Appendix S – SKM/MMA Report – Review of Western Power's Demand Forecasts for the AA3 Period

September 2011

SINCLAIR KNIGHT MERZ

SKM | M | M | A |

westernpower

Review of Western Power's Demand Forecasts for the AA3 Period (2012/13 to 2016/17)

- Final
- 11 November 2010

Review of Western Power's Demand Forecasts for the AA3 Period (2012/13 to 2016/17)

- Final
- 11 November 2010

SKM MMA
ABN 37 001 024 095
590 Orrong Road, Armadale 3143
PO Box 2500
Malvern VIC 3144 Australia
Tel: +61 3 9248 3497
Fax: +61 3 9248 3398
Web: www.skmmma.com

Contents

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
1	24 Sept 2010				Preliminary Draft
2	7 Oct 2010	R Lewis	S Hinchliffe	8 Oct 2010	Draft
3	4 Nov 2010	R Lewis	J Butler	4 Nov 2010	Final Draft
4	11 Nov 2010	G Edwards	J Butler	11 Nov 2010	Final

Distribution of copies

Revision	Copy no	Quantity	Issued to
1	Electronic		Client as progress report and for comment
2	Electronic		Client
3	Electronic		Client
4	Electronic		Client

Printed:	10 August 2011
Last saved:	10 August 2011 09:40 AM
File name:	I:\QHIN\Projects\QH99954\Deliverables\Reports\Final\QH99954R004.doc
Author:	Greg Edwards/Michael Pierce/Richard Lewis
Project manager:	Greg Edwards
Name of organisation:	Western Power
Name of project:	Review of Western Power's Demand Forecasts
Name of document:	Demand Forecast Review
Document version:	Final
Project number:	QH99954

1. Executive Summary

In preparation for Western Power's submission to the Economic Regulation Authority (ERA) for the proposed revisions to the access arrangement (for period AA3), Sinclair Knight Merz through its new division SKM MMA, was commissioned to provide an independent review of Western Power's demand forecasting methodology and forecasts for the electricity supply in the SWIS to assure stakeholders that the results, method and input assumptions are robust. SKM MMA's expertise in conducting network demand forecast reviews is based on staff industry experience and previous assignments that have involved reviews of forecasts prepared by almost all Australian network businesses. SKM has previously reviewed forecasts prepared by Western Power, ActewAGL, TransGrid and others. MMA has reviewed forecasts prepared by all of the network operators in New South Wales, Victoria, Queensland and South Australia; in all cases apart from Victoria on two or more occasions.

SKM MMA generally concludes that the forecasting methodology adopted by Western Power is comparable with good industry practice throughout Australia.

SKM MMA's key findings can be summarised:

- The suite of forecasting software (ForeSite) used by Western Power is perhaps the best integrated demand forecasting package that SKM MMA has reviewed;
- The process and practices used in accessing and processing input data are well established and technically sound;
- The treatment of load transfers and block loads (historical and forecast) is consistent with good industry practice;
- The calculation of trends in historic data and the forecast of future demands using regression analysis is technically sound;
- The forecasts produced by Western Power are robust and repeatable;
- Western Power does not explicitly weather correct the historic data. This is a key difference between the Western Power approach and typical industry practice; there is no evidence that this affects or biases the 50 POE demand forecasts.
- Western Power does not develop an econometric top-down demand forecast. Western Power has made a decision to utilise the IMO econometric forecast for comparison purposes;
- Western Power does prepare an alternate high economic growth scenario demand forecast but this is based on the same underlying growth trend as the base forecast, but with more optimistic assumptions regarding future block load development;

- Western Power's assessment of new block loads over the forecast period is more conservative (lower) than the IMO, resulting in a lower demand forecast than that included in the IMO's Statement of Opportunities;
- The treatment of new block loads and transmission losses account for much of the difference between the Western Power and the IMO 50POE forecasts;
- The adjustment of the 50POE forecast to provide a 10 POE forecast is based on a statistical analysis of the historic series and calculation of a Prediction Interval. This is another key difference between the Western Power approach and typical industry practice which normally uses temperature correction to estimate the demand under a 10 POE temperature condition. The impact of this difference is estimated to be an approximately 50MW understatement of the 10 POE forecast which in the context of Western Power's peak demand of 4000MW is considered not significant.

These findings are discussed in more detail in the body of this report.

SKM MMA also has some more theoretical concerns with Western Power's decision not to explicitly correct for weather on two grounds:

1) The assumption that in the historical figures any abnormal days are distributed evenly across the history – this may indeed be the current situation over recent years, but it is clear that a congregation of abnormal days can skew the trend curve – impacting 50POE as well as 10POE forecasts. SKM acknowledges that this has not affected the data used for the AA3 forecasts which therefore are not skewed but it could affect the approach in future;
2) The assumption that temperature dependence is reasonably constant (therefore represented in the historical series) –SKM MMA analysis suggests that the sensitivity of demand to temperature (MW/degree) appears to be changing – therefore the historic series may not capture future sensitivity. However our tests of an alternative approach that may address this proved inconclusive and in view of the small 50 MW understatement of the 10POE forecast the alternative is not recommended.

SKM MMA believes that the methodology adopted by Western Power and the forecasts produced are technically sound, conservative and generally in line with good industry practice.

2. Background and Scope of Works

2.1. Background

For the next Access Arrangement period (period AA3) between 2012-13 and 2016-17, Western Power is preparing its submission to the Economic Regulation Authority (ERA) for the proposed revisions to the access arrangement and revised access arrangement information for the South West Interconnected System (SWIS). In preparation for this submission, Western Power requires an independent review of its demand forecasting methodology and forecasts for the electricity supply in the SWIS to assure itself and other stakeholders that the results and hence method and input assumptions are robust. In addition, Western Power requires support in reconciling any variations between its demand forecast for the period and that of the Independent Market Operator, as contained in the Independent Market Operator's Statement of Opportunities report.

On 8 September 2010, Western Power appointed SKM MMA to perform this review.

SKM MMA's expertise in conducting network demand forecast reviews is based on staff industry experience and previous assignments that have involved reviews of forecasts prepared by almost all Australian network businesses. SKM has reviewed forecasts prepared by: Western Power; ActewAGL; TransGrid and others – see Appendix E. MMA reviewed forecasts prepared by: Energy Australia; Integral; Country Energy; Inland Energy; CitiPower; Jemena; Powercor; SPI Electricity; United Energy; ENERGEX; Ergon; and ETSA. In all cases apart from the Victorian businesses two or more reviews were conducted. MMA also conducted numerous gas network demand forecast reviews and prepared gas demand forecasts for the Australian Energy Market Operator for the Gas Statement of Opportunities.

2.2. Scope of Works

The scope of this assignment includes the following tasks:

- review Western Power's electricity demand forecasting method and review forecasts for the period between 2012-13 and 2016-17 at a zone substation and then at an aggregated system level, applying appropriate diversity factors across substations;
- identify and comment on the strengths and weaknesses of the method employed, including, for example the method used to develop 10POE (10% probability of exceedance) and 50POE demand forecasts and overall robustness of the process;
- review inputs to the model and assumptions used, including for example assumptions surrounding embedded generation, spot load growth, temperature correlation and comment on their appropriateness;

- describe all relevant inputs and assumptions and report on their suitability and accuracy;
- review the IMO forecast, in so far as data contained in their Statement of Opportunity allows; and
- work with Western Power (and potentially the IMO) to reconcile and document the variances to the Independent Market Operator's Statement of Opportunities report

2.3. Previous Reviews

In November 2006 Sinclair Knight Merz (SKM) and ROAM Consulting were jointly commissioned to undertake a review of Western Power's demand forecasting systems at both the transmission and distribution levels. This included comparison against international good practice as applicable to the current and foreseeable future market conditions in which Western Power operates, and the development of recommendations for improvements in Western Power's demand forecasting processes to achieve appropriate international good practice.

As a part of this commission, SKM/ROAM reviewed a range of demand forecasting models and identified and reviewed forecasting approaches/tools used by other network operators to establish international good practice. Certain key internal and external stakeholders in Western Power's demand forecasting system were interviewed to establish the business requirements for Western Power's demand forecast. Western Power's current forecasting processes were compared against appropriate international good practice and against the requirements identified through these consultations and, using gap analysis techniques, a range of recommendations were developed to move Western Power's current forecasting practice to international good practice.

From the analysis undertaken it was concluded that the load forecasting undertaken by Western Power at the transmission level was at the time generally to a high standard. Methods and procedures were robust and there was a high degree of consistency in the overall approach. In particular, the process for using Supervisory Control and Data Acquisition (SCADA) data and for clean up and undertaking integrity checks of that data was considered robust, albeit reliant on one or two key staff at that time. Also the production of load trends for both summer and winter peaks demonstrated thoroughness even though only a few zone substations are winter peaking. The development of forecasts at the zone substation level (which are then aggregated up, taking account of load diversity, to produce a system wide forecast) provided valuable information to system planning for network and zone-substation augmentation in that it readily enables local factors and regional specific information to be taken into account.

However, the distribution level forecasts were found to be less robust than the transmission level forecasts and less well defined (prescribed) with engineers and planners appearing to have, at that time, a high degree of autonomy in the manner in which forecast were developed. The capture and application of the data used (such as development and choice of ADMD levels, base growth indices) and the manner in which the forecasts were undertaken and employed (for example the process described for predicting overload of distribution level transformers) was not consistent.

At both the transmission and distribution levels, the process for treatment of block loads and for treatment of load transfers also had the potential for inconsistency in approach. This was both in respect of interpretation of the guidelines provided in Western Power's Block Load Forecasting guidance document and in the capture and application of data on block loads.

Similarly, the treatment of embedded generation and demand side management by assuming worst case conditions (i.e. that such measures will not be available to reduce demand at times of high system peaks) fell short of recent developments in international good practice. The tendency here being to assume minimum capacity levels for portfolios of embedded generation, demand side management/demand side participation initiatives.

Finally, the method for incorporating historic high demand peaks (classed as one in ten year weather adjustment) by moving the trend line up to capture the previous highest peak did not reflect international good practice nor did it necessarily capture the 10 % probability of exceedance (POE) extreme temperature influenced peak as intended.

The 2007 report for Western Power by SKM and ROAM Consulting made the following recommendations for improvement and transition to international good practice:

1) **Single point of responsibility and overall co-ordinating group:** The role of the newly appointed System Forecasting Manager should be clearly defined together with the purpose, role, ambit and authority of his group. As part of this process, the make-up of the group should be determined. Coupled with this should be the allocation of ultimate responsibility for the demand forecast to a senior manager or Board member as 'champion' for the process[1].
2) **Well defined procedures and definitions:** One main area to address, which should be taken as a first priority for the System Forecast Manager and his group, is the development of clear, comprehensive and consistent procedures for the entire demand forecasting process across the business. This would include, among other things, procedures for data capture and clean up, for treatment of block loads, load transfers, embedded generation and demand side management. In addition the group should be tasked with the remit of ensuring common reporting styles for all demand forecasts at all voltage levels for both

[1] It is recognised that the recent appointment by Western Power of a System Forecast Manager is the first important step in the process of consolidating responsibility and co-ordination for demand forecasting across the business.

internal and external reporting requirements. The group should also be charged with establishing methods and systems for undertaking audits of the demand forecasting process. This would include periodic software audits/integrity checks for in-house developed software, backcasting to validate processes and comparison of forecasts with actual outturn to validate assumptions. Finally, the processes and procedures for linking the inter-related energy/demand forecasts should be reviewed by the group to ensure that clear links between the system wide demand forecast and the energy forecasts used for tariff setting under the price set regulatory regime can be demonstrated;

3) **Review the decision not to use weather correction and 10 % POE weather events in the forecast:** The current method for making extreme weather adjustments does not adhere to good practice neither in incorporating weather corrections/10 % POE extreme weather event demand projections, nor in terms of capturing one in ten year (on average) peak demands. As such it is recommended, given that air-conditioning load penetration in SWIS is now comparable with that in the NEM, that a study be undertaken to revisit correlating peak demand with temperature and humidity (possibly combined to form a single dimension variable). Should a statistically significant positive correlation be determined, this should be incorporated into the scenario demand forecasting analysis[2]. This should then be extended into a review of other scenario analysis options relevant to the region in which Western Power operates which should include, as a minimum, capturing high low and medium case Gross Domestic Product (GDP) forecasts;

4) **Establish an internal Load Forecasting Discussion Group:** It is not recommended, at this stage, that a Load Forecasting Reference Group similar to that in the NEM be established, incorporating stakeholder representatives external to Western Power (e.g. from the IMO, ERA, DPI). However there is merit in establishing an internal reference group with the ambit of providing guidance to the System Forecasting Group. Consideration should also be given to inviting, at a future date, representatives from Verve, and the System Operator and also from the Western Power technology fore-sighting group. It is also recommended that formal, say quarterly, meetings be established with other external stakeholders such as the IMO, DPI, major land developers and major customers to explore areas for collaboration on demand forecasting;

5) **Develop greater understanding of energy usage and energy usage trends:** To assist with development of a range of ADMDs applicable to different customer groups, and to periodically adjust such, as well as develop ‘shoulder’ forecasts for system stability studies, there is merit in gaining a greater understanding of energy usage amongst different customer groups. This information could be captured from reviews of new

[2] E.g. in the form of an algorithm to develop an ‘x’ MW rise per degree increase in temperature above mean (i.e. the 50 % POE temperature level) for high temperature events over a given number of days.

building codes and other influences on domestic energy consumption (e.g. levels of insulation, switch from electric water heating to gas, air-conditioning penetration in new housing developments depending on target market and so on). A similar process could be repeated for major energy users, coupled with low level economic analysis of different key industries (e.g. changes in aluminium prices could bring forward or delay the construction of additional aluminium smelter plant). Similarly, information on new large loads could be gained through interaction with major customers, land developers etc.

6) **Econometric Forecast:** International good practice would suggest the integration of several forecasting techniques. Consideration should therefore be given to either developing an econometric forecasting capability in house, or, perhaps more pragmatically[3], commission a separate, independent econometric forecasts tailored for Western Power's purposes to provide a comparator to the bottom-up forecast. In either event it is recommended that Western Power wholly owns this forecast and that it be independent of the IMO forecast.

In 2008 SKM and ROAM Consulting were jointly commissioned to undertake a review of Western Power's progress against recommendations made in the SKM and ROAM Consulting's March 2007 report to support Western Power's drive to undertake its demand forecast in accordance with international good practice.

In undertaking this exercise, SKM and ROAM Consulting reviewed documentation provided by Western Power that outlined modifications to the demand forecasting procedures, software and processes, together with example reports produced in light of these improved procedures. SKM and ROAM also conducted in-depth interviews with staff in the System Forecasting Section producing the reports as well as with Western Power management that make use of the demand forecasts and with representatives of the Independent Market Operator of Western Australia (IMO).

In the resulting report SKM/ROAM concluded that significant and impressive progress has been made against the recommendations made some 18 months ago. Formal and well documented procedures had been put in place, a review of temperature correction has been undertaken and this has been integrated into the distribution feeder forecasting software. A highly motivated and balanced team has been put together having a good mix of relevant skills, abilities and ages and work has been started through the auspices of the MONASH University to develop a top down econometric forecast.

SKM and ROAM Consulting concluded at that time that much had been put in place to support the transition of Western Power's demand forecasting systems to what may be considered good

[3] Recruiting a capable economist to undertake such forecasts within Western Power, which may in effect be a full time activity, may prove difficult.

industry practice in Australia and international good practice in line with the recommendations made in early 2007. Following the review, a number of subsequent and additional recommendations were made, the principal recommendations being:

- the next key stage of the process is to integrate the various demand forecasting activities undertaken, that is load forecasting activities associated with the trend based Zone Substation and transmission system load forecast should be fully integrated with spot load forecasting and with the work undertaken on end user energy usage analysis;
- temperature correlation and correction should be implemented for Zone Substation and transmission level forecasts in a similar manner as for distribution feeder forecasts and consideration should be given to integrating economic metrics into the bottom up trend based forecasts;
- the work undertaken by MONASH University, which is recognised as being ‘work in progress’, needs to be finalised; with a clear specification developed for MONASH University as to the requirements for the forecast[4] together with augmentation of the System Forecasting Section Operating Manual to specify how the econometric forecast will be integrated into the overall forecasting system;
- in-house developed software should be independently audited and custody of such (in terms of modifications) should reside outside the System Forecasting Section once the software development has been finalised and it is integrated into the demand forecasting processes;
- the System Forecasting Section Operating Manual should be augmented to capture the integration processes for the different forecasting activities and to formalise the current in-formal, quality approval and peer review process for demand forecast reports;
- as recommended in 2007, consideration should be given to establishing a formal demand forecasting discussion group with representatives from key internal stakeholders on, say, a quarterly basis; timed appropriately to coincide with the key calendar events triggering the requirements for a demand forecast;
- opportunities to collaborate with the IMO on a top down econometric forecast are worth exploring;
- succession planning within the group as well as the, informally occurring, mentoring process between senior and junior team members, would benefit from being formalised.

[4] It is understood that a comprehensive scope of work has been developed for completion of the work by MONASH University but this has not been reviewed.

2.4. Organisational Structure

Approximately two years ago, Western Power re-organised the System Forecasting Section. Previously, it had existed as part of the System Planning group. The Forecasting Section remains within the Network Planning and Development Branch but is independent of the System Planning function.

This separation of these functions removes potential for any perception that forecasts may be tailored to deliver a given System Planning outcome. It also allows for a more specialised resource which offers forecasting expertise throughout the organisation – not restricted to demand forecasting.

3. Forecasting Methodology

3.1. Good forecasting practice

Demand forecasts require a series of standard elements to be good practice. The following two tables outline a set of criteria that have previously been used by MMA in demand forecast reviews of system and spatial demand forecasts. They are based on "Spatial Electric Load Forecasting" by H Lee Willis.[5]

All networks base their capital plans on spatial forecasts, which because of the number required are often based on straightforward methodologies such as trend projections. Many networks also prepare system-wide forecasts using more complex methodologies, for the purpose of testing and possibly aligning the sum of the substation forecasts with macro factors considered only at the system level. Western Power does not itself forecast directly at the system level but derives a system forecast from a summation of substation level forecasts. This system forecast is compared with system forecasts prepared by the Independent Market Operator (IMO) to seek explanations of any differences. The first table below is therefore provided primarily as background information rather than being directly applicable in this review.

- **Table 3-1: Elements of good system demand forecasting - from a recent MMA review**

Element	Description
Weather normalisation	As weather plays such a large part in maximum demand, appropriate weather normalisation is vital.
Use of load research	To be able to better understand the contribution of different customer classes to system maximum demand.
Use of air-conditioner penetration information	Growth in air-conditioner penetration and usage has contributed significantly to maximum demand growth. Local inputs about historical growth and objective assessments of future growth are required.
Model construction	The model needs to have a logical structure and a level of detail that is commensurate with available information.
Model validation	The form of the model used, and any changes proposed need to be validated and tested against alternative model forms. The accuracy of the model over a relevant historical period should be tested.
Reasonableness of forecast inputs	The key forecast inputs need to be both timely and reasonable. Key drivers need to be considered.
Documentation	Detailed documentation of the model is required, in particular the validation of the peak demand model, including tables and figures, sufficient to enable a third party with access to relevant data to replicate the model and forecast. Without such documentation the modeling and forecasting process is incomplete.

Note: The elements in the first column are those from the recent review. The description is not and the evaluation has been omitted.

---

[5] H Lee Willis - Spatial Electric Load Forecasting, Second Edition 2002, Chapter 22

▪ **Table 3-2: Elements of good spatial demand forecasting - from a recent MMA review**

Element	Description
Documentation	The spatial forecast methodology including source of assumptions needs to be fully described and documented.
Approach	The approach needs to be well-considered, objective and unbiased.
Evidence of application of methodology	There needs to be evidence that the methodology described is generally well-followed and consistently applied.
Weather normalisation	As weather plays such a large part in spatial maximum demand, appropriate weather normalisation is considered important, even though difficult at the spatial level.
Consideration of key drivers and reconciliation between global and spatial forecasts	The key drivers need to be recognised in the global forecast and then translated and reconciled with the spatial projections.
Timely information	Timely information incorporating current understanding of key drivers and large new loads needs to be incorporated into forecasts.

Note: The elements in the first column are those from the recent review. The description is not and the evaluation has been omitted.

A high level comparison of Western Power's forecasting approach with typical practices in the eastern states is provided in Appendix D.

SKM's understanding of the Western Power methodology is described and discussed below.

3.2. Network Levels

The Western Power network can be described at four different levels of aggregation.

1) Whole of SWIS level, commonly referred to as System
2) Terminal level, similar to bulk supply point, where the bulk transmission system interfaces with transmission system. Load Development Reports usually cover a terminal substations region.
3) Substations of which there are around 140 existing and 40 future planned. Substation demand is usually measured on the transformers from 132 kV to lower voltages.
4) Individual Feeder level. Western Power has approximately 950 feeders, most with voltages from 6.6kV to 33 kV.

The forecasts focused on in this review are those at Substation level and the aggregation of such on a diversified basis to System level. We note that a similar approach is used for Feeder level forecasts.

3.3. Description of method

Western Power forecasts are based on a bottom-up approach. There is no high level econometric forecast undertaken by Western Power. A system level econometric forecast is produced by NIEIR and published by the IMO. A comparison of the Western Power and IMO forecasts is presented in Section 6.

For each substation a series of forecasts are produced:

- 50 POE[6] substation MD – a trend forecast underlying the 10 POE forecast
- 10 POE substation MD – used for planning network augmentation
- 50 POE substation MD at time of system peak – used to produce the 50 POE system peak forecast

The system peak forecasts are used as a comparison with the equivalent IMO forecasts.

The Western Power 50 POE system forecast is calculated by the summation of the individual substation 50 POE forecast demands at time of system peak. The 10 POE system forecast is calculated by an adjustment to the 50 POE system forecast based on the variability of historical system peak demand using a similar calculation to substation level.

3.3.1. Note on the meaning of POE in the MD context

It is worth noting in more detail what the probability of exceedance means in the context of maximum demand, because alternative ways of expressing it are sometimes used and they do not always have exactly the same meaning. In this report, and we believe, in Western Power's forecasts, the term X POE MD means the level of demand that has X% probability of being exceeded by the **maximum demand recorded in any year**. Thus the 10 POE MD is the level of demand that the **annual** MD will exceed on average once every ten years.

We believe that this definition is consistent with industry usage in Eastern Australia but note that it is not the same as saying that **daily** peak demand will exceed X POE MD on average X/10 times every ten years because in a very "high demand" year several days may exceed it in the same year. In practice this is not particularly important at the 10 POE level but it should be expected that the 50 POE level would be exceeded on more than 5 days every ten years and the 90 POE level would be exceeded considerably more often than 9 days every ten years. Alternatively, if the POEs are calculated this way the values will generally be higher, since they will be calculated from the top demands across all days in all years rather than just the maximum demands in each year.

---

[6] 50 POE – implies 50% Probability of Exceedance

This is illustrated in Table 3-3 using 10 years of Perth weather data rather than demand data, to avoid problems comparing demand in different years. As can be seen there is no difference in the 10 POE values because their exceedance is very rare but there is a small difference at the 50 POE level and a much larger one at the 90 POE level.

- **Table 3-3 Alternative estimates of POE temperatures**

	Max annual temperature exceeds (10 years data)	Daily temperature exceeds (10 years data)	IMO SOO (30 years data)
10 POE	34.2	34.2	34.6
50 POE	31.7	32.0	32.7
90 POE	29.0	31.7	31.4

The IMO SOO temperature POEs are included for comparison because they are based on the second definition and are clearly consistent with that definition, even though they use more years of data than we have available. Some caution therefore needs to be taken when comparing Western Power and IMO demand projections, though the differences at the 50 POE and 10 POE levels are small.

3.3.2. Inputs

For each substation the historic annual demand is captured for both substation peak and time of system peak. This process is described in Section 4.

Block loads that may be included are collated by a central system described in Section 4. The decision on the inclusion of individual block loads is based on a guideline matrix relating to block load size, timing and how far through the development process the project is. Western Power has processes for estimating size, timing, diversity and power factor based on previous similar block load proposals.

For each load transfer between zone substations a size, date, power factor and growth rate are specified. The transfer and future growth is subtracted off the sending substation and added to the receiving substation. The total MVA added and subtracted net out to zero. It is assumed that the transfer has a diversity of 1 with both the sending and receiving substation.

3.3.3. Forecast approach

An adjusted historic series, in MVA, is calculated for each substation. This adjusted series has had the effect of block loads and transfers removed. For the majority of substations, around 95%, a linear trend is fit through this series[7]. The regression statistics from this fit are checked including the R squared, which should be greater than 0.5, and the MVA per year added due to trend growth.

The 50 POE forecast is produced using this trend and including the effect of block loads and transfers, both historical and future.

- A decision is made on whether a block load (or group of small block loads) is considered additional to underlying growth or not. Often a block load, such as a residential subdivision, may be considered to overlap with underlying growth in which case the block load is reduced to account for the overlap. For example, if a residential substation with 2 MVA growth per year has a 4 MVA subdivision added, the block load may be reduced to 2 MVA. This adjustment is documented when it occurs.
- Block loads are diversified. The diversity factor is based on an analysis of customer type peak day profiles against substation types or even the specific substation peak day profile. A description of the Western Power approach to deriving diversity factors in provided in Section 4.3.2.
- Transfers include an assumed growth rate based on the growth rate of the sending substation in that year. Transfers are assumed to have a diversity of 1 with both the sending and receiving substation. Transfers do not impact the calculation of the difference between the 10 and 50 POE forecasts.

The trend growth is forecast in MVA. Blocks and transfers are also added back in MVA. This is converted to MW using the average power factor of the most recent 5 years of history. The power factor can be adjusted if new capacitors are to be added.

The approach taken by Western Power of using historic trends and adjusting for block loads and transfers is considered good industry practice by SKM.

3.4. Calculation of 10 POE relative to the 50 POE trend

Western Power has utilised a different approach to the typical industry practice for forecasting 10 POE demand. We describe the Western Power approach in this section and then typical practice in 3.4.1 and then provide a comparison in 3.4.2.

---

[7] If there is three years or less of history for a substation then a manual fit is applied by the forecaster selecting an appropriate growth rate.

The 50 POE forecast is based on the linear trend line through the historic data that has been adjusted for block loads and transfers as they occur.

The residuals to the linear trend fit through historical data can be used to calculate the Prediction Interval. The Prediction Interval is a statistical estimate of a range in which a future observation will fall. This is based on a Student T test.

The following formula is used by Western Power to calculate its 10POE forecast. Where the probability of X_{n+1} falling in a given interval is then:

$$\Pr\left(\overline{X}_n - T_a S_n\sqrt{1+(1/n)} \le X_{n+1} \le \overline{X}_n + T_a S_n\sqrt{1+(1/n)}\right) = p$$

where T_a is the $100((1 + p)/2)^{th}$ percentile of Student's t-distribution with $n - 1$ degrees of freedom. Therefore the numbers are the endpoints of a 100p% prediction interval for Xn + 1 is

$$\overline{X}_n \pm T_a S_n\sqrt{1+(1/n)}$$

Assumptions

- Distribution of probabilities of exceedance is symmetrical and normal
- Historic data contains the same variability with respect to drivers and coincidence of factors that is likely to occur in the future. These drivers include (but are not limited to) temperature, day of week and time of season.
- 10 POE forecast should incorporate the “risk of uncertainty” e.g. if only a few data points are available then the Prediction Interval is larger.

The difference between 10 and 50 POE demand is calculated as a MW figure, not a ratio or percentage difference. The gap between the 10 and 50 POE forecasts increases gradually over time.

The system level 50 POE forecast is derived by summing the substation 50 POE demand at time of system peak forecasts. The 10 POE system forecast is then calculated by adding this 50 POE bottom-up trend and the variance in the linear fit to the system level historical data.

The impact of new transfers or block loads is not taken into account when calculating the gap between 10 and 50 POE. This would only be significant in the case where a large transfer in or out relative to the size of substation occurred. A future enhancement could be to allocate part of the sending substations 10 to 50 POE gap to the transferred load.

SKM has replicated this approach using Western Power data provided in PoE Calculation Code .xls and Predint.xls, a prediction interval calculation spreadsheet provided by Cornell University (Excel standard statistical functions do not support this calculation directly). The 10, 50 and 90 POE projections produced in this way exactly match the Western Power projections and SKM concludes that Western Power has implemented the methodology correctly.

SKM is concerned that the above approach would not always accurately predict future trends if there had been a run of abnormal temperature years, as has occurred with a number of eastern states distributors whose forecasts SKM has reviewed. For example, if there has been a series of three or more years of mild summers, then this will depress the trend line, resulting in an under forecast of both the 50 POE and 10 POE demands. Similarly if there have been run of above normal temperature summers in recent years, this will increase the slope of the trend line. However SKM acknowledges that this has not affected the data used for the AA3 forecasts which therefore are not skewed.

3.4.1. Typical Industry practice for calculating 10 POE – weather correction

Most, if not all, eastern state distribution and transmission providers explicitly assume that the variability in peak demands between 10, 50 and 90 POE is almost entirely dependent on the maximum daily mean [8] temperature reached on a workday that summer. On non-workdays the reduction in industrial and commercial load eliminates the potential for peak demand at the system level and at many substations.

It is expected that the season's maximum demand will occur on a workday exhibiting a high but not necessarily the highest temperature in a given season – in fact there is generally some lag with demand peaking after two to three high temperature days.

The typical industry approach to forecasting the 10 POE demand, at either system or zone substation level, is to calculate the temperature sensitivity of demand based on the maximum daily demand and daily mean temperature and to adjust the trend data for that temperature sensitivity. This ensures that a recent run of higher than average temperature summers or lower than average temperature summers do not skew the trend line extrapolation. For each summer this produces a temperature sensitivity of MWs demand per degree C relationship. The difference between the 50 POE demand and 10 POE demand is then the difference between 50 POE and 10 POE temperatures

[8] Mean temperature is often calculated as the average of the maximum temperature and the preceding overnight minimum temperature. However, best practice would consider multi day average temperatures as peak demands typically occur after a series of hotter days.

multiplied by the temperature sensitivity. One advantage of this approach is that the 10 POE and 50 POE temperatures can be calculated over a longer historical time period, often 30 years or more, giving greater certainty to the 10 POE value.

A more sophisticated version of this approach simulates each demand profile over 30 years of temperature history, allowing for the error terms in the demand vs temperature equation, which can result in peaks at temperatures other than the peak temperature each year. This approach usually results in higher 10 POE values than the simple approach.

There are various approaches to determine the demand sensitivity to temperature. These are commonly based on either:

1. Simultaneous derivation of time trend and temperature sensitivity coefficients, using daily peak-demand data over a suitable season for a period of years or
2. Deriving a relationship between air-conditioning load and temperature sensitivity. The air-conditioning load will be based on a combination of the number of units and the average demand per unit, both of which are expected to increase over time.

SKM has derived a time-trend plus temperature sensitivity coefficient demand model using data for the period 2004 to 2010 provided by Western Power. Data provided for 2001 to 2003 was rejected as being inconsistent with later data. The "demand" data is understood to be for generation, i.e. demand plus losses, and is approximately 10% higher than demand. The data was filtered to exclude days on which seasonal peaks never occur so it incorporates Tuesdays, Wednesdays and Thursdays when the daily mean temperature was above 20°C for January 16th to the end of March, excluding the Australia Day public holiday on January 26th. Models were also derived with the sample of days restricted to days above 25°C, 28°C and 30°C, to determine whether the temperature sensitivity flattens out at higher temperatures.

The model was derived using linear regression with demand as the dependent variable and three independent variables: date (representing the time trend); daily mean temperature; and date*temperature (representing the potential time trend in temperature sensitivity). The model incorporating these three variables plus a constant is not statistically robust, with t-stats for both date and constant being less than 2. Models excluding either the date variable or the constant are both statistically robust and yield very similar estimates of temperature sensitivity. The results presented below are based on the model with temperature and date*temperature as variables, plus a constant term. The models all have satisfactory t-statistics, indicating strong temperature sensitivity, and R^2 values in the range 0.85 to 0.9.

The temperature sensitivities calculated at 31 January each year are presented in Table 3-4. The models suggest two important aspects of temperature sensitivity:

1. It is increasing over time
2. It decreases at higher temperatures.

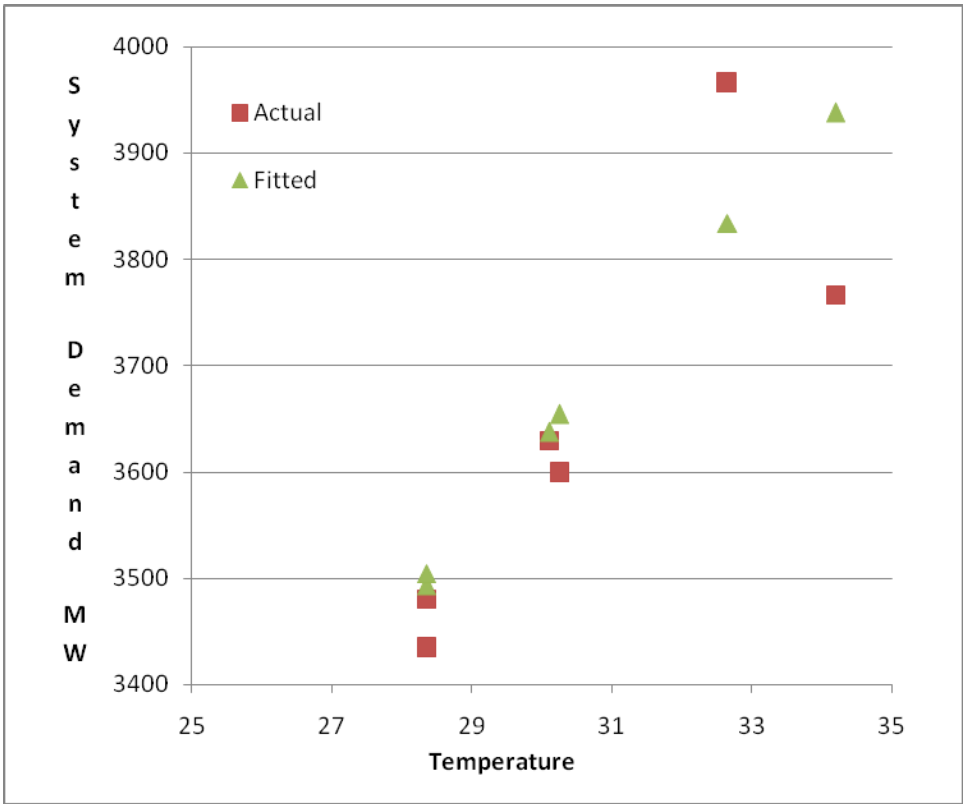
In view of point 2, for the purpose of projecting estimates of peak demand, use of one of the models with the higher temperature thresholds is preferred.

■ **Table 3-4 Demand Temperature Sensitivity**

Year	Temperature Sensitivity MW per °C			
	Days >20°C	Days >25°C	Days >28°C	Days >30°C
2004	82	73	50	53
2005	85	77	54	57
2006	89	81	59	61
2007	93	86	63	65
2008	97	90	68	70
2009	100	94	72	74
2010	104	98	77	78

A chart of the summer 2010 data for the 28^{o} C threshold model is shown in Figure 3-1, which illustrates the actual demand on the six days when the mean temperature was above 28^{o} C and the demand values predicted by the model.

▪ **Figure 3-1 System Daily Maximum Demand vs Mean Temperature 2010**



3.4.2. Comparison of Western Power and Typical Industry approach to 10 POE

In the previous section SKM has derived an MD vs temperature sensitivity model. We can use this in combination with the 10 and 50 POE temperatures for Perth based on historic data to calculate an expected difference, due to temperature variation, between the 10 and 50 POE system maximum demands.

The IMO 2010 SOO states that the 10 POE mean daily temperature for Perth is 34.6°C and the 50 POE temperature is 32.7°C. The temperature difference is 1.9°C. These values, together with the model parameters, can be used to estimate historical and future 10 and 50 POE maximum demands, as explained in Appendix C.

SKM model estimates of 10 and 50 POE maximum demands are compared with Western Power forecasts in Table3-5 below. The absolute values are somewhat confusing owing to the rapid growth in WP projections, offset by the SKM model being based on generation rather than demand. What is notable however is the difference between the 10 POE values and the 50 POE values – gap ranges from 153 MW in 2011 to 201 MW in 2018 for the WP forecast but is consistently about 50 MW higher using the SKM model (which is considered to be immaterial), even though we have used the 28C threshold model which has the lowest temperature sensitivity.

Table3-5 Comparison of 50 POE and 10 POE projections (MW)

	Western Power Forecast			SKM Model Projection		
	50 POE	10 POE	Difference	50 POE	10 POE	Difference
2011	3874	4027	153	3973	4180	208
2012	4173	4332	159	4118	4332	214
2013	4366	4531	165	4263	4483	221
2014	4482	4654	172	4408	4635	227
2015	4643	4822	179	4553	4787	234
2016	4755	4940	185	4698	4939	241
2017	4867	5061	194	4843	5091	248
2018	5015	5216	201	4988	5243	255

The IMO forecasts a difference of 367 MW in 2011 growing to 523 MW in 2018. Details of the IMO temperature sensitivity methodology are not provided in the SOO documentation but comparison with the SKM projections suggests that they are based on considerably higher temperature sensitivities than SKM believes are appropriate.

The Western Power system demands are based on a bottom-up methodology. There is no allowance for substations to have different diversity factors at the time of 10POE system peak than at the 50POE peak. For a 1 in 10 year demand event at system level we may expect a higher coincidence between substations than normally occurs.

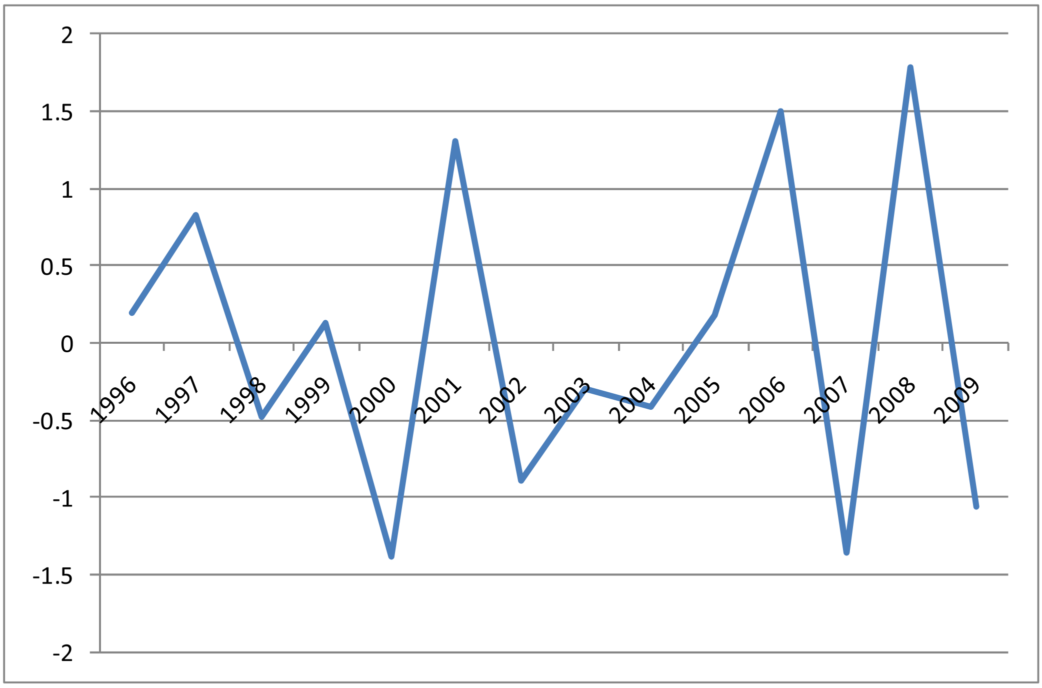
3.4.3. Possible variation to the Western Power approach

The weather correction approach suggests that the temperature sensitivity is increasing over time, most likely due to increasing air-conditioning load, and this leads to an increase in difference between 10 and 50 POE estimates over the historical period as well as the forecast period. The Western Power approach does not reflect this increase over the historical period as it is based on the underlying assumption that the variance in the historical data is constant hence the difference between 10 and 50 POE estimates in any year is due entirely to the relationship of the year to the sample period. For within-sample period years (1996 to 2009) the 10 and 50 POE estimate difference is virtually constant but for forecast years 2010+ the difference grows as the year becomes more distant from the sample period.

The assumption of constant variance, or homoskedasticity, is one that should be tested statistically. Use of ordinary least squares (OLS) estimation on heteroskedastic data where this assumption does not apply leads to incorrect conclusions about variances, even though the parameter estimates will be correct. In the context of the WP forecasts this would mean that the 50 POE forecasts would be correct but the 10 POE forecasts would not be. If for any substation the variance in the data is increasing (decreasing) with time then the difference between 10 POE and 50 POE forecasts will be increasing (decreasing) and the 10 POE forecast based on this will be higher (lower) than the WP forecast. The actual differences will depend on the degree of change in the variances and it is quite likely that different substations will exhibit quite different patterns

Heteroskedasticity can be tested by visually examining the standardised residuals or by using one of a number of statistical tests. The standardised residual plot (Figure 3-2) for the data provided by WP suggests an increasing variability of residuals over time, i.e. it appears that the data may be heteroskedastic.

Figure 3-2 Standardised Residual Plot

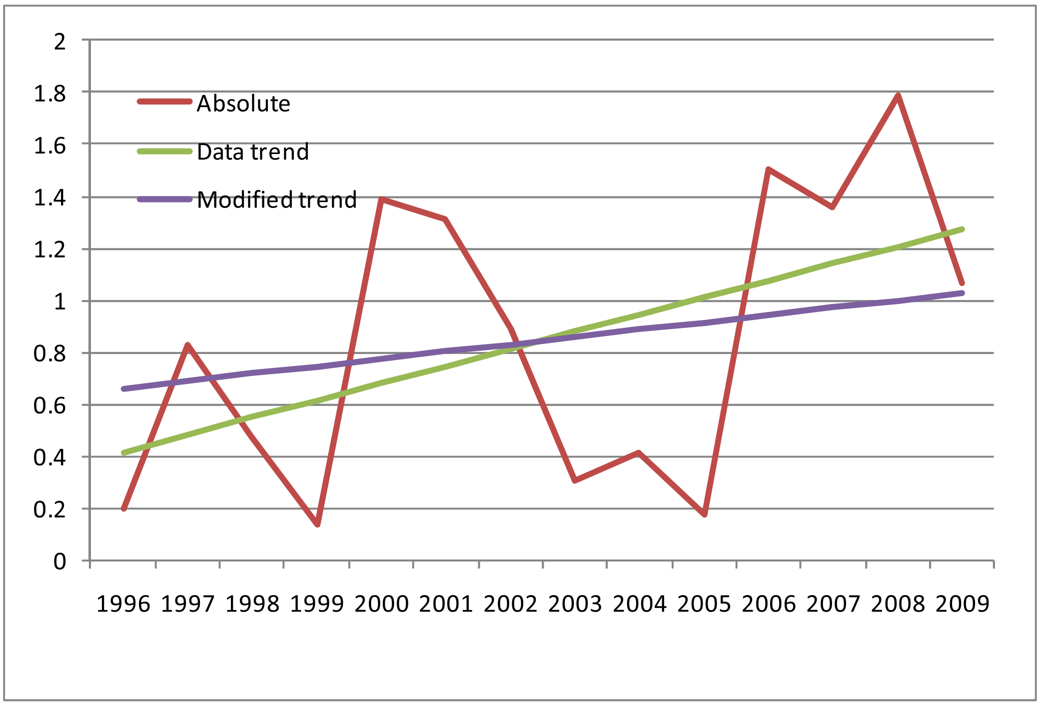


To test for the statistical significance of this increasing trend we have employed the Breusch-Pagan test. This is simply a regression of the residual squared against time, to test the significance of the trend. For this example the R2 is 0.26, F is 4.34 and the p value for F is 0.059 so the trend is not quite significant at the 5% level and heteroskedasticity is not proved conclusively for this substation. SKM acknowledges that Western Power has provided evidence that there is no heteroskedasticity in the system aggregate demand data. However the system forecast was not derived from this data but by aggregation of the substation forecasts and the assessment of heteroskedasticity should take place at the substation level.

The Western Power approach can be adjusted to allow for changes in variance across the historical period. If it is assumed that the variance of demand increases in a linear trend then the regression of demand against time can be replaced by regression of demand÷trend against trend. The variable demand÷trend should have a constant variance. If the prediction intervals are calculated for demand÷trend and then converted back to prediction intervals for demand by multiplying by trend, the prediction intervals will automatically grow in proportion to trend, ie the difference between 10 and 50 POE estimates will grow over the historical period and will grow faster in the forecast period due to the addition of forecasting uncertainty.

SKM has applied this approach to the Western Power data available in PoE Calculation Code .xls, using Predint.xls. The choice of the trend for variance is not straightforward however. Figure 3-3 illustrates the absolute values of the standardised residuals, the trend estimated directly from the data (data trend) and a modified trend calculated to run through the average residuals over the first and last seven years in 1999 and 2006 respectively. SKM believes that the real trend in the residuals is unlikely to be as steep as the data trend and that the modified trend is a better representation.

Figure 3-3 Trends in absolute value standardised residuals



[The outcomes using the modified trend are illustrated below. The differences between the approaches clearly become more significant in the forecast period.

Figure 3-4 Difference between Western Power and SKM estimates of 10 POE and 90 POE, historical period – sample substation

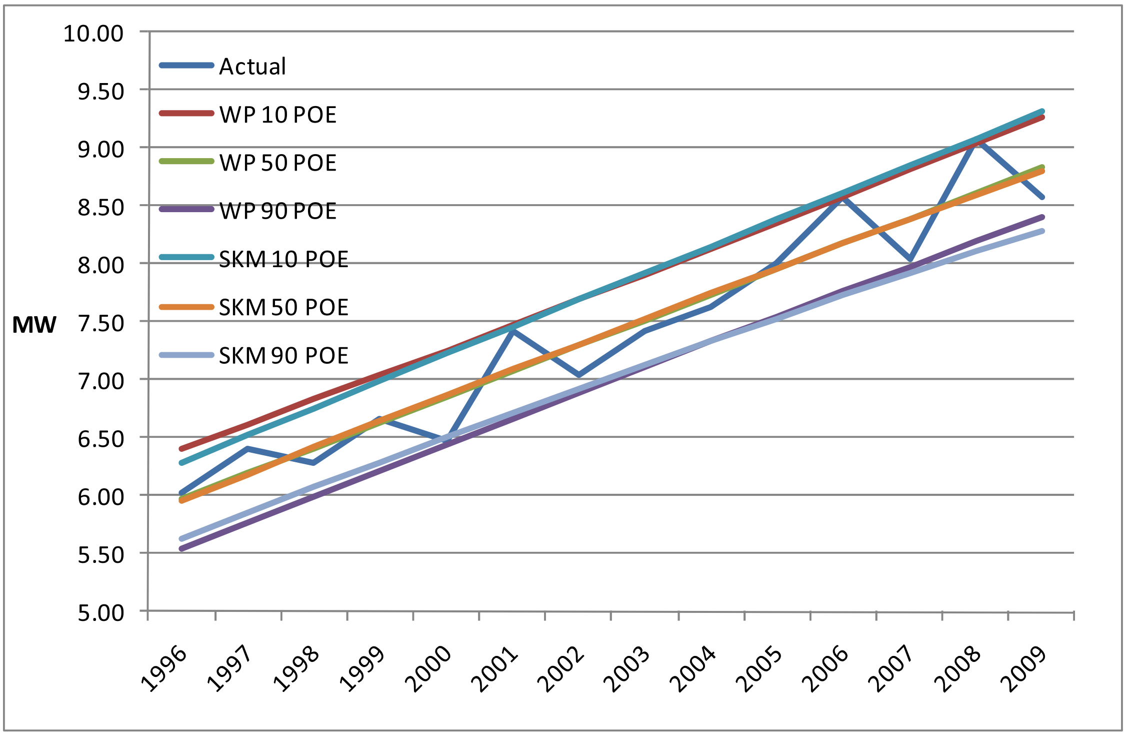


Figure 3-5 Difference between Western Power and SKM estimates of 10 POE and 90 POE, forecast period – sample substation

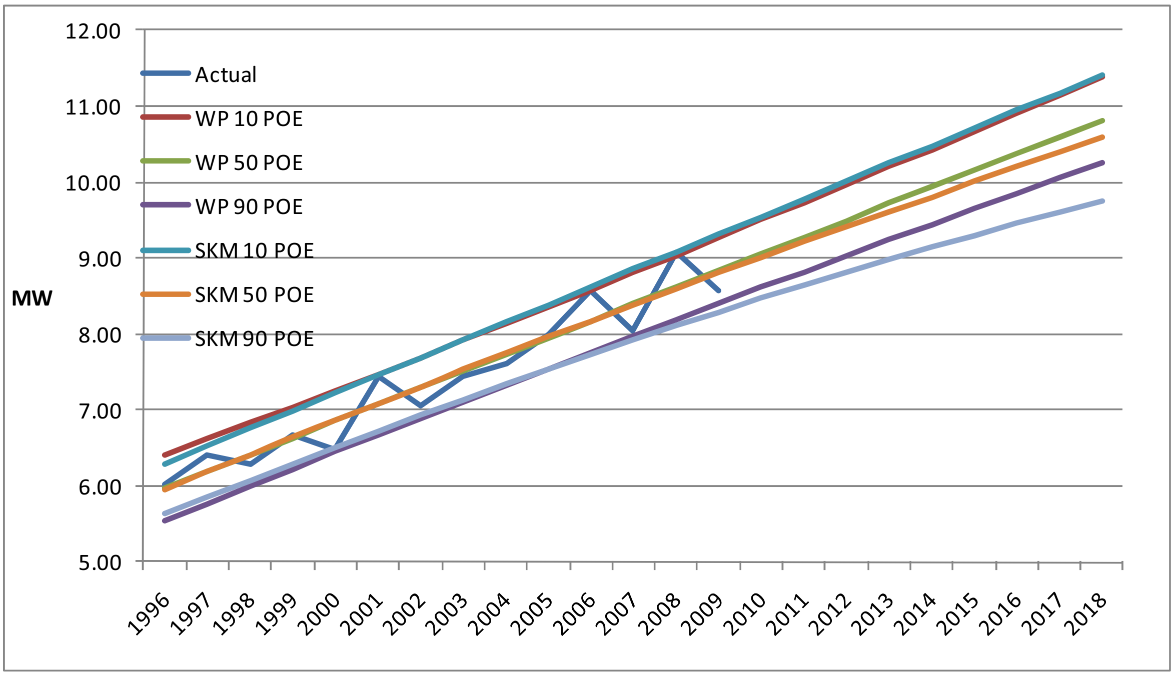
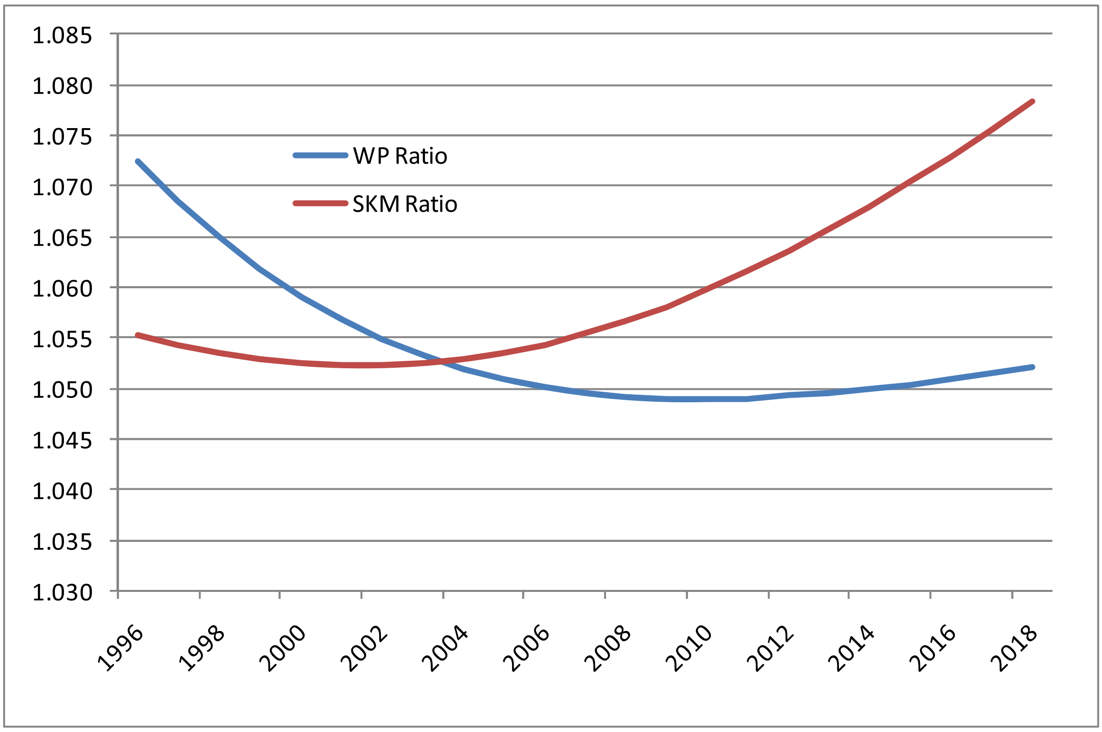


Figure 3-6 Ratio of 10 POE to 50 POE, Western Power and SKM



The ratio of 10 POE to 50 POE demands illustrates that the SKM approach conforms to the expectation that the ratio should grow because of increasing temperature sensitive load, whereas the Western Power approach does not conform to this expectation.

SKM concludes that correction for heteroskedasticity and/or use of the SKM approach outlined above would therefore most likely go some way to reducing the differences between the Western Power and projections based on temperature sensitivity. However, it is recognised that testing and correcting for heteroskedasticity for all substations would be time consuming and potentially difficult to systematise. Given the small 50 MW difference between the WP and SKM weather sensitive model estimates of the difference between 10 POE and 50 POE MDs, and the lack of conclusive evidence for heteroskedasticity in the substation data analysed and in the system MD data, SKM does not recommend that correction for heteroskedasticity be incorporated in the WP methodology at this time. Instead SKM recommends that WP be aware of the differences between their approach and approaches based on weather sensitivity and of the evidence that suggests that WP's 10 POE demand projections may be slightly low.

3.5. Consideration of Drivers

Western Power has considered a series of drivers of maximum demand[9].

- GSP growth has averaged around 4% p.a. historical and independent forecasters (IMO and the Department of Treasury and Finance (DTF)) predict average growth rates of about 4% p.a. for the next 5 years. Population growth forecasts are also similar to the recent historic rates.
- Air-conditioner penetration rose rapidly from the mid 90's until around 2004 from which point the increase in penetration has slowed. Similarly the number of air-conditioners per household is beginning to reach saturation. This does not account for the replacement of old wall units with much larger split-systems or centrally ducted systems leading to increased average diversified maximum demand (ADMD) per unit.
- New connections are expected to occur at a similar rate to the recent history.
- Demand management due to interval meters and smart grid technology is not expected by Western Power to have an impact on the demand forecasts over the review horizon of 5 years. If as part of the regulatory submission Western Power seeks significant expenditure on such programs then some adjustment to the demand forecast would be necessary.
- Electric vehicles are also not expected by Western Power to be a major factor in the next 5 years.
- Temperature has been examined as a driver. Over the last 10 years the maximum demand day has corresponded to the maximum mean temperature day only twice[10]. The summer peak weather over the last 10 years has contained 1 workday above 34.6°C (IMO 10 POE temperature) and 10 workdays above 32.7°C (IMO 50 POE temperature). On this basis recent history does appear to contain a reasonable sample of weather variability. SKM would observe though that such limited correlation between maximum demand day and maximum temperature day does not, in itself, indicate a lack of correlation between electricity demand and temperature.
- Price Elasticity due to rising real prices. Western Power does not expect a significant impact on maximum demand due to rising prices.

SKM has not reviewed these drivers in detail, but does consider it important that Western Power has investigated them and found that in general these drivers are expected to be similar to recent history. On the basis that there are no major changes expected in the maximum drivers it is

---

[9] System Forecasting Input for AA3. Western Power 21/9/2010

[10] As reported by Western Power. However SKM estimates that if weekends and other days when the annual MD never occurs are excluded, this number increases from twice to five times.

considered reasonable to base forecasts on historic demand trends. However, SKM is still of the view that a more complete statistical evaluation of the potential for correlation between demand and temperature should be undertaken as it is SKM's experience that, for example in NSW, where it is accepted that there is a statistically significant correlation between temperature and demand, the maximum demand day does not always fall on the maximum temperature day.

3.6. Conclusion on forecast methodology

SKM has investigated the Western Power maximum demand forecast methodology and reached conclusions summarised in Table 3-6.

Table 3-6 Spatial demand forecasting - Summary

Element	Verdict	Description
Documentation	Good	Western Power documents the approach and assumptions well.
Approach	Good	The approach is well-considered, objective and unbiased. The default procedures are reasonable.
Evidence of application of methodology	Good	See Section 5.
Weather normalisation		WP do not explicitly weather normalize. However they do apply a method that does account for variability. SKM estimates that the WP approach leads to a small understatement of the 10 POE forecast.
Consideration of key drivers and reconciliation between global and spatial forecasts	Fair	WP has considered the key drivers and does not expect any changes from the recent history. WP does not produce a top-down forecast. There is no explicit reconciliation between the IMO system forecast and the WP spatial forecast.
Timely information	Good	The information in the forecasts is updated annually and the regulatory submission will include the most recent 2011 summer period.

There are several elements that we consider to be good industry practice and these appear to be implemented in a consistent and robust manner. The Western Power methodology for capturing historical peak data, adding block loads, tracking transfers and calculating substation trends are all considered to be good practice by SKM. The stages which require forecaster judgement have defined decision processes and any adjustments applied are documented.

The Western Power historical database of previous block load and transfers is a good example of how transmission and distribution service providers should incorporate such data into trend forecasts at the substation level.

The 50 POE forecast demand methodology for substation peak demands and substation demand during system peak is a robust approach and matches good practice.

In terms of network planning and therefore the regulatory submission the most important set of forecasts are the 10 POE substation peak demands. It is on the basis of these forecasts that most of the capital expenditure will occur. Therefore the adjustment from 50 POE to 10 POE substation demand is focused on in Section 3.6.1.

3.6.1. Conclusions on POE approach

The method used to calculate the 10 POE forecast is different to the temperature sensitivity approach typically used by the eastern state distribution and transmission forecasters. The Western Power method incorporates the variability in the historic annual maximum demands, not just the temperature variability. SKM considers that this approach, while implemented correctly, may understate 10 POE demand by approximately 50 MW relative to 50 POE demand at the system level. An alternative approach similar to Western Power's has been considered as a means of resolving this difference. However testing of the alternative is inconclusive and consequently it has not been recommended. Instead Western Power is advised to be aware of the differences between its approach and the more common temperature sensitivity approach and of the potential for slight understatement of the 10 POE demand.

3.6.1.1. POE approach at system level

The WP forecast of system 10 POE is only of interest in terms of comparison with the IMO forecast. This forecast value does not have any associated capital expenditure.

At the system level the WP approach produces a lower increment above 50 POE than the more typical industry approach using a demand vs temperature sensitivity. Our analysis suggests thatt the system level 10 POE forecast from Western Power may be underestimating the potential demand by approximately 50 MW. The same analysis also suggests that the IMO forecast may be overstating 10 POE demand by a greater amount.

3.6.1.2. POE approach at substation level

The Western Power approach to forecasting probability of exceedance is more straightforward at substation level than attempting to calculate demand vs temperature sensitivity for each substation for each year. Many eastern state DNSPs do not attempt to weather correct at substation level due to the unreliability of the correlations for individual substations and the difficulty in accounting for block loads and transfers in the process. However many eastern states DNSPs do reconcile their aggregate substation forecasts with a system forecast incorporating more direct economic and weather sensitivities than their trend based substation forecasts.

Unlike the standard approach, WP has a prediction of the variability for substations where demand is not strongly dependent on temperature. On the basis of our current analysis, the WP POE approach does appear to be at least as robust for substation forecasts as the typical industry practice.

3.7. Areas for Improvement

Given the overall robustness and quality of the Western Power forecasts there are only a few minor areas of improvement to suggest.

To provide overall sensibility checks WP could apply the substation forecast methodology at the Terminal (Bulk Supply Point) and System levels. These would help identify any anomalies between the growth occurring at substation and higher levels.

If transfers above a certain threshold size, say 5 MVA or X% of substation size, occur then an adjustment to the 10 vs 50 POE increment for both the sending and receiving substations should be considered.

From the Western Power methodology it is not clear how they would treat a forecast of substantial changes in key drivers. For the AA3 period this is not a major issue as the drivers are expected to remain similar to the recent past. A process to estimate the impact of driver changes at system level and then incorporate the impact into substation forecasts may be necessary in the future when factors such as carbon price, smart grid demand management and electric vehicles could have a rapid impact on demand.

To date no comparison of the demand and energy forecasts has been undertaken. This is considered to be an essential check on the consistency of these related forecasts. It is understood that the energy forecast is being prepared externally and will be available in the near future.

4. Input Data

4.1. Data Requirements

Key data for the routine summer and winter substation demand forecasts and the resulting system wide forecasts are:

- Historical demand peaks at each substation both at time of substation peak and also at time of SWIS peak;
- Block load enquiries and applications for supply
- Historic transfers and proposed future transfers between substations.

In addition to the routine forecasts, the Forecasting Section also produces Feeder Load Development Reports and Area Load Development Reports on an ad hoc, as required basis, for the system planners. The results of these studies influence the growth rates applied to the routine system wide forecasts. These studies utilise the data described above, in addition to other data such as:

- LGA zoning and assumed load density;
- Development proposals - Department of Planning;
- Population forecasts;
- Other sources of growth.

4.2. Data Sources and Systems

System Forecasting software is grouped under a WP ACCESS database application known as ForeSite. Within ForeSite, the data input packages of most application to the routine forecasts are:

- Pi Peaks - collects actual demand data (averaged over 5 minute intervals) from Western Power's SCADA system;
- TOPAZ - consolidation of all known developments representing a load of above approximately 500kVA.

Information from PiPeaks and TOPAZ are input into the forecasting application (referred to as OPAL) within the ForeSite system.

The other data mentioned above in Section 4.1, is captured in a less formalised manner and fed into the forecasting tool by the forecasting analysts.

The package is well integrated. There will always be a requirement for human intervention at key decision points, so a completely automated data flow is not feasible. There remain some points of data transfer from package to package where the transfer remains manual which creates some risk of human error. The ForeSite system is still under-going development and these points of data transfer are being addressed.

Despite these qualifications, the ForeSite system is perhaps the best integrated demand forecasting package that SKM has encountered in its work with other utilities.

4.3. Processing of Data

4.3.1. Capturing of historic peaks

PiPeaks presents a load chart for the full period under review (summer or winter months) highlighting the ten peak demand days. At the end of each peak demand season the 5 minute data is analysed to determine the peak demand on each substation. The daily profiles with the 10 maximum demands are plotted and examined to check that the profile does not contain any anomalies such as temporary load switching or bad SCADA data reads.

The output from this process is the historical seasonal peak for the substation and the actual contribution of each substation to the system-wide peak. The time of system peak is derived from summated generation load data. There is no check of each substation profile for the system peak day to confirm that no temporary switching was occurring during the system peak.

The analysis undertaken in PiPeak is presented as the "Transmission Load & Circuit Report" for the season.

4.3.2. Blocks Loads, historic and future

TOPAZ is an ACCESS database in which data on potential new loads is collected from various sources. A primary source is WP's Distribution Quote Management (DQM) which contains all approaches received regarding supply enquiries and applications. However, other sources include media reports, direct contact with major customers and developers, plus information from government departments, Local Government Authorities etc.

Included in the entered data for each potential new load, are details of the substation impacted, feeder name, load size, timing and staging. A diversity factor is also allocated to the load in this process. The size assumed is based on the Western Power estimate of power required and not that of the proponent who sometimes over-estimate their requirements.

At the moment a single number diversity is applied for each load type, however, this is reviewed again by the forecast analyst in the forecasting application. In the 2011 forecasts Western Power plans to utilise a diversity factor matrix that compares the block load type with the substation type to determine the appropriate diversity factor. The values in the matrix have been derived by comparing substation and large customer load profiles for all substations and large customers with period metering.

Block loads that are individually below the threshold for inclusion in a substation forecast (usually 1 MVA) are tracked so that if there are several small block loads occurring in the same year that information is available to the forecaster. They can then determine whether those block loads are part of the underlying trend growth or if some or all of the expected demand is considered additional.

Historic block loads are also included in the database. For those block loads with interval meters Western Power has measured the actual maximum demand and diversity.

4.4. Conclusions

SKM has reached the following conclusions:

- Data sources are suitable;
- Software systems are structured to manage the retrieval, processing and auditing of data;
- Some manual points of data transfer remain;
- Availability of accurate historical data for block loads and transfers is important.

5. Review of Demand Forecast

SKM MMA has reviewed the methodology and inputs in the previous chapters. In this chapter we spot check two substations to see if the procedures have been followed and if the forecasts are reasonable. For this check we have selected Albany and Malaga.

5.1. Albany

There is 15 years of historic data available for Albany starting with 26.8 MVA demand in 1996, reaching 42.5 MVA in 2010.

Albany had transfer out in 2002 and block loads added each year from 2009 to 2013. There is a plan to upgrade the capacity in 2012.

5.1.1. Forecast Trend

When the historic transfer and block loads are accounted for the correlation for linear growth has R^2=0.97. SKM has used the Western Power inputs and reproduced the calculations. We forecast a very similar outcome.

5.1.2. Impact of Transfers and Block Loads

The 2002 transfer out of 5.5 MW at substation level has a growth rate of 2%, which is a linear rate of 0.11 MW. However the growth rate at system peak is 4.6% on a 4.785 MW load. It is not clear why the growth rate of the transfer is different relative to the time of substation peak and the time of system peak.

The timing of the substation capacity increase currently due in 2012 is sensitive to the timing and accuracy of the 2011 and 2012 block loads. These two block loads represent about 4-5 years worth of trend growth and so advance the timing of the substation needing new capacity by several years.

5.1.3. Conclusion on Albany Forecast

Overall the substation forecast does seem reasonable. The long-term underlying trend growth of 1.43 MVA per year is based on a very good fit to the adjusted historic data. Demand growth in the short term is driven by the addition of new block loads in 2011 and 2012.

Our understanding is that before the substation augmentation is committed, a further review of the forecast will occur that will reconfirm the timing and size of these block loads. Depending on the cost of the augmentation Western Power may require a connection contract signed with the block load proponent before investing in the substation upgrade.

5.2. Malaga

Malaga is one of the faster growing substations in the Western Power network. The earliest historic data is from 2000 when the peak demand was 25.5 MVA. Over the historic period the power factor has improved due to the addition of capacitor compensation in 2006.

5.2.1. Forecast Trend

The fit to the historic data with the impact of transfers and block loads accounted for is very good. The forecast growth rate of 2.3 MVA per year is similar to the independent SKM calculation. The trend only including data from 2005 onwards is only marginally different.

5.2.2. Block loads and transfers

Historically a block load retirement in 2002 and addition in 2004 have been assumed based on the changes in both substation peak demand and substation demand at time of system peak. The estimate of the size of these block loads seem reasonable. The historic load transfers also appear to be handled correctly, although we do note that the transfer out has a much higher growth rate than the transfer in. About 8 MW of new block load is expected to be added over 2011 and 2012. We are advised that Metro West data centre and Metro West data centre is the same project that is staged over 2 years and not a single 4.05 MW project that has been entered twice. This new load advances the timing of the additional transformer in 2011 by around a year or two.

5.2.3. Malaga Summary

While the 2002 and 2004 block load size assumptions appear to be based on the change in demand growth rather than explicit customer data, the forecast growth rate appears reasonable based on the recent history. The forecast methodology described in Section 3 has been implemented correctly. The growth in the early forecast years is dominated by the 8 MW of block load added so the short term forecast's accuracy is dependent on the accuracy of the timing and size of these two block loads. SKM has previously noted in Section 4.3.2 that the Western Power approach to capturing block load data is good practice.

5.3. Comparison of Predicted and Actual Demands

The Western Power forecasting team compared predicted and actual peak annual substation demands for a range of substations for the summer periods of 2008/9 and 2009/10. This involved 253 records.

The results of this comparison showed that 33 of the actual demands recorded exceeded the 10POE demand forecasts for the relevant substations. This is slightly higher than the expected 10% of observations of 26.

5.4. Conclusion on Substation Forecasts

Based on our two snapshot reviews Western Power appears to correctly apply the methodologies described in Section 3. The underlying trend growths derived are reasonable and have low sensitivity to the inclusion or exclusion of early years. We note that the timing of substation upgrades is sensitive to the addition of block loads in the near future. We understand that the timing and size of block loads are reviewed when decisions are made regarding investment in substation upgrades.

6. Reconciliation with IMO Forecast

6.1. IMO Statement of Opportunities

The Independent Market Operator (IMO) in Western Australia publishes a Statement of Opportunities Report (SOO) on an annual basis[11].

The SOO provides information to current and potential participants in the Wholesale Electricity Market, relating particularly to generation investment opportunities. An integral part of the SOO is a forecast of peak demand and electricity consumption for the SWIS. Although the focus for IMO is on the early years of the forecast period, the included forecasts extend for ten years to 2020/21.

6.2. IMO Demand Forecast

The Demand Forecasts included in the SOO are prepared for IMO by the National Institute of Economic and Industry Research (NIEIR). The NIEIR forecast is provided for the SWIS system. It is a top-down econometric forecast employing a range of inputs including forecasts of national economic growth, Gross State Product (GSP), projections of population growth, dwelling stock increases, penetration of specific appliances and industry growth. The impact of temperature on demand is also modelled. Three temperature conditions are included for peak summer day temperatures that might be exceeded once in ten years (10POE), once in every two years (50POE) and nine times in every ten year period (90POE).[12] This definition is not the same as that used in section 3.3.1 as it does not refer to exceedance by the maximum annual temperature but by the maximum daily temperature. The implications of this are discussed in section 3.3.1.

NIEIR also provide forecasts for High, Expected and Low economic growth conditions.

The primary forecast applied by IMO is the 10POE forecast under Expected economic growth conditions.

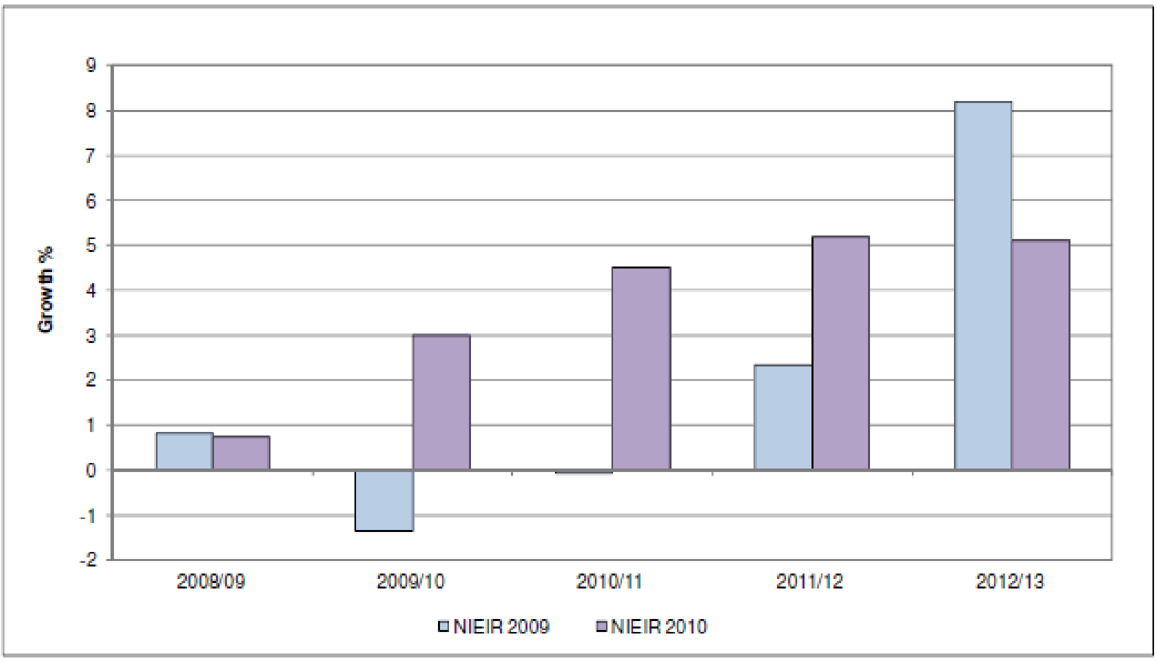
The detail of the NIEIR model is not included in the SOO, so no comment can be provided regarding the correlations used in the model or the impact of the various input parameters on the forecast demands produced.

It is noted that NIEIR has revised their forecasts for the West Australian economic growth since the 2009 IMO forecast was prepared. Forecast growth rates are significantly higher than were forecast in 2009. The changes between the 2009 and 2010 NIEIR demand forecasts do not appear to

[11] Statement of Opportunities Report – Independent Market Operator (July 2010)
[12] 10POE – indicates a 10% Probability of Exceedance

coincide with the changes in forecast economic growth and demonstrate the difficulty in attempting to comment on forecasts provided.

- **Table 6-1 Comparison of NIEIR 2009 and 2010 WA Economic Growth Forecasts[13]**



The movement in demand forecast between the NIEIR 2009 and 2010 forecasts are shown in the Table below.

- **Table 6-2 Variation between NIEIR 2009 and 2010 Demand Forecasts[14]**

Year	2009 10POE Forecast (MW)	2010 10POE Forecast (MW)	Variation
2010/11	4397	4346	-51
2011/12	4725	4793	68
2012/13	5132	4986	-146

The NIEIR forecasts also include several new block loads that have been identified by IMO with sufficient certainty to be included in the demand forecasts. Changes in the IMO treatment of these block loads may account for some of the disconnect between NIEIR's revised economic growth forecasts and demand forecasts suggested by the comparison of these forecasts.

[13] Source – Statement of Opportunities, Independent Market Operator (July 2010) Figure 17
[14] Source – SOO, IMO (July 2010) Table 2

6.3. Comparison of Forecasts

Western Power does not prepare an econometric top-down demand forecast. So there is a fundamental difference in the basis of the Western Power and IMO demand forecasts.

On initial review, the Western Power system demand forecast appears to be significantly lower than the comparative forecast from IMO. This is a relatively unusual situation. Typically, electrical utilities are perceived to have a tendency to forecast higher than more independent bodies.

WP needs to consider their corporate stance in this instance. The Corporation may wish to reconsider their forecasts and associated capex plans to investigate whether there are other benefits to the business in moving their forecast more closely to the published IMO forecast. This section is written assuming that the current forecast remains WP's preferred position.

While it is beneficial to compare the results of forecasts generated by two quite different approaches to provide a level of confidence in the forecasts, it is important to understand the differences in approach and the impact that these may have on the generated results.

The Western Power approach does not attempt to model the relationship between demand and economic inputs. The approach assumes that the full ranges of variations in all drivers are captured in the historical series of data and also assumes that variations in the major drivers in future will not be substantially different from the variations experienced historically.

IMO produces forecasts for three economic growth scenarios – low, expected and high growth. WP produces a Central and a High growth forecast, however, the same base growth is used in both forecasts. The high growth forecast takes a more optimistic view about the probability of new block loads being connected.

Apart from this fundamental difference, there are other differences which need to be considered. These are discussed briefly in the following subsections.

6.3.1. Demands being forecast

IMO forecasts the demand sent-out from generating stations. The Western Power forecast is of the load demand presented at WP substations. All system losses are captured in the metered demands at the generation stations but losses incurred in the transmission and sub-transmission systems are not included in the WP forecast. This difference could account for up to 5% of the forecast demand.

6.3.2. Treatment of Block Loads

Western Power and the IMO have different assessments of the probable impact of potential block loads:

- Generally both parties consider the same set of potential projects although there are some differences;
- WP and IMO hold different views on the probability or timing of some of these developments. The IMO Expected growth scenario is closer to Western Power's High growth scenario – IMO is more optimistic about the timing of these major developments;
- Application of diversified loads – WP considers diversification of block loads while IMO assumes that the new loads peak is coincident with the existing system peak.

The block loads included in the Western Power forecast are shown in the table below.

Table 6-3 Western Power's Assessment of Major Block Loads (Diversified)

Projects	Central Forecast		High forecast	
	Year	MW	Year	MW
Port and Pumping facilities for Grange Resources -SDN	-	-	2015	20
Southern Seawater Desal Plant - Stage 1 & 2	2011	16	2011	31
	2012	15	2016	31
	2018	31	-	-
Simcoa 3rd & 4th furnace expansion project	2012	24.3	2012	24.3
	-	-	2016	24.3
Asia Iron Ltd's. - Extension Hill Mine Site	-	-	2014	112.5
Gindalbie Stage 1.1	2012	86	2012	86
Gindalbie Stage 1.2	2013	23	2013	23
Gindalbie Stage 2.1	-	-	2014	27
Gindalbie Stage 2.2	-	-	2015	45
Gindalbie Stage 2.3	-	-	2017	45
Gindalbie Stage 2.4	-	-	2018	45
Port of Oakajee Stage 1	2014	27	2014	27
Port of Oakajee Stage 2	-	-	2018	15
Oakajee Industrial Estate Heavy (Smelter)	-	-	2017	28
	-	-	2018	30
Grange Resources mine	-	-	2015	160

The set of block loads included in the IMO forecast and their potential impact are shown in Table 6-4 below.

- **Table 6-4 IMO's Assessment of Major Block Loads (Non-Diversified)**[15]

Projects	Low		Central		High	
	Year	MW	Year	MW	Year	MW
Southern Seawater Desal Plant - Stage 1 & 2 & 3	2012	21	2012	21	2012	21
	2020	44	2016	44	2016	44
	-	-	-	-	2020	67
Simcoa 3rd & 4th furnace expansion project	2011	12	2011	22	2011	22
	-	-	-	-	2019	44
Asia Iron Ltd's. - Extension Hill Mine Site	2014	100	2014	140	2014	140
Gindalbie Stage 1.1	2012	85	2012	95	2012	95
Gindalbie Stage 1.2	2014	100	2014	120	2014	120
Gindalbie Stage 2.1	-	-	-	-	2016	170
Gindalbie Stage 2.2	-	-	-	-	2017	220
Port of Oakajee Stage 1	2014	20	2014	30	2014	35
Grange Resources mine Stage 1	2015	60	2015	80	2014	80
Grange Resources mine Stage 2	-	-	-	-	2018	100

The resulting contributions of these block loads to the relevant forecasts are discussed further in 6.4.2 below.

Western power has taken a more conservative approach to the probability of major new load proceeding than has IMO. As noted above, the Western Power high growth scenario forecasts are more comparable with the IMO Central growth scenario. The intention is to treat the potential loads that have not been included in the planning forecast as contingency projects. Under this approach, capital funds would be available if and when the project actually proceeded.

6.3.3. 10POE Adjustment

The different approaches taken by WP and IMO in forecasting the 10POE loads have been discussed previously in Section 3.4.

---

[15] Data provided to SKM by Western Power's forecasting team

6.4. Reconciliation of Forecasts

The raw forecasts from Western Power and IMO are summarised in the tables below.

- **Table 6-5 Comparison of WP Central and IMO Expected Demand Forecasts (MW)**

Year	IMO Expected 10POE	IMO Expected 50POE	WP Central 10POE	WP Central 50POE
2010/11	4346	3979	4027	3874
2011/12	4793	4401	4332	4173
2012/13	4986	4569	4531	4366
2013/14	5370	4928	4654	4482
2014/15	5601	5140	4822	4643
2015/16	5767	5288	4940	4755
2016/17	5955	5453	5061	4867
2017/18	6168	5645	5216	5015
2018/19	6343	5799	5329	5120
2019/20	6517	5951	5454	5236

- **Table 6-6 Comparison of WP and IMO High Growth Demand Forecasts (MW)**

Year	IMO High 10POE	IMO High 50POE	WP High 10POE	WP High 50POE
2010/11	4440	4071	4065	3911
2011/12	4883	4488	4354	4194
2012/13	5097	4676	4598	4433
2013/14	5598	5151	4884	4712
2014/15	5745	5278	5302	5124
2015/16	6057	5570	5490	5304
2016/17	6325	5816	5705	5512
2017/18	6567	6036	5931	5730
2018/19	6791	6238	6048	5839
2019/20	7033	6457	6176	5958

The following discussion of the differences between the WP and IMO forecasts will focus on a comparison of the Expected/Central growth scenarios.

Table 6-7 Summary of the apparent differences between the WP Central and IMO Expected growth forecasts (MW)

Year	10POE	50POE
2010/11	-319	-105
2011/12	-461	-228
2012/13	-455	-203
2013/14	-716	-446
2014/15	-779	-497
2015/16	-827	-533
2016/17	-894	-586
2017/18	-952	-630
2018/19	-1014	-679
2019/20	-1063	-715

At this level of analysis, the Western Power forecast appears to be significantly below the forecast prepared for IMO.

6.4.1. Demands being forecast

The impact of including system losses in the Western Power forecast would be to increase the forecast by amounts to represent the system losses that are unaccounted for in WP's forecast.

If the losses were equal to 5%, then the apparent differences shown in Table 6-7, would reduce to those shown in the table below.

Table 6-8 Differences between the WP Central and IMO Expected growth forecasts (MW) after Losses have been considered

Year	10POE	50POE
2010/11	-118	89
2011/12	-244	-19
2012/13	-228	15
2013/14	-483	-222
2014/15	-538	-265
2015/16	-580	-295
2016/17	-641	-343
2017/18	-691	-379
2018/19	-748	-423
2019/20	-790	-453

The Western Power forecast remains below the IMO forecast in most years of the forecast.

6.4.2. Treatment of Block Loads

As discussed above in Section 6.3.2, there are more new loads included in IMO's forecast than in the Western Power forecast and some difference in the timing of common loads.

Table 6-9 below summarises the block loads included in the relevant forecasts.

Table 6-9 Comparison of Block Loads included in the Forecasts (MW)

Year	IMO Allowance	WP Allowance	Difference
2010/11	22	16	-6
2011/12	138	141.3	3.3
2012/13	138	164.3	26.3
2013/14	428	191.3	-236.7
2014/15	508	191.3	-316.7
2015/16	552	191.3	-360.7
2016/17	552	191.3	-360.7
2017/18	552	222.3	-329.7
2018/19	552	222.3	-329.7
2019/20	552	222.3	-329.7

It is noted that the block loads applied within the Western Power forecast are included as a diversified load, firstly at the substation level and secondly, with additional diversification between substation and system peaks. The IMO forecast appears to apply the full expected peak load of each new block load without any diversification. This will have a relatively minor impact on the load forecast – for example, if the average co-incidence factor for these major new loads was 90%, its application would reduce the contribution of these loads to the IMO forecast by 55MW in 2015/16.

These two areas of difference (losses and the treatment of block loads) account for much of the difference between the 50POE forecasts from IMO and WP.

Table 6-10 Remaining differences after accounting for losses and the difference expectations regarding block loads (MW)

Year	10POE	50POE
2010/11	-112	95
2011/12	-248	-23
2012/13	-255	-11
2013/14	-247	15
2014/15	-221	52
2015/16	-219	65
2016/17	-280	18
2017/18	-362	-50
2018/19	-418	-93
2019/20	-461	-124

The net differences shown between the 50POE forecasts range from -2.4% to +2.4% of the Western Power system forecast.

6.4.3. 10POE Adjustment

The different approaches taken between NIEIR and Western Power to generate the 10POE forecast from the 50POE forecast has been discussed previously – refer to Section 3.4. Our general conclusion based on construction of an independent temperature sensitivity model is that WPs projection understates the difference by approximately 50 MW and consequently we conclude that NIEIR overstates it by a greater amount. Lack of detail on the NIEIR approach prevents us from determining the causes of this but use of temperature sensitivity inappropriate to peak demand is the most likely factor.

Accounting for losses has a small impact on the apparent difference in this adjustment factor – this is summarised in table below.

Table 6-11 Difference in the allowances provided to move from 50POE to 10POE (MW)

Year	NIEIR Allowance	WP Allowance	Difference
2010/11	367	161	-206
2011/12	392	167	-225
2012/13	417	173	-244
2013/14	442	181	-261
2014/15	461	188	-273
2015/16	479	194	-285
2016/17	502	204	-298
2017/18	523	211	-312
2018/19	544	219	-325
2019/20	566	229	-337

If the 10POE forecasts are adjusted by the difference in this approach, the resulting variation between the two 10POE forecasts reduces to the differences shown between the 50POE forecasts in

Table 6-10. As noted above these net differences range from -2.4% to +2.4% of the Western Power system forecast.

6.4.4. Conclusions

The following conclusions can be reached:

- Western Power understands the differences between its own forecast and the forecasts prepared for IMO;
- On an initial review, the Western Power forecast appears to be well below the IMO forecast;
- When losses on the electrical system and the different treatment of block loads are considered, the two 50POE forecasts become much more comparable;
- The remaining differences between the two 10POE forecasts are partly explained by the different approaches adopted to move from the 50POE forecast to the 10POE forecast but there is evidence to suggest that IMO's 10POE forecast is overstated.

7. Conclusions

SKM MMA's conclusions are summarised in this section of the report.

SKM MMA generally concludes that the forecasting approach adopted and practiced within Western Power is comparable with good industry practice throughout Australia. The demand forecasts prepared for the AA3 submission are considered to be technically sound and are expected to be as accurate as might reasonably be expected.

7.1. Organisational Structure

The Forecasting Section within the Network Planning and Development Branch is independent of the System Planning function which removes any perception that forecast outputs might be influenced by network growth plans.

7.2. Forecasting Methodology

The Western Power forecasts are generated by statistical analysis and extrapolation of historic load data adjusted for transfers, block loads etc. This approach is considered to be technically sound.

Western Power does not explicitly weather correct historical input data to generate the 50POE demand forecast. Western Power assumes that the full variability of weather (and other variables affecting demand) is reflected in the historical series and therefore captured in the extrapolated forecast. SKM MMA believes that this assumption is valid for the historical series currently used to generate the demand forecasts. However, if a series of higher than average temperature summers or lower than average temperature summers were to occur, this could skew the trend line extrapolation.

The typical industry approach to forecasting the 10 POE demand, at either system or zone substation level, is to calculate the temperature sensitivity of demand based on the maximum daily demand and daily mean temperature and to adjust the trend data for that temperature sensitivity. Western Power generates the 10POE forecast based on a statistical analysis of the historic series and calculation of a Prediction Interval. SKM MMA's analysis suggests that the difference in outcome from application of these two approaches is approximately 50MW in a base forecast of 4000MW, which is considered not significant.

Western Power does not generate an econometric forecast but does compare their system forecast with the econometric forecast published by the IMO. Western power does prepare an alternate high economic growth scenario demand forecast which uses the same underlying growth trend as the base forecast, but with more optimistic assumptions regarding future block load development.

It is not clear from the Western Power methodology how it would accommodate a forecast of substantial change in key demand drivers. This is more likely to be an issue for longer term forecasts rather than for the five year AA3 period.

To date no comparison of the demand and energy forecasts has been undertaken. This is considered to be an essential check on the consistency of these related forecasts.

7.3. Application of Methodology

A sample review of substation forecasts indicated to SKM MMA that the methodology is being applied consistently and that the forecasts are robust and repeatable.

7.4. Processing of Input Data

The integrated suite of forecasting software used by Western Power is considered to be one of the best that SKM MMA has reviewed.

The capture and processing of historic demands follows a well established procedure. There will always be a requirement for human intervention in this process provides sound rules and tools to assist. This process identifies any anomalies such as temporary switching or erroneous SCADA data.

Historic block loads are captured and excluded from the historic data used in the analysis and trending.

Potential new block loads are collected from various sources and allocated to substations and feeders with details of load size, expected diversity, timing and staging.

SKM MMA believes that the treatment of load transfers and block loads in the forecast process is consistent with good industry practice.

7.5. Reconciliation with IMO Forecast

IMO publishes a system demand forecast as part of the Statement of Opportunities. This forecast is an econometric forecast produced for IMO by the National Institute of Economic and Industry Research (NIEIR).

On initial review, the Western Power forecast appears to be well below the IMO forecast. On further analysis, much of the apparent difference can be explained by factoring in network losses and the different treatments of block loads. The IMO forecast is a forecast of generation requirements and includes losses on the transmission network, while the WP forecast is a summation of substation forecasts and excludes upstream network losses. The IMO forecast also includes a more optimistic view on the connection of new loads. After accounting for these factors, the net difference between the two 50POE forecasts range from -2.4% to +2.4%. This is considered to be not significant.

The differences between the WP and IMO 10POE forecasts appear to be generated by the different methodologies adopted. As indicated earlier, Western Power does not explicitly apply a temperature sensitivity to develop the 10POE. It is understood that NIEIR apply a form of weather correction but the details are not known. SKM MMA undertook an independent assessment of the impact of a “temperature sensitivity” approach. The SKM MMA forecast of the difference between the 50POE and 10POE forecast was within 50 MW of the Western Power forecast. This would suggest that the IMO forecast overstates the temperature dependence of the system load.

Appendix A Documentation Reviewed

The following documents were reviewed:

- Independent Market Operator – Statement of Opportunities Report (July 2010);
- System Forecasting Section Operating Manual DM#: 6296884 QM-REV 2 (01/07/2010)
- Opal User's Companion Version 1.2.2 – Western Power April 2009
- Summer Load Trends Report 2011 to 2030 –Western Power DM# 7387027 (August 2010)
- Draft System Forecasting Input for AA3 – Western Power DM#7449515 (September 2010)

Appendix B List of Interviewees

The following Western Power staff members were interviewed:

Name	Role
Raphael Ozsvath	System Forecasting Manager
Steven Disano	Forecasting Analyst
Veronica Whittleston	Data Analyst
Sevi Rich	Data Analyst
Steve Claridge	Forecasting Analyst
Jason Morrison	Software Developer
Mark McKinnon	Revenue and Pricing Manager

Appendix C Estimating 10 and 50 POE maximum demand using a linear model

1. For the purposes of estimating 10 and 50 POE maximum demand it is assumed that demand is a linear function of a temperature variable.

   $D = a + b * T + e$

   Here D is peak daily demand, T is a relevant temperature variable, a and b are regression parameters and e is the error term. It is critical to the success of the methodology that the error at high temperatures should be purely random i.e. that the equation should be unbiased at high temperatures.

2. Estimate the peak seasonal value of T for a range of seasons eg all winters/summers from 1977 to 2007, to get a sample of peak values.

3. From the sample of peak values, estimate the 50 PoE value of T, denoted T_{50}

4. Assume that

   a. The distribution of peak temperature values is normal, $N(T_{50}, \sigma_1)$ and

   b. The model error term e is normal, with mean 0 and variance σ_2^2, denoted $N(0,\sigma_2)$

5. Then

   $D = a + b * T_{50} + f$

   Where f is a new error term with a normal distribution $N(0, \sigma_3)$

   with $\sigma_3^2 = b^2 \sigma_1^2 + \sigma_2^2$. This follows from the rules for adding normal distributions.

   Then the percentiles of D can be calculated using the appropriate parameters for percentiles of the normal distribution:

$D_x = a + b * T_{50} + k_x * \sigma_3$

x	kx
97.5%	-1.96
95%	-1.645
90%	-1.2815
50%	0
10%	1.2815
5%	1.645
2.5%	1.96

For example:

$D_{50} = a + b * T_{50}$ as may be expected.

However $D_{10} = a + b * T_{50} + 1.2815 * \sigma_3$, which can be shown to be greater than $a + b * T_{10}$

Appendix D Summary of Australian Demand Forecasting Approaches

SKM | MMA

		South Australia		Victoria											
		ETSA Utilities		Citipower		Powercor		Jemena		SP AusNet		United Energy			
		Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment		
System Level															
1.	Is system wide MD forecast externally prepared or reviewed?		Not stated	Y	NIEIR, Victorian wide	Y	NIEIR, Victorian wide	Y	NIEIR, Victorian wide	Y	NIEIR, Victorian wide	Y	NIEIR, Victorian wide		
2.	What are the underpinning methodologies used in the system wide MD forecast? (Trend Analysis/Population Forecasts/ End Use Energy Analysis/Customer Category Forecasts/Macroeconomic Indicators/etc)		Not stated	Y	Econometiric model based on industry O/P, Electricity prices and ambient temperature .	Y	Econometiric model based on industry O/P, Electricity prices and ambient temperature.	Y	Econometiric model based on industry O/P, Electricity prices and ambient temperature.	Y	Econometiric model based on industry O/P, Electricity prices and ambient temperature .	Y	Econometiric model based on industry O/P, Electricity prices and ambient temperature.		
3.	What is the period of the system wide MD Forecast? (5yr/10yr?)		Not stated		Not Stated		Not Stated		Not Stated		Not Stated		Not Stated		
4.	Is the system wide MD forecast supported by energy consumption & customer growth forecasts?	Y	Included the govt initiated or supported (i.e. SA water & Defence)		Not Stated		Not Stated		Not Stated		Not Stated		Not Stated		
5.	Are 10%, 50% & 90% PoE MD forecasts produced or high/medium/low forecasts?	Y	High/Moderate/Low	Y	10%, 50% & 90%	Y	10%, 50% & 90%	Y	10%, 50% & 90%	Y	10%, 50% & 90%	Y	10%, 50% & 90%		
6.	Are historical system MD's weather corrected or are abnormal MD's adjusted in another way?	Y	Weather corrected based on extreme hot days		Not Stated		Not Stated		Not Stated		Not Stated	Y	Not Stated		
Bulk Supply and Zone Substation Demand Forecasts															
9.	Are Bulk Supply & Zone Substation Forecasts externally prepared or reviewed?		Not stated		Not Stated		Not Stated		Not Stated		Not Stated		Not Stated		

		Tasmania		New South Wales & ACT							
		Aurora		EnergyAustralia		Integral		Country Energy		ActewAGL	
		Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment
System Level											
1.	Is system wide MD forecast externally prepared or reviewed?		Not stated	?	Not stated.	Y	Reviewed by CRA Int.(Confidential)	Y	Prepared by NIEIR	Y	Prepared by SKM
2.	What are the underpinning methodologies used in the system wide MD forecast? (Trend Analysis/Population Forecasts/ End Use Energy Analysis/Customer Category Forecasts/Macroeconomic Indicators/etc)		Not stated	Y	Trend / Committed projects / Econometric / Customer category/ Pop'n.	?	Trend / Weather / Demographics / Socio-economic Factors.	Y	Trend / Econometric Variables(Pop'n, Economic activity, Price, Fuel substitution) /Customer Category	Y	Trend / Econometric Variables (Pop'n, Economic Activity, Price, Fuel substitution) / Customer Category
3.	What is the period of the system wide MD Forecast? (5yr/10yr?)		10 Yrs	Y	5yrs	?	5yrs	Y	5 yrs	Y	10yrs
4.	Is the system wide MD forecast supported by energy consumption & customer growth forecasts?		Not Stated	Y	Energy Forecast, Yes. Customer Forecast, not stated.	Y	Details in confidential report.	Y		Y	Energy forecast, Yes. Customer forecast, No.
5.	Are 10%, 50% & 90% PoE MD forecasts produced or high/medium/low forecasts?	Y	10%, 50% & 90%	?	Not stated	Y	Details in confidential report.	Y	10%,50%,90%PoE	Y	10%, 50%, 90% PoE
6.	Are historical system MD's weather corrected or are abnormal MD's adjusted in another way?		Not Stated	Y	Corrected to "normal" weather.	?	Not stated	Y	Weather corrected	Y	Weather corrected.
Bulk Supply and Zone Substation Demand Forecasts											
9.	Are Bulk Supply & Zone Substation Forecasts externally prepared or reviewed?		Not Stated	?	Not stated	?	Not stated.	Y	Prepared internally	Y	Prepared by SKM

		Queensland				Western Australia	
		ENERGEX		Ergon Energy		Western Power	
		Y / N	Comment	Y / N	Comment	Y / N	Comment
System Level							
1.	Is system wide MD forecast externally prepared or reviewed?	Y	Reviewed by ACIL Tasman	?	Not stated	N	Internally prepared. Compared with IMO's forecast in SOO.
2.	What are the underpinning methodologies used in the system wide MD forecast? (Trend Analysis/Population Forecasts/ End Use Energy Analysis/Customer Category Forecasts/Macroeconomic Indicators/etc)	Y	Econometric/ Trend/ Customer Category/ Pop'n Census/ Monte Carlo/ Regression.	?	Not stated		Primarily trend analysis and prediction interval (PoE) adjustment derived from student t-distribution System-wide forecast is the sum of forecast for individual substation contributions to System Peak. Other variables considered in Area, Feeder and Load Development Reports and these may affect the trend analysis and treatment of block loads.
3.	What is the period of the system wide MD Forecast? (5yr/10yr?)	Y	10yr	Y	10 years		20 yr
4.	Is the system wide MD forecast supported by energy consumption & customer growth forecasts?	Y	Also reviewed by ACIL Tasman	Y		N	Not at this time
5.	Are 10%, 50% & 90% PoE MD forecasts produced or high/medium/low forecasts?	Y	10%/50%/90 % PoE.	Y ?	10% & 50%PoE forecasts produced.	Y	50POE System Peak produced by summing individual substation contributions to System Peak. 10POE developed from statistical analysis of historical demand series rather than temperature records. Expected and High forecasts produced based on different treatment of potential Block Loads
6.	Are historical system MD's weather corrected or are abnormal MD's adjusted in another way?	Y	Weather corrected based on temperature data at Amberley	N	Not weather corrected due to geographic diversity.	N / Y	No weather correction of historical data. Historical MD's reviewed to remove transfers, temporary configurations etc & Block Loads
Bulk Supply and Zone Substation Demand Forecasts							
9.	Are Bulk Supply & Zone Substation Forecasts externally prepared or reviewed?	Y	Reviewed by ACIL Tasman	?	Not stated	N	Internally prepared.

		South Australia		Victoria										Tasmania		New South Wales & ACT								Queensland				Western Australia	
		ETSA Utilities		Citipower		Powercor		Jemena		SP AusNet		United Energy		Aurora		EnergyAustralia		Integral		Country Energy		ActewAGL		ENERGEX		Ergon Energy		Western Power	
		Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment
10.	What are the underpinning methodologies used in Bulk Supply & Zone Subs Forecasts? (Trend Analysis, etc)		Extreme hot days/Known demands/ Economic factors/ DM		Historic max load/ Step load changes/ Load transfer/		Historic max load/ Step load changes/ Load transfer/		Economic activities/ growth patterns/ risk/ Regulatory/ customer expectation		Historic max load/ Step load changes/ Load transfer/		Historic max load/ Step load changes/ Load transfer/		Seasonal load/ customer surveys/ govt programs/ DM	Y	Trend/ committed projects/ load transfers / Econometric / Pop'n	?	Not stated.	Y	Trend / load transfers / spot load adjustment	Y	Reconciled to System MD/ Trend / Dynamic Econometric/ Spot load removal.	Y	Trend / Pop'n Census / Other?	Y	Long term, 10 year trend of historical actual loads.		Trend Analysis. Other variables considered in Area, Feeder and Load Development Reports and these may affect the trend analysis and treatment of block loads.
11.	What is the period of the Bulk Supply/Zone sub forecast? (5yr/10yr?)		**Annually produce** **-3 year Feeder Exit Load Forecast** **-10 Year Substation Load Forecast** **-5 year Subtransmission Line Load** **Forecast**		Z/S 5 Yrs BSP 10Yrs		Z/S 5 Yrs BSP 10Yrs		Z/S 5 Yrs BSP 10Yrs		Z/S 5 Yrs BSP 10Yrs		Z/S 5 Yrs BSP 10Yrs	Y	10 Yrs	Y	Zone S/S – 7yrs. STS – 10 yrs.	Y	5 yrs	Y	ESDR – 5yrs	Y	10 yrs.	Y	10yr	Y	5 yrs		20 yr
12.	Is the Bulk Supply forecasts reconciled to the system wide forecast and zone sub to bulk supply?		**Not stated**		Not stated		Not stated		Not stated		Not stated		Not stated		Not stated	?	Not stated	?	Not stated.	Y	Reconciled with NIEIR forecast	Y	Zone sub. To system MD reconciled.	Y ?		Y	Coincidence factors applied.		System-wide forecast built from substation forecast contributions to system peak. No bulk supply forecast produced at this time.
13.	Are 10%, 50% & 90% PoE MD Forecasts produced at BSP/Zone S/S level or high/medium/low forecasts?		**High/Moderate/Low**		50% PoE (long term) Also consider 10%PoE (short term)		50% PoE (long term) Also consider 10%PoE (short term)		50% PoE (long term) Also consider 10%PoE (short term)		50% PoE (long term) Also consider 10%PoE (short term)		50% PoE (long term) Also consider 10%PoE (short term)		50% PoE	?	Not stated	Y	50%PoE forecasts at STS and Z/S level	Y	50%PoE at Zone Sub Level	Y	10%, 50%, 90% PoE	Y	50%PoE	Y	10% & 50% PoE forecasts produced.		10, 50POE are produced based on statistical analysis of historical demand series rather than temperature. Expected and High forecasts produced based on different treatment of potential Block Loads
14.	Are temporary load transfers between substations recorded and removed from historical and forecasts loads? (e.g. planned or emergency switching)	Y	Check annually	Y	Both emergency and long term	Y	Both emergency and long term	Y	Both emergency and long term	Y	Both emergency and long term	Y	Both emergency and long term	Y	Both emergency and long term	Y	Load transfers accounted for.	?	Not stated.	Y	Load transfers accounted for.	?	Not stated.	Y	Load transfers accounted for	Y	Load transfers accounted for.	Y	Historical MD's reviewed to remove transfers, temporary configurations etc.
15.	Are historical spot load increases removed before trend projections performed?		Not stated		Not stated		Not stated		Not stated		Not stated		Not stated		Not stated	?	Not stated	?	Not stated.	Y	Spot loads adjusted.	Y	Removal of spot loads confirmed.	?	Not stated.	?	Not stated.	Y	Historical Block Loads removed from trend analysis.

		South Australia		Victoria										Tasmania		New South Wales & ACT								Queensland				Western Australia	
		ETSA Utilities		Citipower		Powercor		Jemena		SP AusNet		United Energy		Aurora		EnergyAustralia		Integral		Country Energy		ActewAGL		ENERGEX		Ergon Energy		Western Power	
		Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment	Y / N	Comment
16.	Are historical BSP and Zone Sub historical loads weather corrected or are abnormal MD's adjusted in another way? How?		Not stated		Weather Corrected		Weather Corrected	Y	Use 50% PoE to cover abnormal MD.	Y	Weather corrected to produce 50% & 10% PoE forecast.		one in ten year weather probability event		Not stated	?	Not stated	?	Not stated	Y	Use 50%PoE to cover abnormal MD	Y	Weather corrected	Y	Load projections weather correctedat system level, BSP level & Z/S level.	N	Not weather corrected due to geographic diversity.		No weather correction of historical data. Historical MD's reviewed to remove transfers, temporary configurations etc
Distribution Feeder Demand Forecasts																													
19.	Is a forecast of distribution feeder MD's produced? If so, how long? (3Yr/5Yr?)		1 yr, publish annually	Y	5 Yrs	Y	5 Yrs	Y	5 Yrs	Y	5 Yrs	Y	5 Yrs		10 Yrs	?	Not stated	?	Not stated	N	Will do so for spot load and customer requirements.	?	Not stated.	?	Not stated	?	Not stated		Same methodology as the substation forecasts but instead they are produced and recorded in the "Gold" forecasting tool.
20.	Are load flows and steady state voltage profiles modelled, based on forecasts? If so, how often?		Not stated	Y	Mathematical model build based on 5 yrs forecasts	Y	Mathematical model build based on 5 yrs forecasts	Y	Mathematical model build based on 5 yrs forecasts	Y	Mathematical model build based on 5 yrs forecasts	Y	Mathematical model build based on 5 yrs forecasts	Y	Use DINIS model	?	Not stated	?	Not stated	N	CE plans to establish modelling	?	Not stated.	?	Not stated.	?	Not stated	Y	FDR forecasts are requested and used by Distribution Planning on an as-needed basis.
21.	Are temporary load transfers between zone substations recorded and removed from historical & forecast loads? (e.g. planned or emergency switching)	Y	Check annually	Y	Check annually	Y	Check annually	Y	Not stated	Y	Check annually	Y	Check annually		Not Stated	Y	Load transfers accounted for.	?	Not stated	N	If forecast is produced, load transfers are accounted for.	?	Not stated.	?	Not stated.	?	Not stated	Y	Historical MD's reviewed to remove transfers, temporary configurations etc

Appendix E SKM MMA Demand Forecasting Experience

SKM has recently acquired McLennan Magasanik Associates (MMA), which has enhanced SKM's already significant experience and capability in utility market modelling, energy price forecasting and in demand forecasting.

E.1 SKM Capabilities

The following is a representative list of energy demand forecasting assignments undertaken by SKM.

Western Power: ***Demand Forecasting Review:*** Sinclair Knight Merz was engaged by Western Power in 2006 to Review its current demand forecasting system, compare with other utility systems (electricity, gas, water), recommend changes and improvements to Western Power's system from data input to data output and processing to ensure high levels of accuracy and consistency with IMO demand forecasting system.

Western Power: ***Review of Progress re Demand Forecast Recommendations:*** In 2008, Sinclair Knight Merz was engaged by Western Power to review the progress made against recommendations accepted by Western Power management as made by SKM/ROAM in their review of Western Power demand forecasting processes against international good practice and regulatory/business requirements of Western Power.

Transfield Services (Australia) Pty Ltd: ***Power Demand Forecast, North Queensland*** : Sinclair Knight Merz was engaged by Transfield Services (Australia) Pty Ltd to research the potential increase in power demand in North Queensland arising from industrial loads, particularly in the area of Collinsville power plant.

ActewAGL (ACT): ***Demand Forecast Review:*** Sinclair Knight Merz was engaged by ActewAGL in 2007 to undertake a revision of the demand and consumption forecast undertaken by SKM in 2003, with greater emphasis on economic factors such as growth in gas heating, population growth, economic growth impacting on demand and consumption forecast covering 2007 to 2020.

BHP Billiton Mitsubishi Alliance (BMA): ***HV Power Infrastructure Study, Bowen Basin, Qld:*** In 2007, Sinclair Knight Merz assisted BMA to provide a demand forecast for mines in the Bowen Basin. It also conducted preliminary system analysis to consider possible supply arrangements for discussion with utilities.

TransGrid (NSW): ***Load forecast review:*** In 2010, Sinclair Knight Merz reviewed the demand forecast for north NSW prepared by Transgrid and produced an independent, weather corrected forecast, compared the two and provide narrative as to any discrepancy, in particular explained the reduction in demand in 2007/08 due to the mild summer:

Dhofar Power Company (DPC, Oman): ***Five Year Business Plan, Oman:*** In 2009 Sinclair Knight Merz was engaged by DPC, Oman to review of previous 5 year plans, gap analysis, demand forecast and system development plan, development and presentation of new 5 Year Plan for DPC, Oman.

E.2 MMA Capabilities

The following is a representative list of energy demand forecasting assignments undertaken by MMA prior to joining SKM.

Australian Energy Regulator (AER): ***Review of demand forecast methodology for ENERGEX and Ergon Energy:*** MMA has recently completed for the AER a pre-lodgement review of demand forecast approach and methodology for ENERGEX and Ergon Energy in Queensland and subsequently carried out a review of the demand forecasts.

Australian Energy Regulator (AER): ***Review of demand and energy forecast for DNSPs in NSW:*** MMA completed an assignment for the AER reviewing the demand and energy forecasts of two DNSPs in NSW.

Essential Services Commission (ESC, Vic.): ***Review of energy and maximum demand forecasts for the Victorian electricity distributors:*** MMA has worked for the ESC in Victoria in reviewing energy and maximum demand forecasts for the Victorian electricity distributors. MMA reports from the assignment are available on the ESC website.

Queensland Competition Authority (QCA): ***Review of energy and maximum demand forecasts for the Queensland electricity distributors:*** MMA has worked for the QCA in Queensland in reviewing energy and maximum demand forecasts for the Queensland electricity distributors. MMA reports from the assignment are available on the QCA website.

Independent Pricing and Regulatory Tribunal (IPART, NSW): ***Development of demand forecasts for NSW's electricity network service providers:*** MMA has worked for IPART to develop energy consumption and demand forecasts for NSW's electricity network service providers and to review the three growth cases developed by the four NSPs. MMA reports from the assignment are available on the IPART website.

Alinta (WA): ***Demand forecast***: MMA provided advice on electricity demand forecasts to Alinta in Western Australia to determine future electricity supply requirements.

Independent Competition and Regulatory Commission (ICRC, ACT): MMA has completed a study for the ICRC in the ACT to assess the reasonableness of the ActewAGL and ACTEW's growth scenarios for electricity demand for electricity network distribution business for the period from 2004/05 to 2009/10.