:
  - A test for linearity and;
  - A test for whether or not the most recent observation in the historical data is an outlier.
  - If either of these tests rejects the null hypothesis, the linear trend is replaced by the cubic trend.
- For the 2015 VIC CP forecasts, AEMO adopted and applied an improved statistical test for linearity which is more appropriate for the cubic trend alternative. This test was previously recommended by Frontier and was used by AEMO for the 2015 NSW and QLD forecasts.
- For VIC CPs characterised by industrial load, AEMO manually overrode these test results and applied a zero/population growth rate.
- During the VIC review, some problems became evident in applying rules for selecting a horizon value for the cubic trend model which resulted in some counterintuitive results. The decision rules for choosing a horizon value for

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6 A horizon value represents a maximum demand value assigned to some date in the future in order to anchor the fitted cubic trend line (i.e. the fitted cubic trend is forced to pass through the chosen horizon value). This ensures that the fitted cubic trend line produces realistic forecasts.

the cubic trend were revised for the final forecasts which resulted in improved forecasts.

4. **Calculation of baseline forecasts**

- This is done by projecting the linear or cubic trend line to cover the years in the forecast period. In cases where a zero growth rate was selected, this growth rate was applied to the last weather normalised point. In all these cases, the weather normalised point was quite close to the fitted line.

5. **Post-modelling adjustments for photovoltaic solar generation (PV), energy efficiency improvements (EE) and block loads and transfers**

- Under the original methodology, AEMO determined the PV forecast at the CP level as a pro-rata allocation of the NEFR system level PV estimate based on the residential customers per CP. A limitation of this approach is that it implicitly assumes that all CPs have the same time of MD as the system (coincident) MD.
- Under the revised methodology, AEMO estimates the change in MD at the half hourly level with/without PV output for each CP. This requires pairing half hourly demand with half hourly PV traces. It is a more data intensive approach to accurately estimate PV output at the half hourly level, but the approach captures the effect of PV output on possibly changing the time of MD for each CP, and it also allows for different times of MD for each CP.
- AEMO has further improved the solar PV traces used for these adjustments. Originally, the same average solar trace was used for all CPs. For the previous QLD CPs – and also applied for these 2015 VIC CP forecasts - customised PV traces were used for each CP which recognises differences in location and solar irradiation by time of day.

6. **Reconciliation of CP maximum demand forecasts to system maximum demand forecasts**

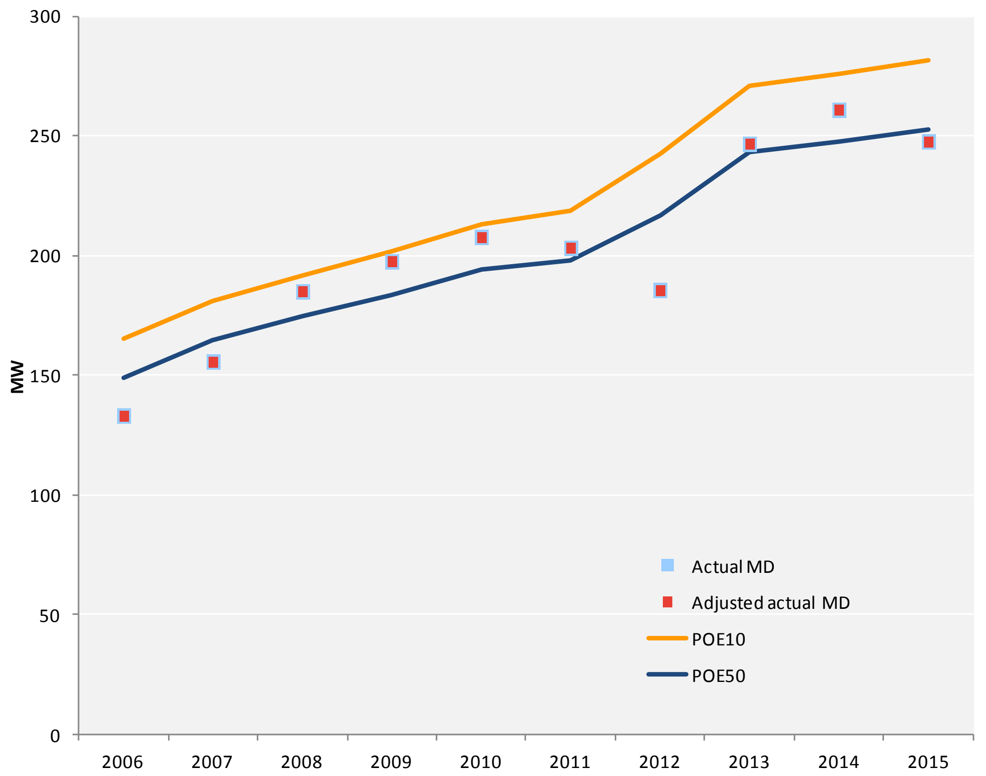
- Frontier did not review AEMO's reconciliation for the Vic 2015 forecasts.

2.2 Worked example of a connection point forecast

This section shows a worked example of the steps in the revised methodology, using the CBTS66A summer forecasts for illustration.

Steps 1 and 2: Data preparation, weather normalisation and simulation

Figure 3: Example: CBTS66A summer



Step 1. Data preparation. Light blue dots reflect historical actual MD with estimates of historical PV output added back (i.e. assuming PV generation of 0MW). Actual observed MDs from 2009 onwards would be lower than this since PV generation supplies some of the demand. This adjustment is made at the half hour level prior to determining MD, which is a revision to the original methodology.

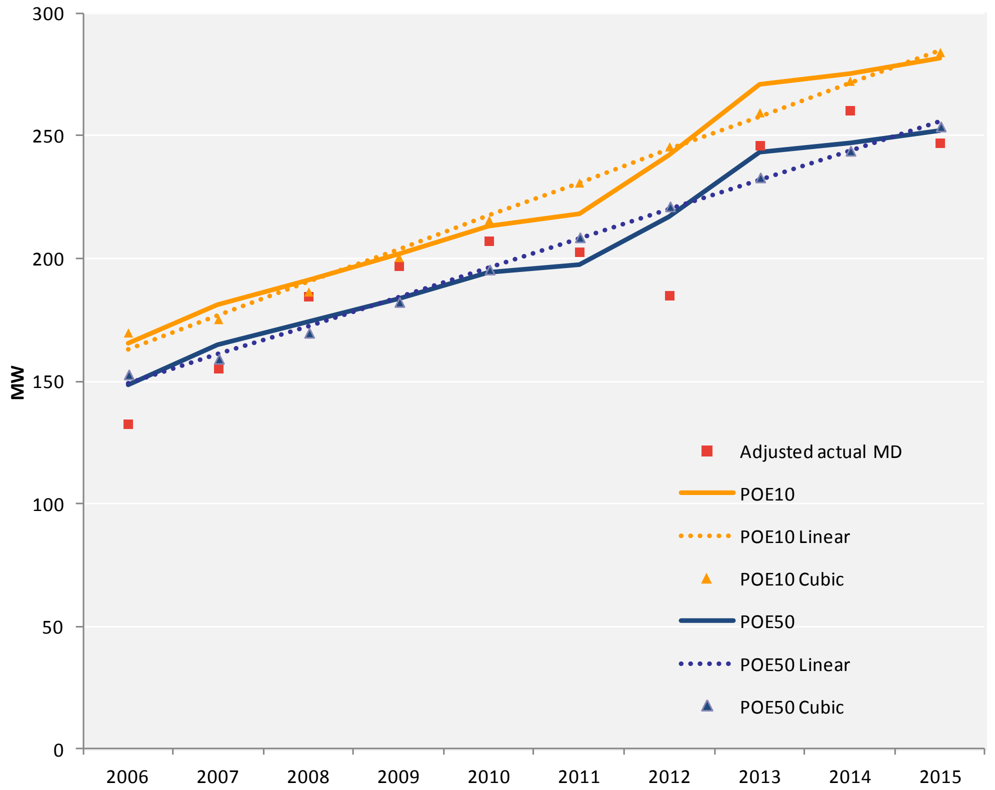
Red dots incorporate an additional adjustment to historical MDs to reflect differences between the historical years and the latest year (2015) with respect to block loads and load transfers. In this case, this reflects no change.

Step 2. Weather normalisation and simulations. The orange line reflects the POE10 MDs and the navy blue line reflects the POE50 MDs obtained from the simulation. Around half of the red dots should be above the navy blue line, and around 10% should be above the orange line (on average). These are close in this example (in 2008-2010), though none are above the POE10.

Source: Frontier Economics analysis of data provided by AEMO

Step 3: Trend and starting point

Figure 4: Example: CBTS66A summer, Trend and starting point (trend selection)

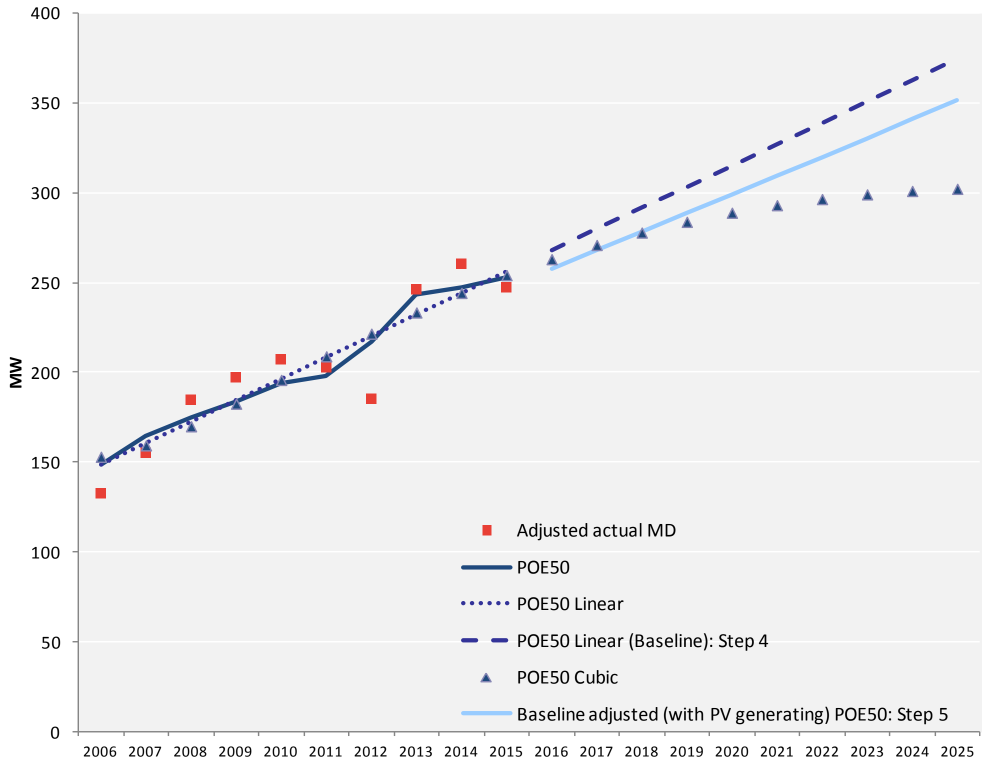


Step 3. Cubic and linear trends estimated and statistical tests applied. For CBTS66A summer, the test found that the linear trend should not be rejected. Hence the linear trend (dotted line) was chosen for the growth rate for each of the POE50 and POE10 demands. The starting point in this case is the last point on the linear trend line.

Source: Frontier Economics analysis of data provided by AEMO

Steps 4, 5 & 6: Baseline forecasts, post-model adjustments, reconciliation

Figure 5: Example: CBTS66A summer, POE50: Baseline forecast, post-model adjustments and reconciliation (final forecasts)



Step 4. The **navy blue dashed line** shows the Baseline forecasts, which reflect the starting point and trend for the linear trend line (selected in the previous step).

Step 5. The **light blue line** reflects the Baseline forecast adjusted for (1) block loads and transfers, (2) less post-model adjustments for future EE and (3) PV. This provides an unreconciled, non-coincident MD estimate. For this CP, the initial adjustment for block loads is a reduction in MD. The adjustment for EE only reflects a deviation from the historical trend: in this case the EE trend is toward *more* energy efficiency, which reduces the future MD forecasts downward. The adjustment for PV reflects an estimate of the total contribution of PV to reducing future MD. The adjusted forecast will start lower than the historical actual MDs (simulated MDs), as the historical actual MDs have PV output added back (i.e. the forecast is not directly comparable to the historical given that under this methodology, adjustments for PV are now made **before** the simulations). This is illustrated in the stylised example in Figure 6.

Frontier did not review AEMO's reconciliation for the VIC 2015 forecasts.

Source: Frontier Economics analysis of data provided by AEMO

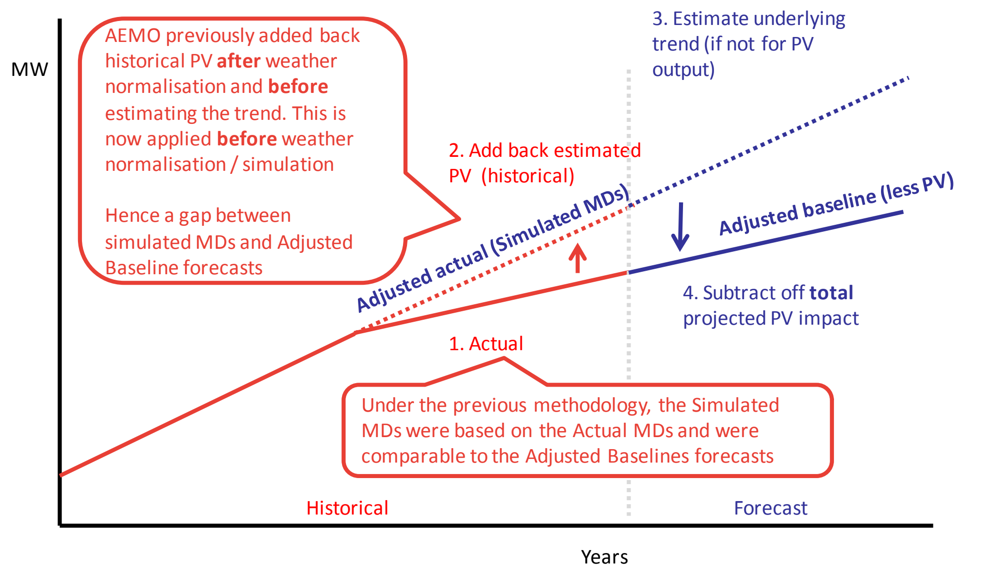
Stylised example of PV and EE adjustments

Figure 6 and Figure 7 show stylised examples of the difference in treatment of PV adjustments and energy efficiency (EE) adjustments. Figure 6 also illustrates the difference between the historical simulations (which reflect PV output of 0MW) and the baseline adjusted forecasts (which reflect a positive PV output and hence lower MD forecasts).

For PV, estimates of the total historical PV are added back to the historical MDs, the underlying trend is estimated and projected into the future (reflecting demand with PV not generating), and then estimates of the total PV impact in future are subtracted off the future forecasts. As discussed later, the PV "impact" on future MD is the estimated change in MD with/without PV in the future which, due to a possible change in the time of MD with/without PV, is not the same as estimated PV output at any given time.

EE is treated differently: historical EE is not added back to historical MD, hence the underlying trend that is estimated reflects the impact of EE. The methodology assumes that the impact of EE on MD is linear and continues to grow in the future at the same rate as in the past. Hence, the EE adjustment to future MD forecasts reflects only an estimate of the deviation from the historical, linear trend for EE impacts (which is less than the total EE impact).

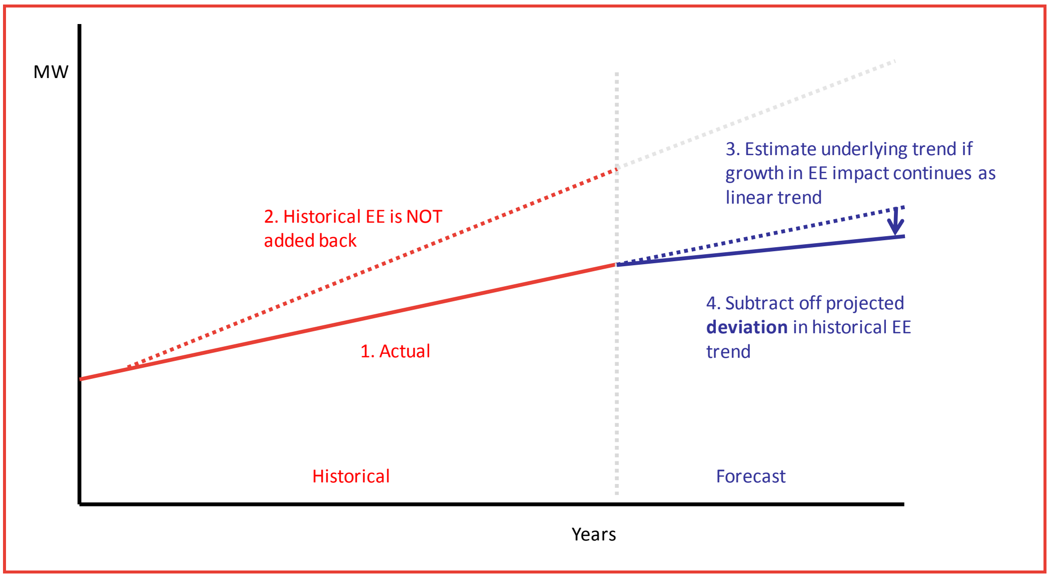
Figure 6: Methodology for PV adjustments



Note: Previously, future PV adjustment was based on pro-rata of NEFR, assuming same time of MD for all CPs. For the VIC forecasts, the PV estimates differ for each CP reflecting (a) a different time of MD for each CP (and allowing for changes over time) and (b) a customised PV output trace for each CP. Hence the sum of the CP PV adjustments can be larger than in the NEFR.

Source: Frontier Economics

Figure 7: Methodology for EE adjustments



Source: Frontier Economics

3 Review of AEMO's implementation of forecasting methodology

In this section we review AEMO's implementation of the revised forecasting methodology compared with that outlined in the ACIL Report and implemented in previous forecasts for other states.

Table 1: Summary of methodology, changes and recommendations

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Data preparation	Prior to undertaking 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). **No adjustments were made for historical PV at this stage in the original methodology.**	On Frontier's recommendations, for the VIC 2015 forecasts AEMO adjusted historical data for block loads and load transfers and added PV load ***before*** weather normalisation and simulations. AEMO changed the "base year" for block loads/ transfers to reflect the last year of the data (as opposed to the first). This required AEMO to estimate historical PV output for each half hour, as opposed to a single estimate of historical PV output for each year/season. Frontier has not inspected the files or data where AEMO applied these historical PV adjustments, as this is highly data intensive. ***The methodology as described is reasonable and appropriate and in theory provides a more robust estimate of the underlying MD trend (without solar PV output) than the previous approach. This is subject to the calculation of estimated PV output at the half hour level given that this is not measured. From our review, the PV output estimates appear reasonable at the half hour level.*** Frontier has not inspected the data showing removal of major industrial load or the addition of embedded generation. We understand that in some cases (non-permanent events) data was not available and AEMO has made judgment calls on appropriate block load/transfer adjustments.	***The revised methodology applied for historical PV adjustments (and applying these prior to weather normalisation) reflects an improvement in methodology. Frontier recommends that this should continue to be applied/ considered in future implementations.***

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Weather normalis-ation	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	**No modifications to methodology were adopted for the final forecasts other than that adjustments to historical load were undertaken prior to weather normalisation.** **Weather normalisation:** Frontier has previously recommended pooling observations across years when estimating maximum demand-temperature models in order to more effectively use the available data. AEMO tested the pooling approach for the SA forecasts and, in line with Frontier recommendations, implemented the approach for prior QLD forecasts. This was continued for the VIC 2015 forecasts, in line with Frontier's recommendation. The approach pools 3 years of data when estimating temperature sensitivity models (1 year before/after the year of interest) and year dummy variables are included to allow for differences in the level of MD between years. **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 POE50 levels, and about 10% lie above the POE10 levels. ***Frontier recommended reviewing the weather simulation results against historical actual data and this review was undertaken for the VIC CPs. In most cases the simulation results appear within the bounds of reasonableness.***	***Frontier recommends that AEMO continue to apply data pooling for weather normalisation in future forecasts.***

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Estimate historical trends	Prior to estimating the trends, AEMO adjusted historical POE values for block loads and load transfers, and adds PV load to identify the underlying MD trend (if not for the impact of solar PV). Regression is used to fit linear trends through the historical POE50 and POE10 values.	PV adjustments In the modified methodology, adjustments for historical PV are made prior to weather normalisation/simulation rather than after, so no further PV adjustment is required at this stage. Cubic trends Some trends in the historical data are non-linear. When this is the case, it is inappropriate to use a linear trend line to determine the growth rate. AEMO fitted linear and cubic trends through the historical POE50 and POE10 values. Choice of horizon for cubic trends Fitting the cubic trend requires the choice of a horizon value, which in earlier forecasts was based on the historical maximum demand. Frontier previously recommended consideration of alternative horizon values, in particular the historical minimum demand where the demand trend is falling. AEMO adopted this approach for the 2015 QLD forecasts. Frontier previously recommended an improved statistical test to help choose from a range of potential horizon values. For the preliminary VIC 2015 forecasts, AEMO applied the statistical test to eight potential horizon values (ranging from the historical minimum demand to the historical maximum demand plus 30% of the difference between the historical minimum and maximum values). Initially this resulted in some counter-intuitive horizon value choices. Frontier recommended changes to the approach, which AEMO adopted for the final forecasts. ***The final approach appears reasonable and has been appropriately applied for the VIC forecasts.***	***For future implementations, we recommend further investigation of the method for choosing horizon values, including review of the results to ensure that results are sensible.***

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
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. During previous CP forecasts for other regions, Frontier recommended two statistical tests to determine whether the trend model is "well specified", in which case "off the line" should be used as the starting point.	When the linear trend was applied for a forecasts, the starting point applied was "off the line", consistent with the previous methodology. This is equivalent to projecting the estimated trend line to the years to be forecast. This methodology was revised to include an appropriate alternative when the cubic trend was applied. In this case, the estimated cubic trend line was projected to the years to be forecast. Where a zero trend was applied, the starting point was "off the point". Frontier previously recommended an improved statistical test to help determine whether to apply a linear or cubic trend (and hence starting point) and this was also applied in the VIC 2015 forecasts. ***This approach appears reasonable and appropriate and was implemented by AEMO in the final forecasts.***	**Frontier recommends that AEMO continue to apply the revised statistical tests for linear/cubic trends.**

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Determine the trend	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. In previous CP forecasts for other regions, 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.	Linear and cubic trends were fitted to the historical data (above), and statistical tests were applied to determine the appropriate trend to apply for the forecasts. Frontier previously recommended an alternative test for linearity which is more appropriate for considering the cubic alternative. AEMO has adopted and applied this modified test for the VIC 2015 forecasts. The basis for choosing a linear or cubic trend was the result of the statistical tests, subject to possible override based on judgement. For example: - If the tests accepted **both** linearity and found that the last point was not an outlier then the default position was to adopt a linear trend - If **either** the hypothesis of linearity is rejected (accepting non-linearity) **and/or** the last point is deemed to be an outlier then the fallback position is to adopt a cubic trend. AEMO correctly applied this revised test for the VIC 2015 forecasts, using a statistical threshold of 5% (having considered and tested a threshold of 10%). A trend of zero was applied in cases where there was insufficient data to apply the tests or where the CP load was industrial. ***This approach is reasonable and appropriate and was implemented by AEMO in the final forecasts.***	Frontier recommends that AEMO continue to apply the revised statistical tests for linear/cubic trends. For the VIC 2015 forecasts, AEMO adopted a statistical threshold for these tests of 5%, which tends to favour a linear trend over cubic. For future forecasts, Frontier recommends that AEMO continue to visually review results to observe whether cubic trends appear more appropriate given the data.
Baseline forecasts	Apply the selected (linear) growth rate to the selected starting point to produce baseline forecasts	As above, the revised approach includes linear or cubic trends. ***The recommended approach was implemented by AEMO in the final forecasts. (This is an outcome of the starting point and trend determined above.)***	

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Post-model adjust-ments	Make post model adjustments to take into account factors that are known but not yet incorporated into the trend forecasts. Factors include: • new large block loads, load transfers • energy efficiency and the uptake of solar PV **Energy efficiency**: AEMO adjusted CP forecasting for EE 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). **Solar PV:** AEMO adjusted CP forecast for PV based on a pro-rata adjustment of the NEFR statewide PV estimate at time of MD. This was adapted to reflect the same time of (region) MD for POE50 and POE10.	**Energy efficiency** ***This is unchanged from before, and the approach is reasonable and appropriate*** **Solar PV** The previous approach was consistent with the NEFR and relatively simple to apply given data availability and time constraints. However, one limitation of the previous PV approach is that it implied that all CPs have the same time of MD (which was the same as the statewide MD). This implied a "coincident PV" output. For the VIC forecasts, AEMO adopted the approach adopted for the QLD CP forecasts. This combined a half hourly trace of demand without PV with a half hourly trace of PV output (scaled to installed capacity) to estimate half hourly profiles with/without PV for each CP. This provided estimates of (a) the change in time of MD with/without PV for each CP for each year, (b) the level of MD for each CP with/without PV, and (c) the difference between the two, which reflects the contribution of PV to reducing the MD. This last term is not an estimate of the actual PV output at either time of MD (with/without PV), but it is a better estimate of the impact of PV on MD where PV is causing a change in the time of MD. For example, if PV output was causing the MD to shift from midday to evening: - PV output at midday would likely overestimate the impact of PV on MD; - PV output at night would likely underestimate the impact of PV on MD; - the net impact of PV on MD would lie between the two. AEMO also applied more accurate (customised) PV trace for each CP; previously AEMO used the same average PV trace for each CP, which did not entirely capture small differences in PV output by CP location/time of day. This improvement was developed for the previous QLD forecasts and Frontier recommended that this should be applied in future. ***The revised approach adopted by AEMO is reasonable and appropriate and an improvement on the previous methodology.***	***The revised methodology applied for future (post model) PV adjustments is a further improvement in methodology. Frontier recommends that this should continue to be applied/considered in future implementations.***

Step	Original methodology	Implementation (and modifications adopted) for VIC 2015	Improvements to consider in future
Recon-ciliation with system forecasts	Scale the individual connection point forecasts so that the totals of the CP forecasts match the system level (regional) forecasts. AEMO estimates the diversity factor for each CP by averaging the annual diversity factors for the latest five years.	***Frontier did not review AEMO's implementation of the reconciliation process for the VIC 2015 forecasts***	

3.1 Weather normalisation

3.1.1 Methodology

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.

3.1.2 Pooling

Frontier previously recommended pooling the data across years when estimating the temperature sensitivity models.[7] 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 previous rounds of forecasts. For the 2014 NSW and TAS forecasts, AEMO did not implement data pooling due to

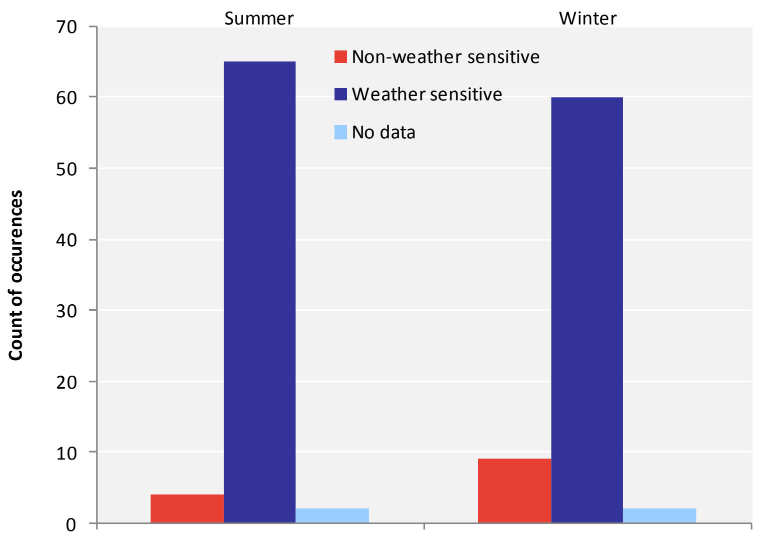
7 The pooled model recommended by Frontier includes yearly dummy variables to capture differences in the average level of demand from year to year. But determining the best approach to pooling the data across years requires further investigation.

time constraints and to adhere to the original published methodology. AEMO tested the pooling approach (without year dummy variables) in the 2014 SA forecasts and judged that further investigation was required before implementing it. AEMO implemented the pooling approach for the 2015 NSW and QLD forecasts.

The pooling approach was also adopted for the VIC 2015 forecasts. The pooling is based on pooling data over 3 years, and the model includes year dummy variables to capture differences in the level of MD between years.

Figure 8 summarises the count of temperature sensitivity by CP in VIC.

Figure 8: Temperature sensitivity of VIC CPs



Temperature sensitivity is only applicable to 71 Victorian CPs. This is not relevant to five new CPs, which are based on future load transfers from existing CPs.

Source: Frontier Economics analysis of data provided by AEMO

3.1.3 Review of temperature model /simulation results

The distribution for maximum demand produced by AEMO's simulation procedure should result in, on average, about 50% of the historical actual adjusted MDs below the POE50 levels, and about 90% below the POE10 levels.

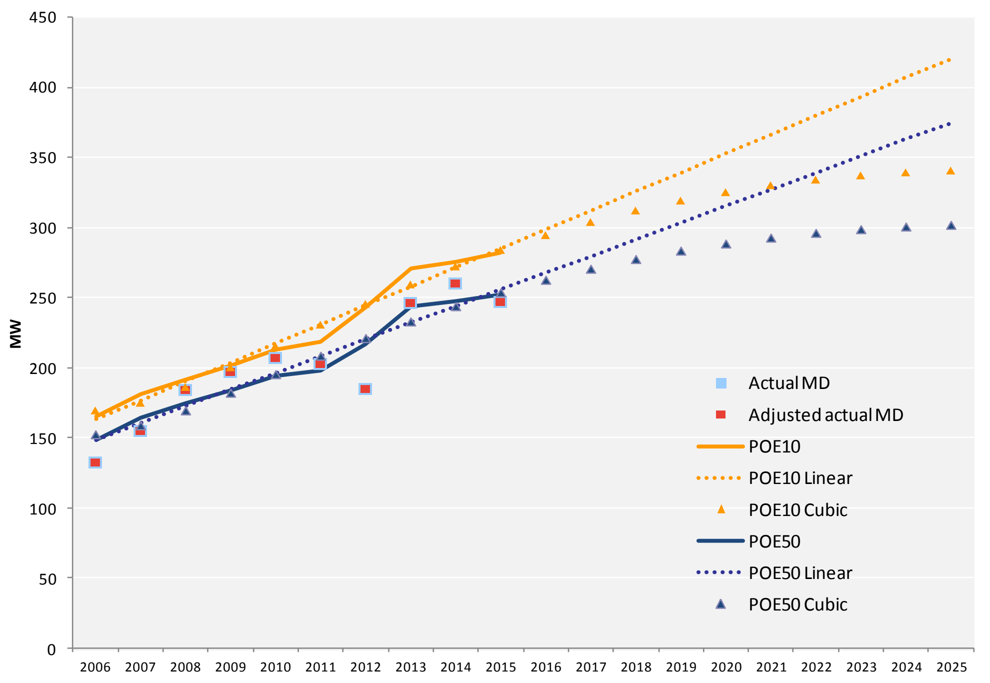
As an example, the results for CBTS66A summer are shown in Figure 9. Comparing the "adjusted actuals" (red dots) against the simulations, 40% (4 out of 10) are below the MW POE50 simulations (navy line) and 100% (10 out of 10) are below the MW POE10 simulations (orange line).

In general, the simulations appear reasonable when compared with historical adjusted actual MDs across the CPs.

Across all CPs and historical years (with available data) 80% of adjusted actual MDs are below the summer POE10 simulations and 43% are below the POE50 simulations (weighted by the number of occurrences by CP and years, not load). This is broadly as expected.

For winter, 80% of adjusted actual MDs are below the winter POE10 simulations and 56% are below the POE50 simulations (weighted by count of occurrences by CP and years, not load). This suggests that the simulations are a reasonable fit.

Figure 9: Example: CBTS66A summer



Source: Frontier Economics analysis of data provided by AEMO

Future recommendations

We recommend that in future AEMO undertake similar statistical analysis of simulation results to complement the visual reviews. For example, counts of simulations>adjusted actuals can identify potentially problematic CP simulations.

3.2 Historical trends in MDs and starting points for the forecasts

3.2.1 Previous methodology

ACIL's original methodology to determine growth rates includes fitting a linear trend line through the historical weather normalised MD data. However, for a number of CPs it appears that the time trend is non-linear or that there is a structural break in the series.

The methodology was extended in previous forecasts rounds (SA) to account for non-linear trends. AEMO's default for extrapolating demand into the future is to use a linear trend. Alternatively, AEMO uses a cubic trend with a horizon value if the linear trend is not a satisfactory fit to the historical data. In previous forecast rounds, the choice between the linear and the cubic trends was based on two statistical tests, developed with Frontier's assistance:

(a) a test for non-linearity which tests whether the addition of a quadratic term to the trend equation significantly improves the fit of the model, and

(b) a test to check whether or not the most recent observation in historical data is an outlier with respect to the linear trend model.

If either of these tests rejects the null hypothesis, the linear trend is replaced by the cubic trend.

For the previous QLD CP forecasts, Frontier recommended an improvement to the non-linearity test which takes account of the cubic trend alternative to the linear trend. This test was adopted for the QLD forecasts and continued in the VIC 2015 forecasts.

3.2.2 J-test: cubic or linear

The two statistical tests were developed at a time when the cubic trend model had not yet been adopted. At that time the alternative to the linear model was a subjective trend extrapolation from the last actual data point ("off the point"). Frontier recommended an alternative to the first of the tests which is more appropriate for the cubic trend alternative that was adopted by AEMO and applied for these forecasts. We recommend that this test continue to be used instead of the previous quadratic trend test to test for non-linearity. The outlier test should still be used as it is presently.

3.2.3 Application of the test

Table 2 summarises the number of instances when the tests determined that a linear or non-linear trend should be applied in VIC, including where manual adjustments were applied to the trend implied by the statistical tests. Where there was insufficient historical data (NA) or there was known industrial load at a given CP, an alternate trend was applied, which in most cases was zero (where the CP reflected known industrial load which were assumed to remain relatively constant), despite the result of the statistical tests. For 5 CPs, these were forecast separately as part of the 2015 NEFR, hence these were not revised or remodelled as part of the connection point forecasts (the trend applied was NA). Table 2 summarises the test results (and final trends applied) in summer and Table 3 provides the same summary for winter.

Table 2: Trends applied to VIC CPs: Summer

Trend	Trend based on tests	Modified trend				
		Linear	Cubic	Alternate	0	NA
Linear	32	29	0	3	0	0
Cubic	36	0	35	1	0	0
Zero	2	0	0	0	2	0
NA (insufficient data, or forecast in NEFR)	6	0	0	1	0	5
Total number of CPs [1]	**76**	**29**	**35**	**5* (3 of these applied zero growth)**	**2**	**5**

Source: Frontier Economics analysis of data provided by AEMO

1) *The total number of CPs at the time of Frontier's review. We understand that AEMO revised the number of CPs before publishing the forecasts.*

Table 3: Trends applied to VIC CPs: Winter

Trend	Trend based on tests	Modified trend				
		Linear	Cubic	Alternate	0	NA
Linear	35	33	0	2	0	0
Cubic	32	0	30	2	0	0
Zero	2	0	0	0	2	0
NA (insufficient data, or forecast in NEFR)	7	0	0	2	0	5
Total number of CPs [1]	**76**	**33**	**30**	**6* (3 of these applied zero growth)**	**2**	**5**

Source: Frontier Economics analysis of data provided by AEMO

1) *The total number of CPs at the time of Frontier's review. We understand that AEMO revised the number of CPs before publishing the forecasts.*

3.2.4 Future recommendations

We agree with the enhancement to the methodology and with AEMO's application of these modifications in the VIC 2015 CP forecasts.

For the previous QLD forecasts, Frontier recommended testing of an assumed 10% threshold for the statistical tests, to allow for greater preference for cubic over linear trend selection. We understand that AEMO tested this threshold for the VIC 2015 forecasts but after comparing the results decided to retain the 5% threshold test.

The biggest area for investigation/further development in the VIC 2015 forecast was the method for selecting a horizon value for the cubic trend model. Frontier previously recommended an improved statistical test to help choose from a range of potential horizon values. For the preliminary VIC 2015 forecasts, AEMO applied the statistical test to eight potential horizon values (ranging from the historical minimum demand to the historical maximum demand plus 30% of the difference between the historical minimum and maximum values). Initial forecasts appeared to be counterintuitive in some instances and the results of the cubic horizon test appeared to be sensitive to changes in the model specification and baseline year. Frontier recommended changes to the approach, which AEMO adopted for the final forecasts. The results in the final forecasts appear reasonable. For future implementations, we recommend further investigation of the method for choosing horizon values, including visually inspecting the results to ensure that they are sensible.

3.3 Solar PV adjustments

The original methodology applied for PV adjustment was reasonable given time constraints and data availability, but some limitations were identified in both the pre-model adjustments and post-model adjustments for PV.

The methodology was revised for the SA and QLD forecasts to attempt to improve the forecasts and address these limitations. The improved approach has been applied again for the VIC 2015 forecasts.

3.3.1 Pre-model adjustments for PV

Original methodology

Under the original methodology, a single PV adjustment was applied for each year/season *after* weather normalisation/simulation based on an estimate of PV output at the time of MD. This is a manageable and implementable approach (as estimated PV output can be derived from the NEFR) but it implicitly assumes that either the MD for each CP is at the same time as the MD for the region or that the PV contribution is the same (if the time of MD is different). Although PV only begins to affect MD after around 2010 (when installed capacity increases) this may have an effect on estimates of the underlying trends if the time of CP MD differs from the statewide MD (and PV output would be different for each).

Revised methodology

Under the updated methodology, estimates of historical PV output are added back to historical half-hourly demands *prior to* weather normalisation. If the PV adjustments can be estimated accurately then this should better reflect the underlying demand trend (in the absence of PV) for each half hour, capturing differences in time of day and the "cloudy day" effects (when solar radiation was lower on some days).

This revised approach was first implemented in the SA forecasts using the same solar PV output trace for all CPs. Although this approach was an improvement, one limitation of using a single PV trace is that it does not fully reflect location differences by CP. In general, the PV output trace should be marginally earlier in the day for eastern CPs and slightly later in the day for western CPs. This was further developed in the QLD forecasts to apply a customise PV trace developed by the University of Melbourne for each CP. This has been adopted for the VIC 2015 forecasts.

Frontier did not review the actual calculations (as this was beyond the scope of the review) but the methodology appears sound and reasonable and worth implementing in future forecasts.

One implication of these revisions to the methodology is that the "Actual MDs" (historically) that form the basis of the simulations are after PV adjustment (i.e. reflect underlying demand, assuming 0MW PV output). This is not comparable to the actual MDs used for the simulations in prior forecasts (which reflect underlying demand less PV output). This also means that the historical actual MDs (which are now based on 0MW PV) should be compared with the final unreconciled forecasts *prior* to the post-model PV adjustments; previously, these would be compared against the final unreconciled forecasts *after* the post-model PV adjustments.

3.3.2 Post-model solar PV adjustments

Original methodology

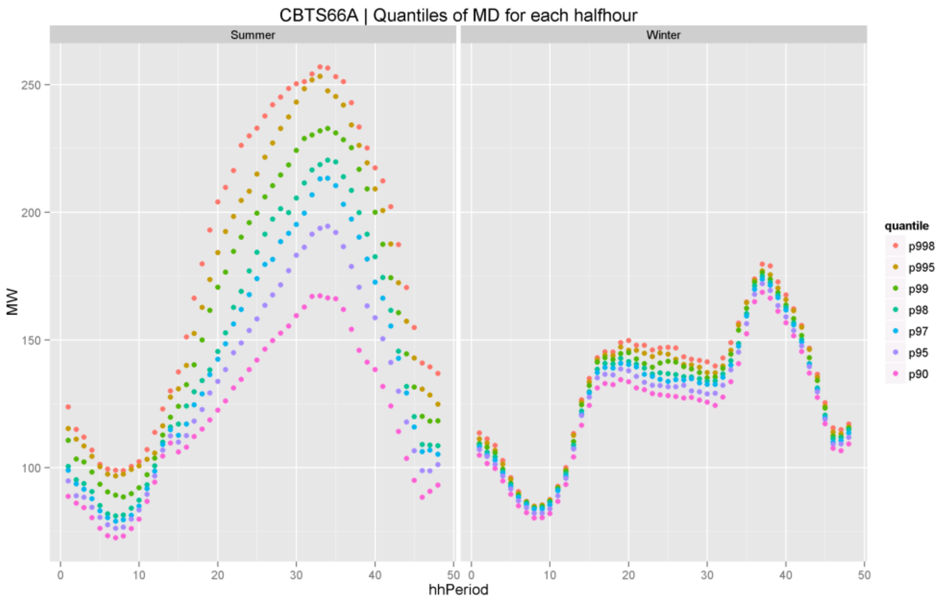
Under the previous methodology, AEMO determined the PV forecast at the CP level as a pro-rata allocation of the NEFR system level PV estimate based on the residential customers per CP. This is a reasonable approach given time and data constraints, but a limitation is that it implies that all CPs have the same time of MD as the system (coincident) MD, or otherwise that PV output is the same at both times. This is potentially a problem where there is a shift in the time of the regional MD from the middle of the day (high PV output) to the evening (low PV output).

Revised methodology

Under the revised methodology, AEMO estimates the change in MD at half hourly level with/without PV output for each CP. This requires pairing of half hourly demand with half hourly PV traces. This is a more data intensive approach to accurately estimate PV output at the half hourly level, but if this can be reasonably estimated given the available data, then the approach should better capture the effect of PV output on changing the time of MD for each CP, and allow for different times of MD for each CP.

As an example, Figure 10 shows a typical trace for demand across a day at CBTS66A if PV output were zero.

Figure 10: Hourly demand trace example, CBTS66A (PV output of zero)



Source: AEMO

The 99th percentile of this demand trace (with zero PV) is then combined with an estimate of PV output across the day for that CP (i.e. the estimated PV output is subtracted from the demand trace). The estimated PV output at each CP is based on:

(a) a typical PV trace for that CP and season, using a spline-smoothed PV output from the top five demand days for each season over 10 years; and

(b) estimated PV capacity by CP.

For the VIC 2015 forecasts, a marginally different PV trace is applied to each CP to reflect differences in location and resulting PV output.

The estimated demand trace with/without solar output is shown in Figure 11. This is used to identify the changing time of MD with/without PV, and the difference caused by solar output. Ther

e is no difference in the estimated PV output for the POE10 and POE50 demand level.

Figure 11: Hourly demand with/without PV example: CBTS66A

Source: AEMO

Comparing the MD with/without PV in the chart above, it is evident that an estimate of PV output at the time of "MD without PV" (midday) would result in too large an adjustment as PV output is higher in the afternoon. Similarly, an estimate of PV output at the time of "MD with PV" (evening) would result in too small an adjustment as PV output is lower in the evening. Neither approach would accurately capture the effect of PV output pushing MD to later in the day (the changing time of MD). However, the blended approach applied by AEMO (looking at the difference between MD with/without PV) appears to reasonably reflect this.

Frontier has reviewed this revised methodology for PV and it reflects a reasonable improvement to the forecasting approach. Frontier has not reviewed all calculations and code used in applying these PV adjustments in the final implementation, as this was beyond the scope of the review. However, the direction and magnitude of the adjustments applied is reasonable.

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 VIC 2015 CPs, Frontier confirms that (a) the revised methodology adopted for the CP forecasts is reasonable and appropriate, and (b) it appears that AEMO has correctly implemented the revised methodology.

Our overall assessment of the methodology and implementation is that it meets the standard of good industry practice. The 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 also commends AEMO's commitment to the continuous improvement of the methodology.

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