High level review of transmission connection point forecasting procedure

A REPORT PREPARED FOR THE AUSTRALIAN ENERGY MARKET OPERATOR

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Figures

Tables

Executive summary

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

In 2013-14 the maximum demand methodology is being implemented for the first time to derive maximum demand forecasts for all CPs in New South Wales (including ACT) and Tasmania which can serve as an independent benchmark for the upcoming revenue reset assessments conducted by the Australian Energy Regulator.

AEMO engaged Frontier Economics (Frontier) to provide an independent review of AEMO's maximum demand and electricity consumption forecasting methodologies at the CP level and its implementation to produce forecasts for New South Wales and Tasmania. The review process included:

- a peer review of ACIL's proposed methodologies for forecasting maximum demand and energy consumption. This included a comparison of the proposed methodologies with the methodologies employed by AEMO for the 2013 NEFR. On the basis of this review we have made a number of recommendations to AEMO as to how best to implement the proposed approaches.
- two Red Flag reviews in which we identified key issues that should be addressed in the implementation of ACIL's methodology for forecasting maximum demand for the New South Wales and Tasmania CPs to ensure the statistical integrity of the resulting forecasts
- ongoing advice and interaction with AEMO regarding the maximum demand methodology and its implementation.

On the basis of our review of AEMO's implementation of the maximum demand forecasting methodology for the New South Wales and Tasmania 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. Some of these issues relate to areas of ACIL's methodology where judgment calls were required to interpret the recommendations. Others relate to conceptual or theoretical aspects of the proposed methodology.

Frontier has made a number of recommendations in regard to these issues. Several of our recommendations have been adopted by AEMO in this first implementation of the methodology for the New South Wales and Tasmania CPs. Other recommendations involve further analysis and could not be implemented in time for the current forecasting process; we understand that these will be considered in future refinements of the methodology.

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.

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). AEMO also commissioned ACIL to develop a methodology for forecasting energy consumption at the CP level. The proposed methodology was presented in a report titled 'Energy Consumption: Overview of a Forecasting Methodology[2]'.

In 2013-14 the maximum demand methodology has been implemented for the first time to deliver maximum demand forecasts for all CPs in New South Wales (including the ACT) and Tasmania. This enables AEMO to provide input into the upcoming revenue reset assessments for these jurisdictions by the Australian Energy Regulator (AER).

Frontier Economics (Frontier) has been engaged by AEMO to provide an independent review of AEMO's maximum demand and energy consumption forecasting methodologies and the current implementation of the maximum demand methodology for New South Wales and Tasmania. In this report we present a high level overview of the review process and an assessment of AEMO's implementation of the methodology.

The independent review process consisted of a number of steps:

- a peer review of ACIL's proposed methodologies for forecasting maximum demand and energy consumption. This included a comparison of the proposed methodologies with the methodologies employed by AEMO for the 2013 NEFR. On the basis of this review we have made a number of

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

2 http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report-2013/~/media/Files/Other/planning/NEFR/2013/Forecast%20Methodology%20Information%20Paper.pdf.ashx

recommendations to AEMO as to how best to implement the proposed approaches.

- two Red Flag reviews in which we identified key issues that should be addressed in the implementation of ACIL's methodology for forecasting maximum demand for the New South Wales and Tasmania CPs to ensure the statistical integrity of the resulting forecasts
- ongoing advice and interaction with AEMO regarding the maximum demand methodology and its implementation.

In an earlier report for AEMO we provided an assessment of both the maximum demand and the energy consumption methodologies from a theoretical and conceptual perspective.[3] Since in the current forecasting project only the maximum demand methodology is being implemented, this report focuses on the implementation of the maximum demand methodology.

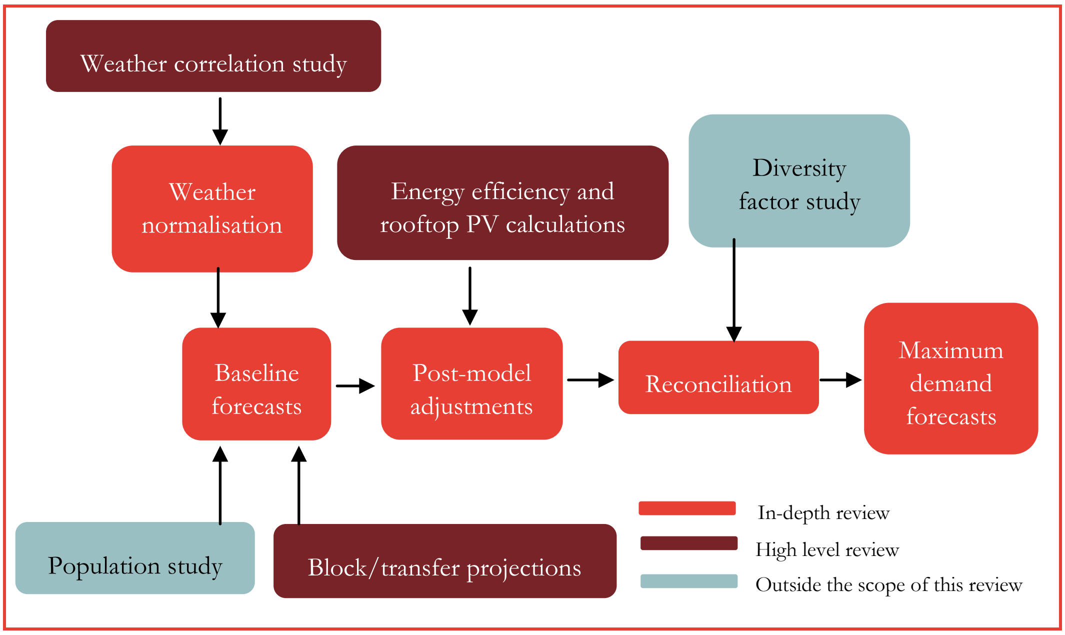
1.2 Scope of our review

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).

3 Frontier Economics (April 2014), *Review of Connection Point Forecasting Methodology – Final.*

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.

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)[4] 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.
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.

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

2.2 Worked example of a connection point forecast

Figure 3 presents an example of some of the main stages of the forecasting process for connection point TNN2 (New Norfolk) in Tasmania. The different panels of the chart represent different seasons (Summer and Winter) on the X-axis, and different levels of the probability of exceedence (POE) of annual maximum demand on the 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 maximum demand (MD). These MDs are shown as the 'Actual MD' and 'Simulated MD' traces in the relevant panels of Figure 3. These MDs represent demand measured at the connection point, with (non-PV) embedded generation added on and major industrial loads removed.

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 MD' traces.[5] In this case, these adjustments are minor, so that the 'Simulated MD' and the 'Adjusted simulated MD' traces virtually coincide.

The 'Trend line' in each panel is the time trend through the 'Adjusted simulated MD's, and provides the growth rate for the 'Baseline forecast' line in the chart.

The 'Baseline forecast' line can start either from the last point on the 'Trend line' or from the last observed simulated data point. The decision on whether to start the forecasts 'off the line' or 'off the point' is discussed in more detail in the next section. The Summer P50 panel exemplifies a baseline forecast 'off the line', the Winter P50 panel exemplifies a baseline forecast 'off the point'.

If a forecast is deemed unreasonable, an 'Alternative forecast' is used instead of the 'Baseline forecast', in which the growth rate is replaced by either the growth rate of the population in the connection point supply region. An example is shown in the Winter panels in Figure 3. In some cases, when the historical trend is unclear and the population growth rate seems inappropriate, a zero growth rate is applied.

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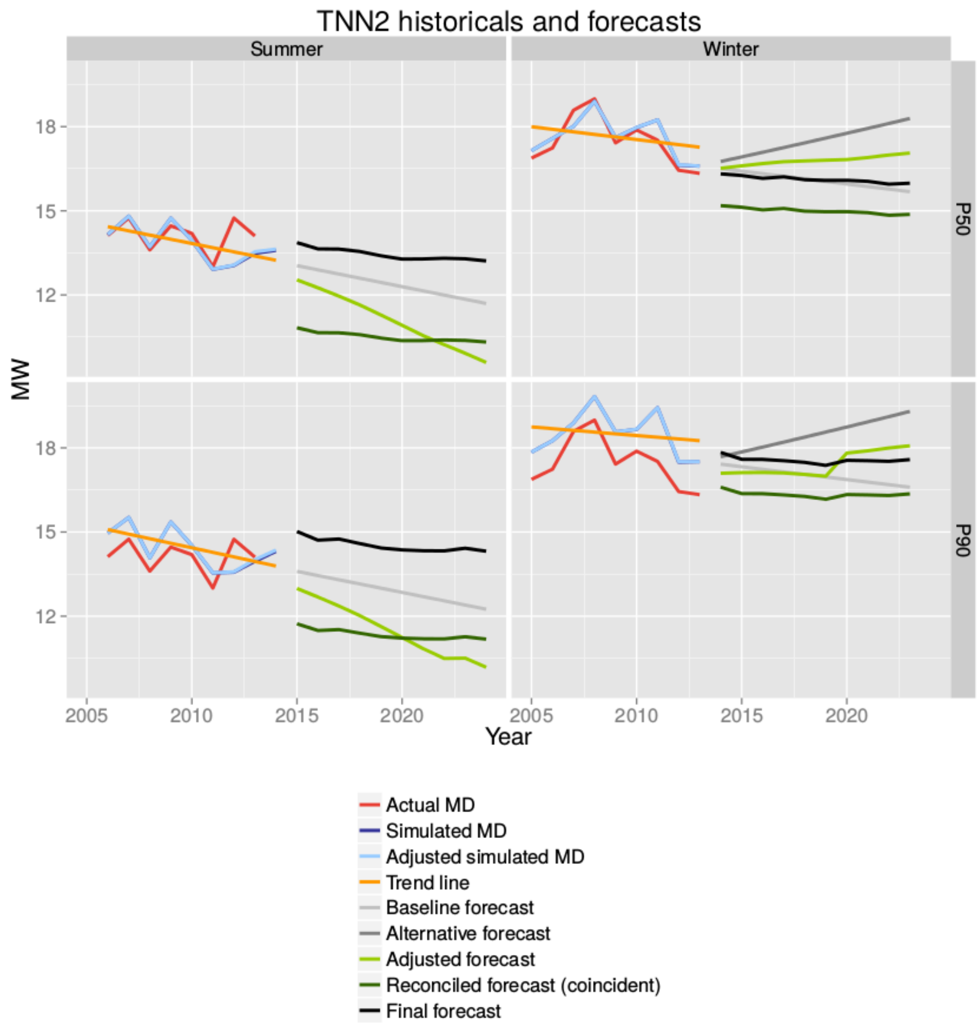
5 Historical PV output is *added* to the historical simulations *before* establishing the growth trend. This is so that the underlying trend in MD is not affected by growing PV output over time. Once the underlying trend is established and forecasts produced, the estimated PV impact on MD in the future 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.

Figure 3: Forecast of connection point TNN2 at each stage of the process



Source: Compiled from AEMO data

Note: The 'Simulated MD' line is mostly hidden by the 'Adjusted simulated MD' line

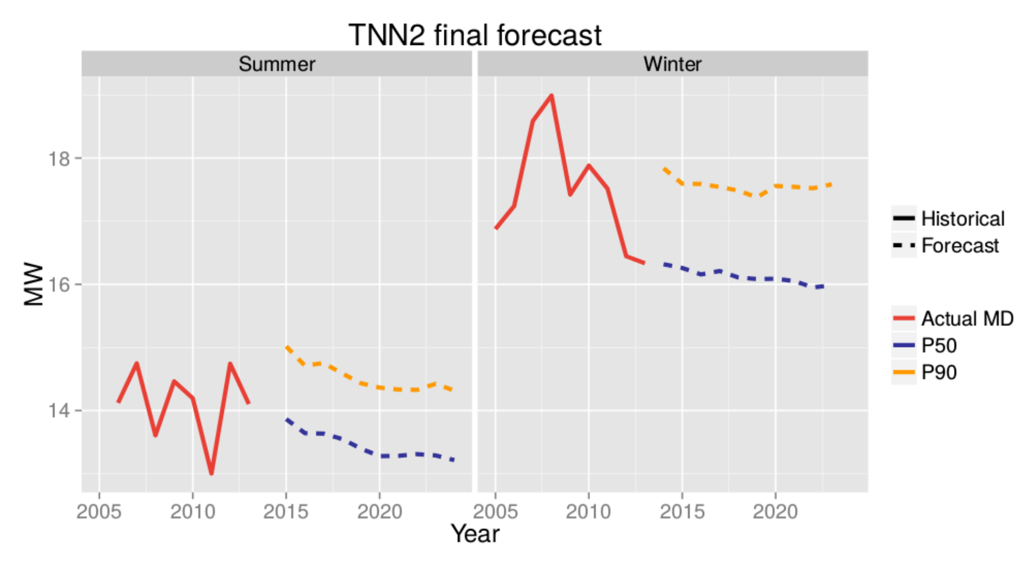
The 'Adjusted forecast' is either the 'Baseline forecast', or the 'Alternative forecast' (if used), with adjustments made for future block loads and transfers, PV and energy efficiency improvements.

The final two 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 connection point, a diversity factor is used to convert the forecasts of MD at the time at which the CP peaks, to forecasts of coincident maximum demand (CMD), i.e. the demand for that connection point at the time of system 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 system level forecasts.

The 'Reconciled forecast (coincident)' line in Figure 3 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.

Figure 4 shows the historical actual MD data and the final forecasts for TNN2 without the intermediate steps.

Figure 4: The final forecast for connection point TNN2



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, areas 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 (from the NEFR) is netted out for weather normalisation. Offsetting adjustments are made later.	For some CPs, incomplete data on block load and load transfers prevented full implementation of the recommended methodology. Where it couldn't be implemented problematic data points were excluded, which is the next best alternative to adjusting the historical data, as the inclusion of these loads would produce incorrect trends. Frontier has not inspected the files providing details of the removal of major industrial load or the addition of embedded generation (partly due to confidentiality reasons). ***This approach 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	**Temperature sensitivity equations:** The recommended methodology for estimating demand-temperature models was producing a significant number of cases where demand was judged 'not temperature sensitive'. Frontier suggested pooling observations across years when estimating its maximum demand-temperature models in order to more effectively use the available data. AEMO investigated this approach but it was not applied in the final forecasts, we understand partly due to time constraints and partly to adhere to the published methodology. We understand that AEMO may still consider this in future implementations. ***Frontier recommends that further analysis be undertaken to address this issue in future implementations*** **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. **Simulation for temperature insensitive CPs:** For temperature insensitive CPs AEMO had implemented a 'bootstrapping' simulation approach. This often produced POE50 and POE10 values that were identical. Frontier recommended that AEMO revert to using normally distributed residuals with a standard error produced by the 'constant only' temperature model which is consistent with ACIL's proposed methodology. ***This recommendation was implemented by AEMO in the final forecasts***

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. ***This 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.	AEMO experimented with different heuristics for determining whether the point was 'close' to the line or not, but this produced fragile results. This led AEMO to use "the point" as the default starting point. Frontier argued that, 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. 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. ***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.	It became apparent in the implementation of the proposed methodology that some trends in the historical data were nonlinear. When this is the case, it is inappropriate to use a linear trend line to determine the growth rate.	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 whether to use the local area population growth rate or a zero growth rate. ***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. Frontier recommended changes to the procedure to overcome these issues. ***The recommended approach was implemented by AEMO in the final forecasts***
Post-model adjustments	Where necessary, make post model adjustments to take into account factors that are	ACIL does not appear to make specific recommendations for post-	Adjustments to maximum demands for block loads (typically large industrial loads) which can cause step-change variations in maximum demand. Block loads and transfers are included 'bottom up' on a case by case basis using data sourced from

<table>
<tr><th>Step</th><th>ACIL approach (summarised)</th><th>Further decisions during implementation</th><th>Resolution/recommendation and notes</th></tr>
<tr><td></td><td>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</td><td>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 POE10 forecasts, which led to complications in adjusting for PV by POE level</td><td>DNSPs.

Given the potential bias for NSPs to overestimate the likely size and/or timing of new load, ACIL suggests inclusion of adjustments by ‘wait’ or ‘weight’ – wait until load is definite before including it, or use the expected value of the load.

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).

For each state, 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.</td></tr>
</table>

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 sometimes led to the P90 (POE10) MD forecast falling below the P50 (POE50) MD forecast in the baseline forecasts. These anomalies are partly overcome in the reconciliation process. Frontier recommended an approach to overcoming these anomalies in the baseline forecasts ***The recommended approach was implemented by AEMO in the final forecasts*** Theoretical statistical analysis showed that the current approach to combining percentiles from the maximum demand and PV distributions is only valid under extreme assumptions. In general, it is not valid to add the percentile values from different distributions, particularly at the P90 (POE10) level. This is a complex statistical issue that requires further investigation ***Frontier recommends that further analysis be undertaken to address this issue in future implementations***
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 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
			The scaling factors have positive trends over time and, in some cases, they become quite large; for e.g. for POE50 in TAS the ratio between the NEFR system forecasts and the sum of the CP forecasts rises to almost 125%. The source of this discrepancy should be investigated. ***Frontier recommends that further analysis be undertaken 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 recommends that further analysis be undertaken 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 5.

Figure 5: '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

Two issues that arose in the weather normalisation process were:

- for many CPs, the coefficients on the temperature variables are statistically not significant; i.e. the load at those CPs appears not to be temperature sensitive. In these cases, the simulation step of the weather normalisation process only incorporates the random variation component of the model. Table 2 summarises the number of connection points that were found to be temperature sensitive or not.
- 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.

Table 2: Temperature sensitivity of CPs

Region	Number of CPs	Summer		Winter	
		Not temperature sensitive	Temperature sensitive	Not temperature sensitive	Temperature sensitive
NSW	73	21 (29%)	52 (71%)	16 (22%)	57 (78%)
Tas	45	35 (78%)	10 (22%)	10 (22%)	35 (78%)

Source: Frontier Economics analysis of data provided by AEMO

Frontier suggested that pooling the data across years when estimating the temperature sensitivity models would ameliorate both issues.[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. However, 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. Frontier recommends that further analysis 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.

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, sometimes referred to as forecasting 'off the line'.

For a considerable number of CPs it appears that the time trend is non-linear or that there is 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 has provided only vague 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 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 3 summarised the number of instances when the tests determined that the forecasts should be taken 'off the line' versus 'off the point'. In the majority of cases that forecasts are taken 'off the line', the exception being NSW Winter when there is a slight preference for taking forecasts 'off the point'.

Table 3: Starting points used for CPs by state and season

Starting point	NSW		TAS	
	Summer	Winter	Summer	Winter
Off the line	44	35	34	25
Off the point	29	38	11	20
Total number of CPs	**73**	**73**	**45**	**45**

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 change in the time of the MD in Tasmania from day time to night time for some percentiles[7]. 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 the present forecasting exercise, 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

[7] For P90 in Winter and P50 in Summer (though the latter is beyond the CP forecast horizon)

disappear in most cases in the reconciliation process. However, the underlying issue is still present.

Frontier has recommended an approach to addressing these anomalies in the baseline forecasts. This approach overcomes the problem of the baseline P50 (POE50) forecasts exceeding the P90 (POE10) forecasts, and it has been implemented by AEMO. However, this should be seen as an interim measure. Frontier has flagged this as an area for further development work.

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.[8] 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.[9]

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 New South Wales and Tasmania 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.

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8 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.

9 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.

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.

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