AusNet Electricity Services Pty Ltd

Electricity Distribution Price Review 2016–20

Appendix 4A: Distribution Demand Forecasting

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ACIL ALLEN CONSULTING

REPORT TO
AUSNET SERVICES

17 APRIL 2015

DISTRIBUTION DEMAND FORECASTING

COMPARISON OF AUSNET SERVICES AND ACIL ALLEN METHODOLOGIES

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C O N T E N T S

. FIGURES

. TABLES

1 INTRODUCTION

AusNet Services is a large 'energy delivery' business in Victoria. Among other assets it operates an electricity distribution network with more than 49,816 kilometres of power lines supplying 668,000 properties in Melbourne's north east and throughout eastern Victoria.[1]

As with all electricity distribution network service providers (DNSPs) in the National Electricity Market (NEM), AusNet Services is subject to economic regulation administered by the Australian Energy Regulator (AER) under the National Electricity Rules (NER). AusNet Services current regulatory period will end on 31 December 2015 and it must submit a regulatory proposal for the next five-year period by 30 April 2015.

Among many other things, AusNet Services' proposal must include forecasts of maximum electricity demand. AusNet Services prepared those forecasts 'in house' using a proprietary methodology it has developed in recent years (AusNet Services' methodology).

In 2013 ACIL Allen prepared an electricity demand forecasting methodology (the ACIL Allen methodology) for the Australian Energy Market Operator (AEMO). That methodology was designed for AEMO to use in developing maximum demand forecasts at the connection point (terminal station) level. That methodology was not developed specifically for use in forecasting demand within a distribution network, though ACIL Allen considers that it is suitable for this purpose and has used it for this purpose in other projects.

The ACIL Allen methodology and the AusNet Services methodology are not the same. In this report, ACIL Allen was engaged to provide a comparison of the two methodologies to accompany AusNet Services' regulatory proposal to the AER.

In drawing that comparison, ACIL Allen had regard to the following:

- A document authored by AusNet Services entitled "Demand Forecasting Procedure, Electricity Distribution Network"
- Meetings with AusNet Services forecasting staff and emails clarifying issues that arose a those meetings
- ACIL Allen's report to AEMO of June 2013 describing the ACIL Allen methodology.

It should be noted that this project was conducted over a compressed timeframe. It excluded consideration of AusNet Services' forecasts, to which ACIL Allen has not had access.

This report is structure as follows:

- Chapter 2 describes ACIL Allen's forecasting methodology as background for the comparison
- Chapter 3 provides our understanding of AusNet Services' methodology
- Chapter 4 provides the comparison of the two methodologies.

1 AusNet services, "About Us", http://ausnetservices.com.au/About+Us.html, accessed 24 March 2015.

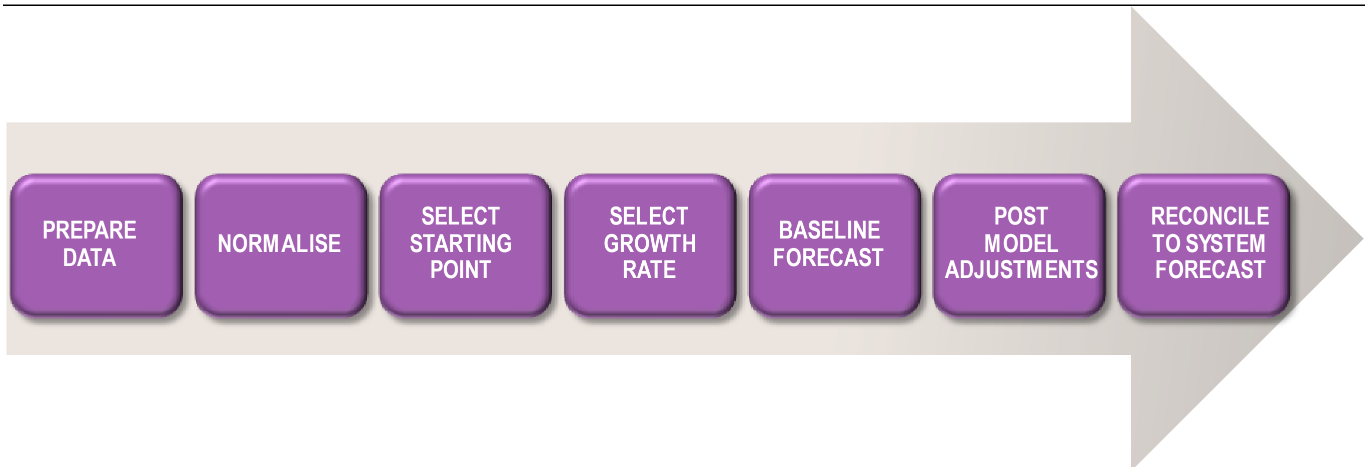
2 ACIL ALLEN'S METHODOLOGY

This chapter provides an overview of the ACIL Allen methodology as background. Further detail is available in ACIL Allen's report to AEMO of June 2013.

There are seven steps to the ACIL Allen methodology as illustrated in Figure 2.1. Each step is discussed in turn below.

The methodology as published by AEMO refers to forecasts being prepared for network elements (CPs). In this report, references to CPs are replaced by references to network elements, referring to zone substations and/ or feeders.

FIGURE 2.1 – **FORECASTING METHODOLOGY**



2.1 Prepare data

The first step in the ACIL Allen methodology is to collect the necessary data and manage it appropriately. Typically, three datasets will required.

It is important that the data used in preparing forecasts are accurate, sourced transparently and cannot be said to have been chosen selectively to the forecaster's benefit.

A good approach is to take historical data from publicly available sources such as the Australian Bureau of Statistics and the Bureau of Meteorology (BOM). Of course some data are only available from DNSPs. Those data should be taken from the most accurate source possible according to a consistent process, such as giving preference to data from revenue meters over other sources. The sources should be accurately described.

2.1.1 Demand data

The first dataset to collect is a time series of high frequency demand (30 minute interval) for each network element to be forecast. Ideally this time series should go back for at least 10 years.

These data should be well understood and should relate closely to what is being forecast. They should usually be obtained from the DNSP's internal systems.

Three factors may require adjustments to the historical data:

1. network configuration
2. block loads
3. output of embedded generation.

These should be adjusted where possible to ensure that the historical data reflect the future in particular where substantial loads have been transferred between network elements (e.g. from one zone substation to another). The objective is to create a dataset that reflects what load *would have been* with current network configuration.

2.1.2 Weather data

The next dataset to collect is weather data for normalisation. Daily maximum and minimum ambient temperatures should be obtained as well as other weather variables, such as rainfall, humidity etc.

The Bureau of Meteorology publishes weather data for many weather stations in Australia and one must be chosen and assigned to each network element for normalisation.

The choice of weather station and variable is empirical. It would be appropriate to test data from several stations to identify which is most closely correlated to demand at each network element, which may reflect microclimatic influences etc.

30 years (or more) weather data should be collected. It does not matter that this will be longer than the time series of demand data as a longer time series is required for weather normalisation.

Weather data will typically have some missing observations. These should be imputed.

2.1.3 Other data

A variety of other data may be useful in forecasting demand at network elements. Some of these data will not be used formally, but may assist in making the various judgements that must be made along the way. These include data relating to:

1. planned transfers between network elements (for either post model adjustments or altering network configuration)[2]
2. changes in relationship between drivers and demand due to:
   a) changed use of demand management
   b) ongoing uptake of embedded generators, in particular solar PV systems
   c) block loads, historical and future
   d) regional economic and population data
3. metadata concerning network elements, such as:
   a) industrial/ commercial/ residential mix of customers
   b) nature of industry/ commerce.

2.2 Normalise

It is well established that weather is a significant driver of demand for electricity. Because weather varies from year to year it is important to normalise historical data to allow a constant basis of comparison over time.

The objective of demand forecasting is not to forecast what *actual* electricity demand will be in any given year.

Rather, the objective is to forecast what demand *would be* under 'normal' conditions. Generally this is taken to mean demand under normalised weather conditions.

This requires that the component of demand that is weather sensitive is 'normalised' out of historical data before forecasts can be produced.

In some cases the key source of variability may be something other than weather. For example, in some areas the key source of variability in demand may be water pumping load, which may be only loosely connected to

[2] This assumes that historical transfers are been accounted for in the adjustments to the demand data. If not, historical data should be collected here.

temperature. In these cases it may be more appropriate to normalise for this other factor. However, the ability to do so depends on identifying that other factor and appropriate data to measure it.[3]

The weather normalisation procedure comprises four steps:

1. prepare the dataset for normalisation
2. estimate the relationship between temperature and demand at the network element
3. create a distribution of maximum demands for each network element for each year
4. identify 'normal' maximum demand from that distribution.

The procedure is performed separately for each season for which demand forecasts are required, typically winter and summer.

The appropriate dataset to use for normalisation is a subset of the demand data collected at stage 1. Generally, it should:

1. reflect only the season of interest, i.e. summer or winter
2. be one year's data unless conditions were very mild or very extreme
3. be truncated to remove:
   a) 'mild' days
   b) non-working days.

Weather may be daily maximum and minimum temperature, the average of these or another (weather related) variable. This could be examined empirically to identify which is most closely correlated with demand at the network element in question. It may change between network elements and between seasons. For example winter demand may be correlated with temperature at 6:00PM rather than daily (overnight) minimum.

As an example, consider using maximum and minimum demand to compute a linear regression in the form:

$$MD_d = m * MAXtemp_d + n * MINtemp_d + c + e_d \tag{1}$$

Where MD_d is maximum demand observed on day d for all days in the dataset. $MAXtemp_d$ and $MINtemp_d$ are daily maximum and minimum temperature respectively *m, n* and *c* are regression parameters, and *e* is an error term.

The coefficients of the regression model and the standard error of the estimate are collected and used with *all* of the available weather data to produce estimates of what daily maximum demand *would have been* in the most recent season under *all* historical weather conditions observed.

The final step of the normalisation process is to identify the 'normal' maximum demand for the season from that distribution of simulated demands.

This is simply a matter of collecting demand at the desired percentile. For example, 50 POE demand is the 50th percentile of the 3000 demands produced in the previous step. 10 POE demand is the 90th percentile etc.

Any POE level can be taken from the distribution of simulated demands.

2.3 Selecting the starting point

The next step is to select the starting point for the forecasts. Conceptually, this is the weather normalised demand in the last year for which actual data are available.

However, there are two practical choices, so a judgement must be made.

The options are to define the starting point:

— 'off the point' taking the simulated 50 (or 10) POE value for the last available year
— 'off the line' taking the value off a regression line fitted to the weather normalised history.

The difference between 'the line' and 'the point' is associated with the standard error of the regression. Therefore, it is due either to randomness in the demand values or to factors that have not been incorporated into the analysis at this point.

Generally speaking if the two options are close to one another the preferred approach is to take the starting point 'off the line' to reduce the extent to which randomness influences the forecasts. However, if the line and point are 'far' from one another there may be more than randomness to explain the difference. In this case, it would be appropriate to search for an explanation as to why 'the line' and 'the point' are different. If an

3 In the specific case of water pumping load, it may be most appropriate to treat it as a block load by deleting it from the historical series and adding projections of it to the forecast.

explanation can be found it should either be incorporated in the demand data or, alternatively, forecasts may start from 'the point'. If no explanation can be found it may be preferable to stat forecasts from 'the line'.

It is also important to remember that this choice will be rendered largely obsolete by the reconciliation process.

2.4 Select the initial growth rate

Growth rates are chosen based on the regression developed in choosing the starting point, though again some judgement is required.

The first step is to use the growth rates implied by a regression of historical weather normalised maximum demand and a time trend.

The second step is to sense check this projection with local area experts.

In these cases it may be necessary to modify the growth rate suggested by the regressions or to substitute a growth rate selected manually, for example by substituting the growth rate from a nearby network element or from the system forecast. The decision to do this, and the reasons the particular changes were made, should be recorded.

As with the starting point, it should be noted that the reconciliation process will 'override' the initial choice of growth rate. This choice influences the relative share of total demand at each network element. However the total level of demand is constrained by the system level forecast and the reconciliation process.

2.5 Baseline forecasts

At this stage baseline forecasts could be computed by applying the growth rate to the starting point and adding anticipated block loads and future network transfers.

It may be appropriate at this point to make adjustments to these forecasts to account for policy changes, though this will depend on the nature of the policy and the available data.

In most cases these baseline are not published and in some cases they are not produced at all other than as an interim step in a model.

2.6 Post model adjustments

The forecasts are now adjusted to account for changes in demand that have not otherwise been accounted for.

This is to ensure that factors that *are* expected in future but *are not* incorporated into the system or baseline forecasts are reflected in the final forecasts.

The most frequent post model adjustment is accounting for known block loads, either increments or decrements, to be made at given network elements.[4]

Perhaps the next most frequent cause of post model adjustment is a change in Government policy, or factors caused by such a change, that impact maximum demand. For example, the uptake of solar photovoltaic (PV) systems driven by the various feed-in tariffs and other policies that have been developed in the last five years would have justified a post model adjustment when preparing forecasts of that time. Another example is increased use of demand side management.

Another possible cause is increasing energy efficiency, though energy efficiency is essentially targeted at average demand. Its relationship with *maximum* demand is complex.

The appropriate way to forecast the impact of a policy change will vary with the particular policy in question. The key issue is to focus on *changes* in maximum demand attributable to that policy.

Some post model adjustments are inherently difficult to prepare and contentious. By their nature they rely on assumptions which are difficult or impossible to verify. They often rely on expectations of future Government policy, which can change. It is imperative that the adjustments made and the assumptions and methodology used to develop them are stated explicitly and available for review. To the maximum extent possible the forecast impacts should satisfy the same principles as the forecasts themselves.

[4] Adding these block loads to the network elements where they are expected will improve the *allocation* of growth between network elements but, because it is done before reconciliation, will not allow *total* growth to exceed growth in the system forecast. This is important as applying block loads after reconciliation would lead to double counting because the block loads are 'in' the system growth.

2.7 Reconciliation to system forecast

The final stage in the demand forecasting process is to reconcile the network element forecasts to an independently prepared system forecast. In this context 'system' refers to forecasts of maximum demand or the distribution region. For a DNSP this is a fairly hypothetical concept as there is no network element or meter at which this demand is observed.

The purpose of preparing this hypothetical forecast is to 'import' the likely impact of drivers of electricity demand into the network element forecasts. Some drivers, such as economic activity are not well understood or forecast at the network element level and lend themselves more to incorporation into a higher level forecast. Depending on their nature, some policy changes will be more appropriately modelled at the system level and 'imported' into the network element forecasts.

In doing this it is necessary to account for system losses and for diversity.[5]

[5] Diversity is the possibility that maximum demand at a given network element will occur at a different time than system maximum demand.

3 AUSNET SERVICES' METHODOLOGY

This chapter provides a description of AusNet Services' demand forecasting methodology. A comparison between this and the ACIL Allen methodology is in 4.

Broadly, AusNet Services methodology is to:

1. analyse demand per residential customer at the feeder/zone substation level
2. project customer numbers, reconcile these to Victorian Government forecasts of population (household numbers) and 'roll up' the reconciled feeder forecasts to the zone substation level
3. analyse:
   a) the relationship between demand and weather
   b) demand per customer as it has changed over time
4. produce demand forecasts at feeder and zone substation levels based on the projections of customer numbers and demand per customer.

These steps are described in turn in the following sections.

3.1 Analysis of historical demand per customer

The first step in AusNet Services' forecasting methodology is to analyse demand per residential customer. Two datasets used for this, namely:

1. number of customers (National Metering Identifiers - NMIs) connected to each feeder
2. daily maximum demand on each feeder.

The customer numbers data are available for the period from 2002 until the present. The data are monthly, meaning that there are 144 data points between 2002 and 2014. Daily maximum demand data are available from 2008 onwards.

For these purposes the historical data are reconstructed to reflect the current configuration of the network. For example, some customers may have been connected to feeder BDL3 in 2002 but be connected to BDL1 today. For forecasting purposes this customer appears in the dataset as if they were connected to BDL1 all along. Therefore, historical data exist, or are reconstructed, on a 'steady state' basis.

3.1.1 S-Curves

A defining characteristics of AusNet Services' methodology, which distinguishes it from other methodologies, is that it makes substantial use of S-shaped curves. These are defined by a 'start year' and a 'turn year' (or inflection point)..

The use of S-curves reflects the expected pattern of growth in demand at a smaller network element (zone substation of feeder).[6] Typically, demand starts off growing very slowly as land that was basically farmland or otherwise vacant. They then enter a ramp up phase when new developments start to come online. During this

6 This pattern is not expected at 'higher' network levels as these are the aggregation of numerous 's-shapes' at the lower level. By the time they are aggregated with different timing, the shape tends to be lost.

phase they exhibit quite high rates of growth. This high growth rate is driven predominantly by increasing customer numbers and can persist for an extended period.

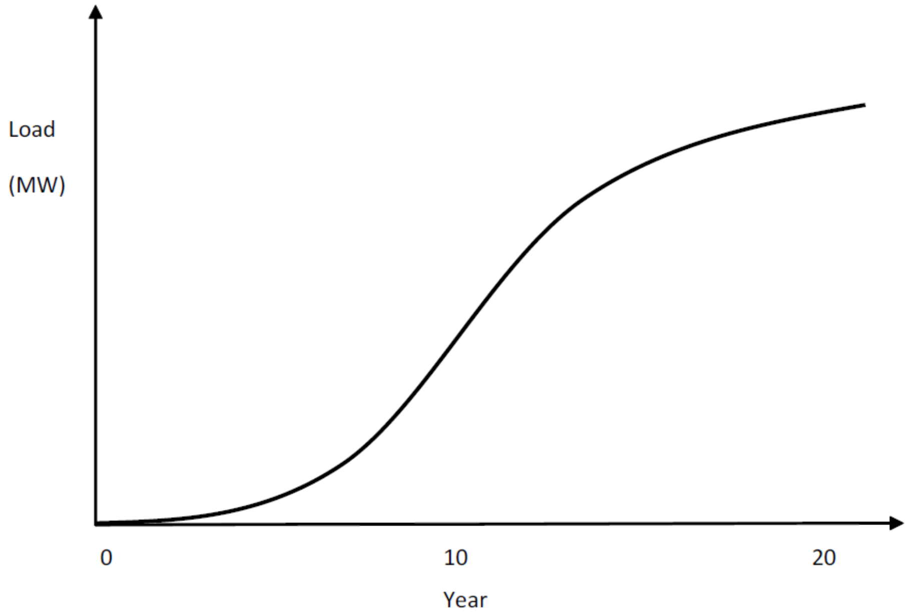
As the area in question reaches saturation, growth in demand begins to slow. Increasing demand during this phase generally comes from increases in demand per household rather than increasing customer connections.

The pattern of load growth is characterised by Figure 3.1.

In assessing the individual zone sub-stations it is important to recognise which phase of growth the particular zone substation is in. This recognition is informed by recent historical growth, local development and economic activity and an assessment of the longer term growth potential of the local area.

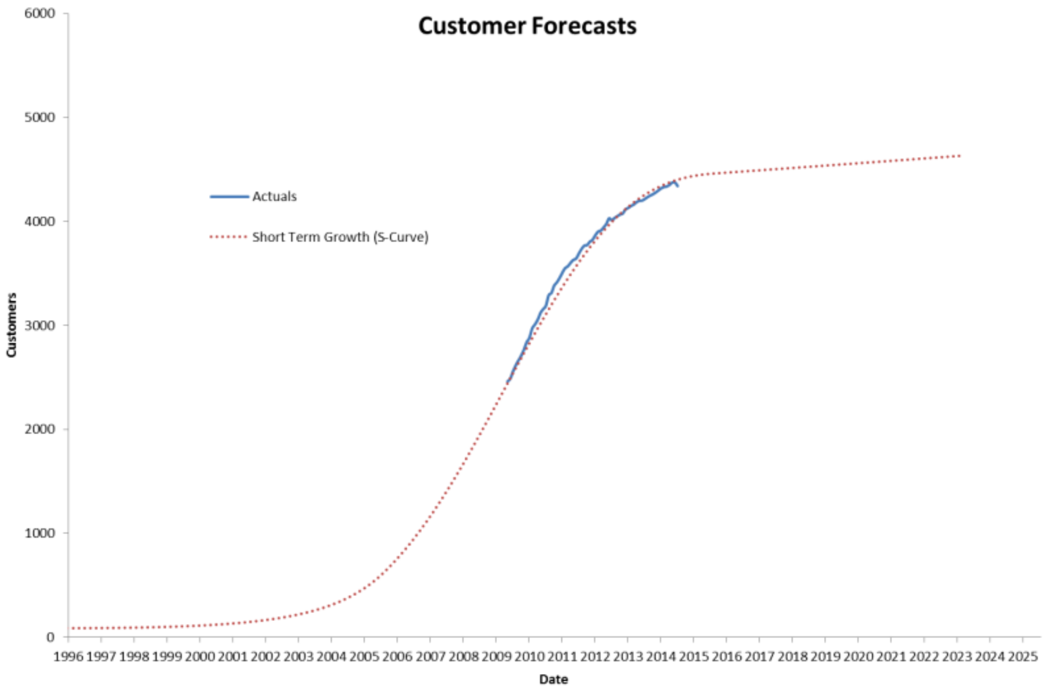
Knowledge of where an individual zone substation fits in its life cycle can help inform the network planner as to what kind of growth rate can be expected from that zone substation in the future. The diagram also highlights the importance of being able to determine the inflection points in the curve which may signal the transition from a low growth zone substation to a high growth zone substation and vice versa.

FIGURE 3.1 – **TYPICAL LIFE CYCLE BEHAVIOUR OF A ZONE SUBSTATION**



A typical S-curve fitted by AusNet Services to the number of customers connected to a feeder is illustrated in Figure 3.2.

FIGURE 3.2 – **S-CURVE FOR CUSTOMER NUMBERS**



SOURCE: AusNet Services

There are four broad parts to the S-curve in Figure 3.2. Reading from left to right:

1. from 1996 until approximately 2004, growth in the number of customers implied by the S curve is slow and accelerating
2. from approximately 2004 until approximately 2010, the growth in customer numbers is rapid and accelerating
3. from approximately 2010 until approximately 2016 the growth in customer numbers is rapid and decelerating
4. from approximately 2016 until the end of the curve, the growth in customer numbers is slow and decelerating

If the curve is extended to the extremes, either left or right, the growth in customer numbers approaches zero asymptotically. At the 'left hand end' of the curve is a 'start point' where growth moves away from zero. In Figure 3.2, the start point is 1996

There is an inflection point in an S-curve when growth stops accelerating and begins to decelerate. AusNet Services refers to this as the 'turn year'. In the S-curve shown in Figure 3.2, the inflection point is in approximately 2010.

There are a wide range of possible shapes that the S-curves can take. Some change slowly, appearing close to linear over a short time frame, while others change quickly resembling Figure 3.2.

3.1.2 Fitting S curves to customer numbers

To fit its S-curves, the start year and turn year (inflection point) must be chosen. Broadly, AusNet Services chooses these to minimize the sum of the absolute difference between actual (observed) data and values estimated by the curve. In practice for customer numbers, this is done using the growth rates rather than the levels.

AusNet services considers S-curves with:

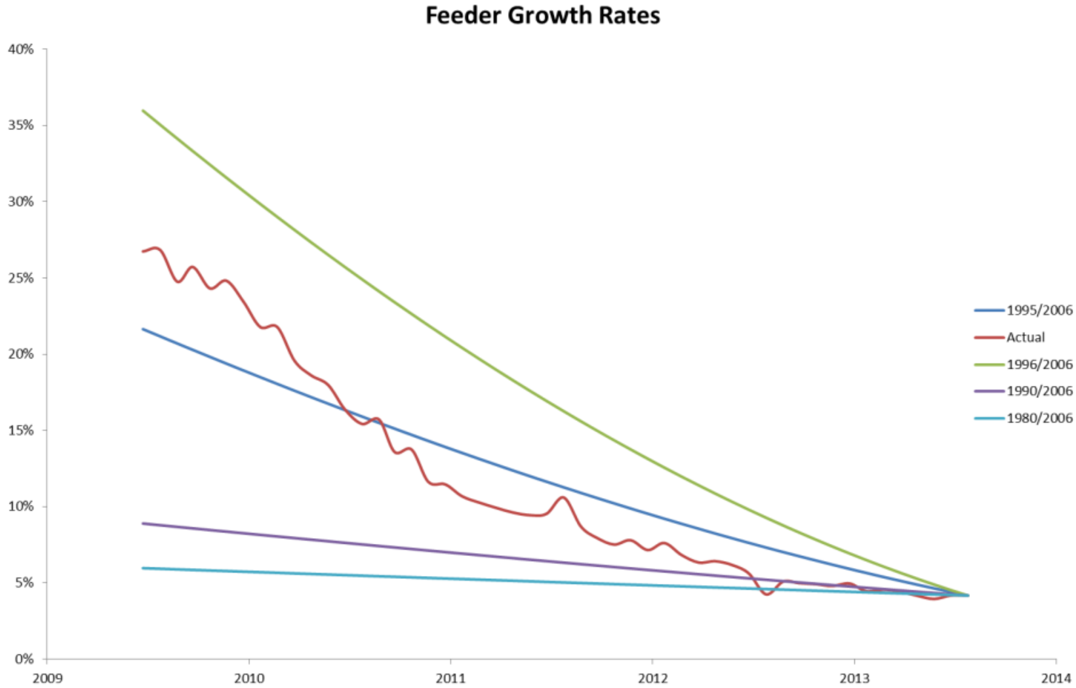
— start years ranging from 1830 to 2011
— turn years ranging from 1920 to 2020

This leaves a large number of possible S curves. To manage these, AusNet Services has developed computer code which applies each possible S-Curve to the data observed at each network element and identifies the combination which minimizes the (absolute) error.

A characteristic of S-curves is that the 'bottom (region 1) resembles the 'top' (region 4) – both are characterized by slow growth over time. However, for forecasting purposes it is important for the algorithm to 'decide' whether a given network element which has shown slow growth is in region 1 or 4. The algorithm does this based on whether growth was accelerating or decelerating over this period.

An example from the forecasting procedure is shown in Figure 3.3. In this case the best fit from among the three S-curves shown was the curve with 'start year' 1995, inflection point 2006. [7]

FIGURE 3.3 – **FEEDER GROWTH RATES - ILLUSTRATION**



Source: AusNet Services

3.2 Project and reconcile customer numbers

At the completion of this first step AusNet Services has fitted S-curves to the number of customers supplied by each of its feeders (approximately 350 in total). A baseline forecast of customer numbers could be taken by simply reading off each curve in future years.

However, before finalising its forecast of customer numbers, AusNet Services aggregated its feeder level forecasts to Local Government Area and compares the implied growth rates with forecast growth rates obtained from "Victoria in Future 2012".[8]

ACIL Allen understands from AusNet Services that the 'baseline' forecasts implied by the S-curves have invariably exceeded the Victorian government forecasts at the LGA level. Therefore, AusNet services reduces its forecasts so that they do not exceed the Victorian Government forecasts.

It is important to note that this reconciliation is done with growth *rates* between AusNet services forecast of *customer* numbers and Victorian Government forecasts of *household* numbers. AusNet services customer numbers will invariably exceed household numbers due to business and other non-residential customers.

By taking this approach, AusNet makes the implied assumption that the ratio of residential to non-residential customers on a given feeder will be constant through the forecast period.

[7] This figure shows annual growth in customer numbers. However, the S shape is in the customer numbers themselves, so it is not seen in this figure.

[8] Victorian Government, Department of Planning and Community Development, 2012.

3.3 Analyse demand per customer

At this point in the process AusNet Services has the following:

1. a historical data series of demand per customer (as well as maximum demand and customer numbers) at the feeder and zone substation level
2. projections of the number of customers at the feeder and zone substation level that are consistent with Victorian Government forecasts at the local Government Area level.

The focus of the methodology now turns to analysing demand per customer.

There are two steps:

3. analyse the relationship between demand and temperature (section 3.3.1)
4. analyse and project changing demand per customer (section 3.3.2).

3.3.1 Relationship between demand and temperature

Similarly to the analysis of customer numbers, AusNet Services uses S-curves to describe the relationship between daily maximum demand per customer and temperature. The process is as follows:

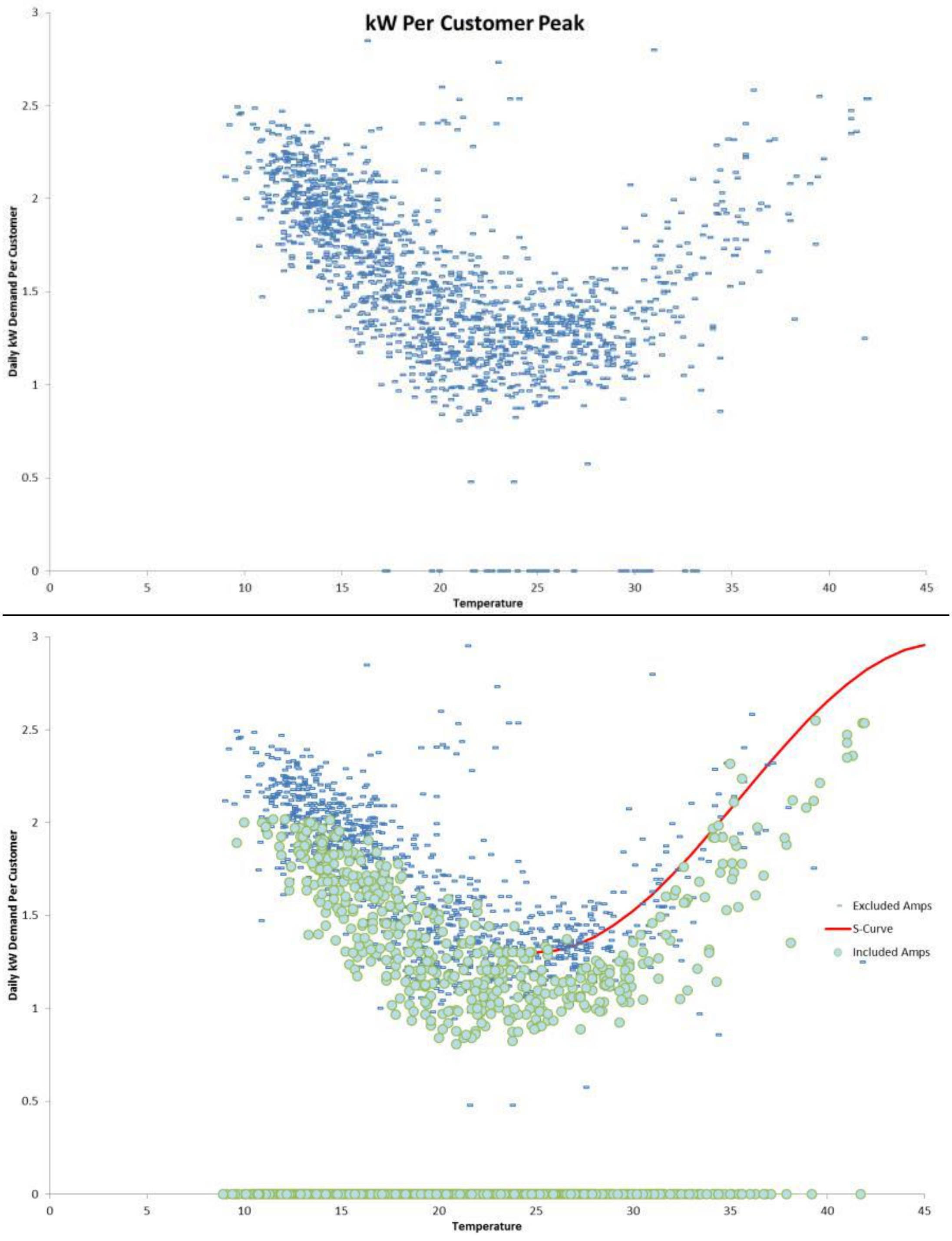
1. pool daily maximum demand per customer data for all available years and compute conditional mean maximum demand (conditioned on maximum daily temperature)

2. plot daily maximum demand per customer against daily maximum temperature as measured at the closest of the following weather stations:
   a) Scoresby (central region feeders)
   b) Wangaratta (northern region feeders)
   c) Latrobe (eastern region feeders)
3. omit data that lie more than two standard deviations from the conditional mean
4. identify the maximum demand observed at each temperature level in the pooled data (i.e. the maximum maximum demand at each feeder conditional on temperature)
5. fit an S-curve to the demand points identified in step 3 to minimise the sum of the absolute error between the curve and the actual data.

The process is illustrated below.

First the available data are pooled as shown in the upper pane of Figure 3.4 where the data are plotted against daily maximum temperature. Second, data are removed from the analysis if they fall more than two standard deviations from the conditional mean. Where a feeder has undergone a large step change, due to a load transfer or similar, the data that precede that load transfer are also omitted. The result is illustrated in the lower pane of Figure 3.4 - blue data points are omitted, green are retained. There are blue (omitted) data points interspersed with the green due to a load transfer on this particular feeder.

FIGURE 3.4 – **DAILY PEAK DEMAND PER CUSTOMER FOR A FEEDER**



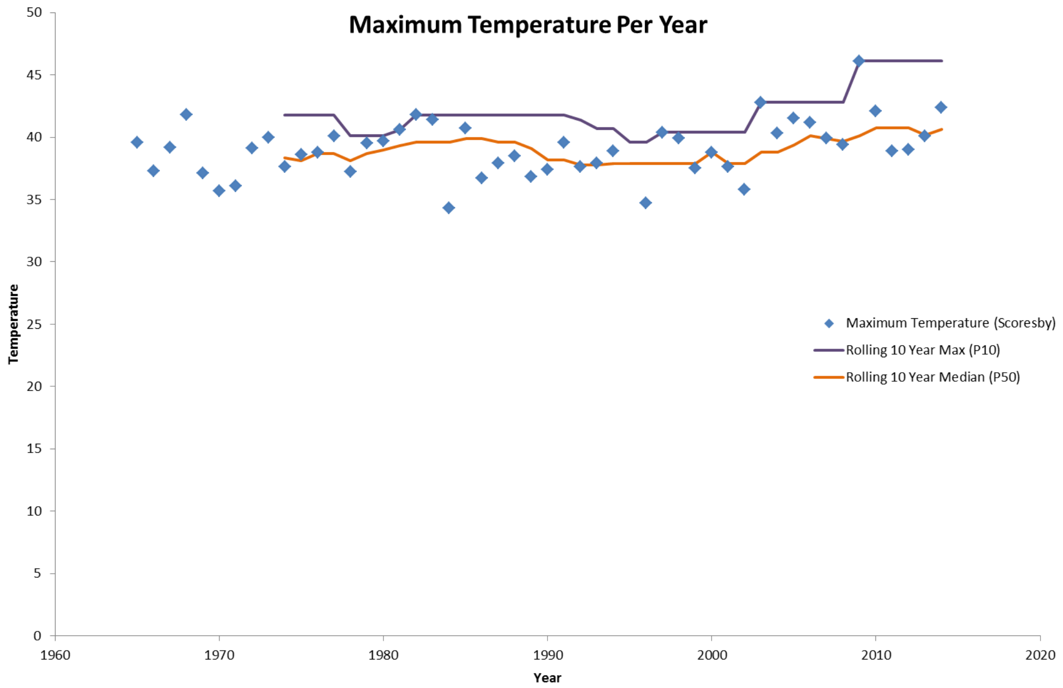
SOURCE: AUSNET SERVICES

Third, an S-Curve is fitted to the maxima of the remaining data conditional on temperature (i.e. the maximum demand observed on a day when maximum temperature was at a given level). This S curve is also shown in the lower pane of Figure 3.4.

This process is repeated at each of AusNet Services' approximately 350 feeders with a separate S-curve produced for each.

Separately, AusNet Services tracks the *annual* maximum temperature at each of the three weather stations mentioned above. It records the rolling ten yearly maximum and ten yearly median value as illustrated in Figure 3.5 (for Scoresby weather station).

FIGURE 3.5 – **ANNUAL MAXIMUM TEMPERATURE – SCORESBY WEATHER STATION**



SOURCE: AUSNET SERVICES

AusNet estimates the 10 % probability of exceedance (POE) maximum demand by 'plugging in' the rolling ten yearly maximum temperature to the S-curve that was fitted between temperature and demand for each feeder (i.e. red curve in lower pane of Figure 3.4). It estimates the 50% POE demand using the ten year rolling median temperature.

3.3.2 Changing 'demand' efficiency

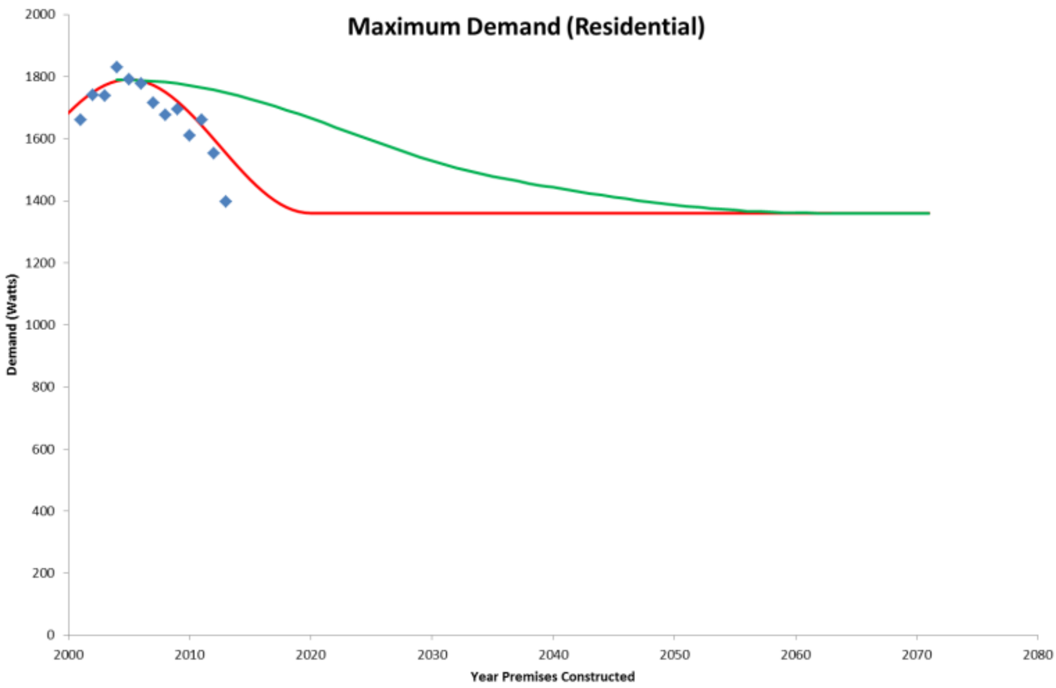
The second aspect of AusNet Services' analysis of demand per customer is to consider the rate at which this has changed in recent years. AusNet Services does this using a cohort type analysis. On 16 January 2014 demand on AusNet Services' main residential tariff, NEE 11, peaked. A sample of customers was drawn and the date when the customer first connected to the network was noted. Each customer's actual demand when NEE 11 peak demand occurred was captured. The average of those demands is shown in Figure 3.6 by 'age cohort'.

This figure shows, for example, that when NEE 11 peaked on 16 January 2014, the average demand of a customer who was first connected to the network in 2001 was slightly more than 1,600 Watts. At the same time the average demand of customers connected in 2004 was in excess of 1,800 Watts (the highest level in the sample) and customers connected in 2013 had an average maximum demand of approximately 1,400 watts.[9]

AusNet Services has analysed the pattern of these data over time using an S curve approach similar to that used in other parts of the methodology. It uses this analysis to project the demand of customers connecting to the network in future. This is done separately for new connections and renovations as depicted in Figure 3.6 (green curve reflects renovations, red curve reflects new connections)..

[9] Note that these include demand from customers with and without air conditioners and other appliances. They also include the demand of customers who may not have been home at the time so they are not as high as individual customers' maximum demands.

FIGURE 3.6 –**DEMAND EFFICIENCY BY AGE COHORT**



SOURCE: AUSNET SERVICES

3.4 Produce demand forecasts

At this point in the process AusNet Services has the following:

1. a historical data series of demand per customer (as well as maximum demand and customer numbers) at the feeder and zone substation level
2. projections of the number of customers at the feeder and zone substation level that are consistent with Victorian Government forecasts at the local Government Area level
3. an estimate of the demand per customer that can be expected on each of its feeders under certain weather conditions
4. estimates of the:
   a) maximum demand of new customers
   b) rate of decline in maximum demand of existing customers.

The final step in the process is to bring these component parts together to a forecast of demand.

4 COMPARISON OF METHODOLOGIES

This chapter provides our comparison of AusNet Services' demand forecasting methodology with our own. Consistent with the scope of the project, this chapter:

1. highlights areas where the AusNet Services and ACIL Allen methodologies differ
2. in light of those areas, provides an overall view on whether the AusNet Services' methodology is a reasonable methodology for forecasting demand
3. identifies areas for improvement.

The review follows the seven steps of the ACIL Allen methodology as illustrated in Figure 2.1.

A summary of our conclusions in relation to each step is in Table 4.1.

TABLE 4.1 – **SUMMARY OF COMPARISON OF METHODOLOGIES**

Step	Comment
Preparation of data	ACIL Allen considers AusNet Services'' data preparation to be reasonable.
Normalise	AusNet Services' use of an S-shaped relationship between maximum demand and temperature is different than ACIL Allen's approach, but it is a reasonable approach. AusNet Services' approach to weather normalisation appears to have a tendency to overstate demand. It would be improved if the regression and simulation approach was used. AusNet Services uses a short time series of weather data for normalisation. Given that this includes the extreme weather experienced in 2009, the process has an inherent upward bias regarding 10 POE demand relative to using a longer time series. However, this is mitigated to some extent by the adoption of S curves which assume that demand saturates at very high temperatures.
Starting point	AusNet Services' selection of the starting point is incorporated in the way it fits S curves to customer numbers.
Growth rate	AusNet services methodology does not include a separate step for selecting growth rates because these are implied by the S curves fitted to customer numbers growth. The selection of the inflection point for each of these S curves is made with a mathematical algorithm. In our view this should be (and is) done in conjunction with network planners.
Baseline forecasts	AusNet Services does not publish baseline forecasts separately, which his reasonable. This is a working step in ACIL Allen's methodology.
Post model adjustments	AusNet Services adjustment for changes in 'demand efficiency' appears reasonable. It may be appropriate to consider other post model adjustments, though the impact on maximum demand may be small.
Reconciliation	AusNet Services methodology includes reconciling customer numbers to a top down series, but excludes reconciling to a top down forecast of demand. The methodology does not incorporate the impact of economic drivers of demand such as electricity prices. In our view the methodology would be improved if the forecasts were reconciled to an independently prepared system level forecast of maximum demand.

SOURCE: ACIL ALLEN CONSULTING

4.1 Preparation of data

ACIL Allen considers AusNet Services data preparation to be reasonable.

The first step in the ACIL Allen methodology is data preparation. The particular data that AusNet Services collects and manages are somewhat different than are required for the ACIL Allen methodology. However, insofar as data preparation is concerned, ACIL Allen considers that AusNet Services' processes are reasonable.

4.1.1 Demand and customer numbers data

The first issue with data preparation is ensuring that the data used for forecasting are as accurate as possible and are able to be extracted consistently. AusNet Services operates an automated database system for extracting and managing demand and customer numbers data. As far as the *forecasting* process are concerned, the data appear to be extracted appropriately and in a way that can be replicated. We cannot comment on the accuracy of the data entered into the database because this is beyond the scope of our review, but we have no reason to expect problems with this.

A key aspect of data preparation in the ACIL Allen methodology is to make appropriate adjustments for reading errors, switching (temporary transfers) and permanent transfers.

Insofar as errors and switching are concerned, AusNet Services applies a two standard deviation band around the conditional mean (conditional on maximum temperature) and excludes observations that lie outside this band.

ACIL Allen considers that this is a valid way to correct the feeder level data for extreme movements that are driven by changes network configuration. An alternative approach might involve physically accounting for every switching event over time across the whole network. While this might provide a more accurate way of accounting for changes in network configuration it is considerably more costly in terms of time and resources required. The statistical approach is therefore a far more efficient way of removing outliers from the datasets. We also note that the statistical approach is validated by Network planners.

AusNet Services makes no adjustment for permanent transfers, which is a difference in its methodology and the ACIL Allen methodology. However, we do not see this as a problem with the AusNet Services methodology.

By approaching the historical data on a per customer basis AusNet Services automatically accounts for load transfers across feeders and zone substations because load transfers are reflected in customer movements between feeders and zone substations. While total demand changes with a load transfer, demand *per customer* does not, because the customers transfer with the load.

There will be exceptions to this. For example if a very small number of very large customers (relative to the load on a given feeder) were transferred, there would be a change in demand per customer. In a case such as this we understand that AusNet Services would make a manual adjustment, though it has not done so because, in its view, no such case has occurred to date. Also, such a transfer would result in a step change which would be identified and excluded using the two standard deviation rule.

4.1.2 Weather data

In addition to ‘internally sourced data regarding demand and customer numbers, AusNet Services uses weather data sourced from the Bureau of Meteorology. The Bureau of Meteorology is our preferred source of these data.

We understand that the three weather stations that are used were chosen based mainly on the length and consistency of the data series they can provide. Some weather stations move or have disruptions in historical data series, and it is appropriate to select from among weather stations that do not have these characteristics.

4.1.3 Other data

The ‘other data’ referred to above are:

4. planned transfers between network elements
5. changes in relationship between drivers and demand due to policy changes, economic activity, population growth and other things
6. metadata concerning network elements

As discussed elsewhere in this report, the AusNet Services methodology focusses on demand per customer, rather than the absolute level of demand. To do this, AusNet Services collects customer numbers data, which are in the ‘other’ category in the ACIL Allen methodology.

Insofar as data management is concerned, a key implication of this approach is that the frequency of the demand and customer numbers data series are consistent with one another. In this case we understand that the data series are consistent with one another, both being on a monthly basis.

Unlike the ACIL Allen methodology, the AusNet Services methodology does not include collecting data regarding future planned transfers or block loads. We understand that adjustments are not made for these if they are ‘routine’ because, when they occur, they generally coincide with feeders that are in the second or third stage of the S-curve (see section 3.1.1). If a block load was foreshadowed that was larger than the forecast growth on a feeder this may be incorporated separately, though we understand that AusNet Services does not currently expect any such block loads.

4.2 Normalise

AusNet Services' methodology for weather normalising the average demand per customer in the most recent historical period involves using a pool of all available data regarding daily average maximum demand per customer and the daily maximum temperature to establish a non-linear relationship between the two.

AusNet Services fits an S curve to these relationship by placing the curve at the top of the block of average maximum demand data so that a one for one link is established between highest observed average maximum demand at each observed maximum daily temperature. It then 'plugs in' the 10 year maximum and median temperature to produce 10 POE and 50 POE demand estimates. This differs from the ACIL Allen approach in three ways:

7. it uses an S-curve rather than a linear approximation
8. AusNet services analyses a pool of data for all available years and focuses only on the maximum demand 'ever' observed at each temperature, whereas our approach is to analyse the relationship one year at a time and consider all working day demand levels
9. It uses only ten years of weather data whereas we use more, typically thirty years.

4.2.1 S curve or linear approximation

AusNet Services' use of an S-shaped relationship between maximum demand and temperature is different than ACIL Allen's approach, but it is a reasonable approach.

The first difference between AusNet services approach to weather normalisation and our own is AusNet Services' use of an S-Curve.

ACIL Allen agrees with AusNet Services that the relationship between demand and temperature is typically S-shaped. However, rather than attempting to fit the S-curve, our approach is to estimate relationship between temperature and demand with a linear approximation. We do this by omitting data on the first part of the S-curve, i.e. the range where demand is unresponsive to changes in temperature. The 'top' of the curve, which occurs at very high temperatures, is only observed rarely and, in our view, cannot usually be estimated when data are considered one at a time (see below).

However, while AusNet Services approach is different to ours, we do not consider it unreasonable.

4.2.2 Pooled data or one year at a time

AusNet Services' approach to weather normalisation appears to have a tendency to overstate demand.

It would be improved if the regression and simulation approach was used.

The second difference between AusNet Services approach to weather normalisation and our own is in the data that are used.

AusNet Services fits its S-curve using only the 'top' of the data of the dataset. That is, it considers only the highest maximum demands 'ever' observed at each maximum temperature. AusNet Services then takes the 10 and 50 POE level demand levels directly from the fitted curve.

Our approach is quite different. ACIL Allen uses multiple regression to fit a relationship to all of the data (omitting non-working days) and then applies stochastic analysis to account for the errors of the model. Some of the variation in day to day demand levels (whether per customer or absolute) is due to factors other than weather. Many of these factors are not observed.

In our approach the impact of these other factors is addressed by using a Monte Carlo simulation which incorporates the standard error of the estimated regression between average maximum demand and temperature.

In the AusNet Services approach these other factors are not addressed.

Another difference in the two approaches is that AusNet Services pools data whereas we (typically) work with one year's data at a time.

Temperatures that are unusually high are, by definition, observed infrequently. Therefore, in AusNet Services approach the S-curve is calibrated to data that are outdates. In practice, the very high temperature observations in the normalisation process are likely to have been observed in 2009, because temperatures that year were extremely high.

This means that the AusNet Services methodology does not describe for the relationship between very high temperatures and demand to the extent that there may have been changes since 2009. Those changes may be due to changing appliance efficiency or economic growth for example.

The problem of limited data under extreme weather conditions is by no means limited to AusNet Services. In our approach we respecify the (linear) curve each year. This allows us to account for changes at temperature levels that are observed, and to extrapolate those changes to higher temperatures, but there is still uncertainty about behaviour at unusual temperature levels.

An alternative solution that would be consistent with AusNet Services' methodology would be to adjust the level of average maximum demand in the previous year's up or down to that of the most recent year. This can be done by estimating a regression between average maximum demand and maximum temperature with indicator variables representing each of the previous years in the regression. The estimated coefficients will indicate the extent to which the level of average demand differs from the most recent year.

In our view our approach also has other advantages over AusNet Services approach, such as has a number of other advantages. Specifically, it:

— controls for other variables that can affect maximum demand, particularly non-working days and holidays
— controls for changes in maximum demand over time due to economic growth or
— allows for more complex temperature relationships to be estimated, such as those using the overnight minimum and previous days maximum
— can be validated with statistical testing and the use of diagnostic tools.

4.2.3 Length of temperature series

AusNet Services uses a short time series of weather data for normalisation. Given that this includes the extreme weather experienced in 2009, it is likely to overstate the 10 POE demand level relative to using a longer time series.

The next step in the AusNet Services methodology is to find the 10 and 50 POE maximum temperatures to plug into the S curve and extract the associated 10 ad 50 POE average maximum demand.

AusNet Services takes the S-curve described above and 'plugs in' temperature values at the 10 year rolling average of the 90th percentile (for the 10 POE) and median (for the 50 POE)

This means at any point in time, there are only 10 data points used to calculate the 10 and 50 POE temperature that is used to calculate the 10 and 50 POE level of demand. We consider that this isn't a sufficiently long time series to accurately reflect the possible distribution of temperatures that might be observed in the future. This is particularly true for the 10 POE maximum temperature, which would be based on only a single observation if using a 10 year rolling average. Moreover, the last 10 years contains the extreme weather events of 2009, which lie well above the 10 POE level of demand using a longer time series of temperature data. Using a 10 year rolling average, the 2009 highest maximum temperature is used to obtain the 10 POE average maximum demand. In our view, this is likely to be biased upwards due to the extreme weather of 2009.

To alleviate this bias, ACIL Allen recommends that a longer time series of at least 30 years is used to estimate the 10 and 50 POE maximum temperatures.

One concern with using longer term data is that it implicitly assumes that future temperatures will reflect the last thirty years of history, which may conflict with expectations of climate change. If it were possible to build well specified econometric models showing a trend in the highest annual maximum temperatures observed over time then they should be used to project the maximum temperatures into the forecast period.

In our experience, this is not an easy task. While it is possible to show a warming trend over whole years on average, the behaviour of temperature on the hottest days of the year varies significantly and randomly over time, with runs of very hot summers often interspersed with milder years. Given these difficulties it is better to base the weather correction on the long term distribution of weather data.

We also note that changes in temperature due to climate change is expected to be slow, so it may not affect maximum demand over the five or ten year term.

4.3 Select starting point

AusNet Services' approach is broadly equivalent to forecasting 'off the line' in the ACIL Allen methodology and as such is appropriate within AusNet Services' methodology.

In the AusNet Services methodology the forecasts 'start' from the S curve fitted to demand per customer after weather normalisation. This is broadly equivalent to forecasting 'off the line' in the ACIL Allen methodology and as such is appropriate within AusNet Services' methodology.

4.4 Select growth rate

In the ACIL Allen methodology this step refers to assigning an initial growth rate to each network element before the reconciliation process is implemented. In AusNet' Services methodology the initial selection of growth rate is not a separate step. Rather, the growth rate is determined by the S-curve, so fitting that curve also implicitly chooses the growth rate.

AusNet services methodology does not include a separate step for selecting growth rates because these are implied by the S curves fitted to customer numbers growth. The selection of the inflection point for each of these S curves requires judgement. As such it should be (and is) done in conjunction with network planners.

A key part of fitting an S curve is choosing the inflection point, which is the point where growth stops accelerating and begins to slow (i.e. the point that defined the end of the second and beginning of the third stage described in section 3.1.1.

In AusNet Services methodology the choice of inflection point (referred to as 'turn year') is the result of an automated process of fitting a large number of options to find the option which minimizes the (absolute) deviation between actual and estimated values. AusNet Services methodology relies on the expectation that demand per customer and, separately, customer numbers, will grow in line with an S-curve and that this S-Curve can be identified from the data that have been observed.

There is a risk with this approach, and with any automated process, that the outputs will not pass a 'common sense' test. In such a case, AusNet Services methodology relies on the experience and judgement of the forecasting staff and network planners to 'step in' and override the automatic process. We understand that this has not been necessary before, but that it would be done if the need arose.

We do not consider this approach unreasonable, but suggest that it should be carefully tracked. We understand from AusNet Services that it is common for a planner to suggest that a particular block load should be added to the forecast for a feeder only to discover that the forecast for that feeder accelerates due to the S-curve in question. To the extent that this happens it provides comfort that the selection is appropriate. However, it is just as important to consider how often S-curves imply growth that does not eventuate.

In ACIL Allen's approach these issues are addressed partially by the use of a top down system forecast informed by projections of economic activity and other drivers. That forecast 'caps' a bottom up forecast that is based on linear curves. To some extent the use of external driver forecasts reduces the need for judgement in the forecasting process.

4.4.1 Final validation by planners

The final maximum demand forecasts are reviewed again by the network planners. The planners consider the final growth rate of each zone substation and feeder and assess their reasonableness. For those feeders or zone substations where the projected growth rates differ substantially from the network planners expectations the point in the life cycle of the feeder or zone substation is re-assessed and the position of the data on the S curve is reconsidered.

4.4.2 Problems mitigated by reconciliation to Victorian Department of Planning forecasts

The S curve methodology described above is effectively used to measure the relative growth rates between the individual feeders. These growth rates are then adjusted to match the household growth rates for the relevant LGA in which the feeders are located. The growth rates of the feeders located in each LGA are scaled proportionately up or down (usually down) to match the LGA growth rate from the Victorian Department of Planning.

Those feeders which are considered to have low or no growth are excluded from the reconciliation process.

The reconciliation between the growth rates derived from the S curves and the Victorian Government's projections helps to reduce the impact of any systematic biases that can arise from poorly fitting the S curve to the historical customer data or from misjudging the stage of a feeder's life cycle.

ACIL Allen considers that this method of reconciling the growth rates from the S curves to the independent VDP projections is sound.

4.4.3 Commercial customer growth linked to residential growth rates

It is important to note that the customer number growth is driven by projections of residential customers through the S curve and also through the reconciliation to the VDP household projections. The number of commercial customers is assumed to grow at the same rate as that of residential customers.

For commercial customers that service population centres, this is not an unreasonable assumption as commercial operations can be expected to increase to service the expanding residential population.

However, for larger industrial customers this is unlikely to be the case. Those customers will typically connect to the 22kV or 66kV network and, as such, are excluded from the forecasts discussed herein. We understand that changes in demand at this level are addressed on a case by case basis similar to our own approach to block loads.

4.5 Baseline forecasts

AusNet Services' baseline forecasts are the result of the fitted S curves. These are not published separately, which is reasonable. This is a 'working step' in the ACIL Allen methodology.

4.6 Post model adjustments

AusNet Services adjustment for changes in 'demand efficiency' appears reasonable. It may be appropriate to consider other post model adjustments, though the impact on maximum demand may be small.

The only adjustment AusNet Services makes is to account for gains in the demand efficiency of new dwellings.

For peak demand, AusNet Services have calculated this to be an efficiency gain of approximately 1 % per year for newly constructed dwellings.

We consider the post model adjustment for changing efficiency to be reasonable.

Insofar as block load adjustments are concerned, AusNet Services' methodology attempts to anticipate these by choosing the correct point in the life cycle for each of the feeders. Network planners play a key role in this. Block loads are not added on separately because they are already included in the customer growth forecasts.

We consider this approach to be reasonable to the extent that it can be validated with actual planned projects and developments in the area. If no projects can be identified either through customer enquiries or council planning departments then we believe it will be difficult to justify a ramp up phase for a particular feeder or zone substation. In this instance care should be exercised not to forecast a ramp up of growth for which there is no evidence to support it.

As our review did not include a review of the forecasts themselves, we cannot comment on the extent to which this is a real issue. That is, we do not have information as to the number of feeders forecast to undergo accelerating growth or of projects that may account for this.

In general we consider it necessary to make additional post model adjustments for each of the following:

- Adjustments for any demand management initiatives
- Adjustment for increasing solar PV penetration
- Adjustments for the demand impact of time of use tariffs

We have no information as to how AusNet services accounts for demand management initiatives or indeed as to whether any such initiatives are proposed for AusNet Services' region. If they are planned it may be appropriate to incorporate their impact into the forecasts. On the other hand, doing so would tend to complicate analysis of the value of those projects, making the business case circular. As long as the purpose of these forecasts is well understood, and the fact that they are made 'before' the impact of demand management, this is an appropriate approach.

It is possible that the impact of increased uptake of solar panels is addressed in the adjustment for demand efficiency. We also note that solar panels future impact on maximum demand would reasonably be expected to be small.

In our view it would be appropriate to consider whether the demand efficiency change is sufficient to account for the impact of time of use tariffs and, later in the forthcoming regulatory period, of cost reflective network tariff structures. However, we note that this is a rapidly evolving area where forecasting is difficult. We understand that AusNet Services intends to consider this more closely in the context of its tariff structure statement later in 2015.hat

AusNet Services methodology includes reconciling customer numbers to a top down series, but excludes reconciling to a top down forecast of demand. The methodology does not incorporate the impact of economic drivers of demand such as electricity prices. In our view the methodology would be improved if the forecasts were reconciled to an independently prepared system level forecast of maximum demand.

4.7 Reconciliation with top down system forecast

AusNet Services reconciles its customer growth forecasts to Victorian Government forecasts of household formation in AusNet Services' region.

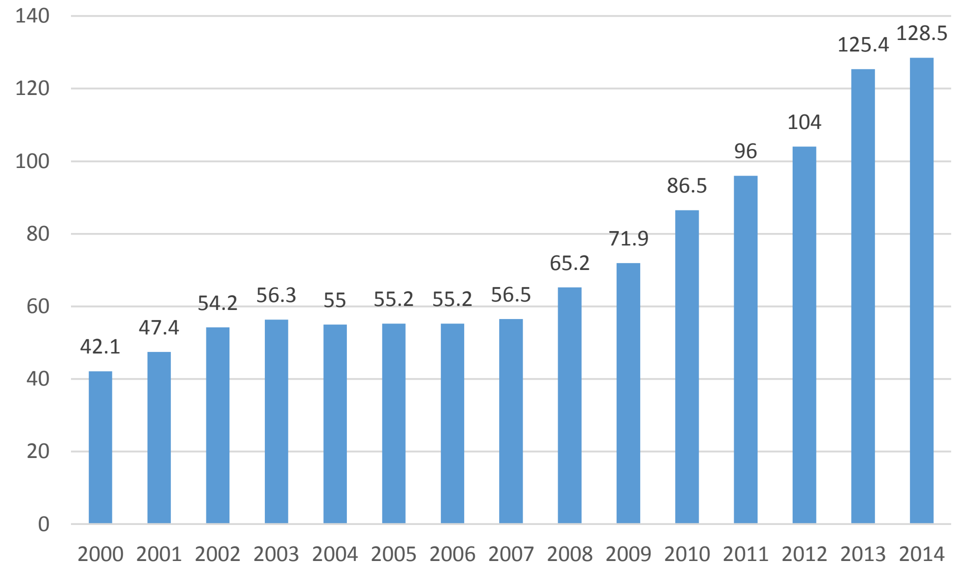
AusNet services also incorporates changes in 'demand efficiency' due to the age of the customer's home (or other premises).

However, the methodology appears not to account for changes in average maximum demand per customer due to other factors such as changing economic growth and household incomes, increasing air conditioner penetration or rising electricity prices.

As household incomes increase over time we can expect greater household expenditures on electrical appliances. Changes in economic growth will also affect commercial and industrial maximum demand.

Also, the rise in retail electricity prices has been unprecedented in the last 7 years (see Figure 4.1). Between 2007 and 2014, nominal electricity prices in Melbourne increased by a factor of 2.3. While electricity prices matter more for energy consumption, there is some likelihood of a negative demand response to such a large increase in the price of electricity.

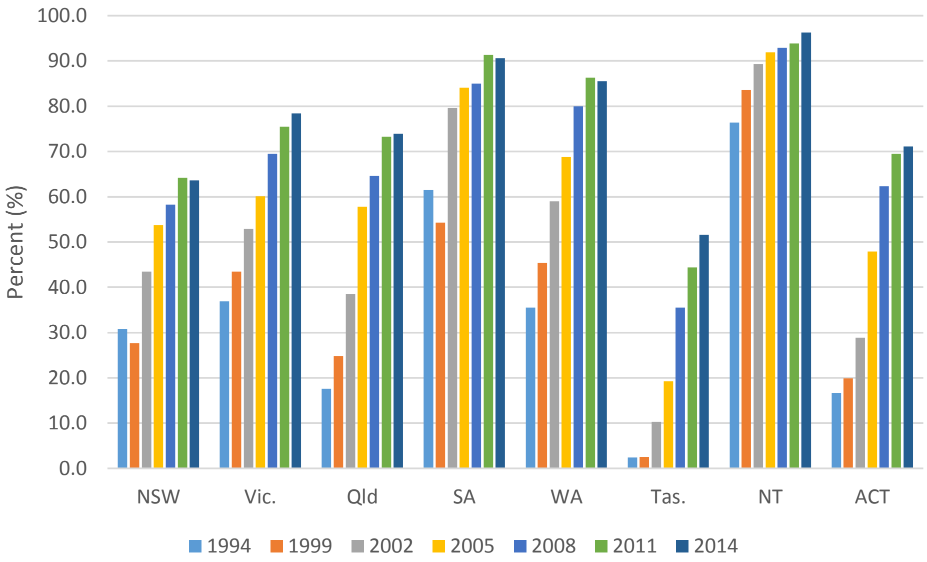
FIGURE 4.1 – **INDEX OF NOMINAL MELBOURNE ELECTRICITY PRICES, 2000 TO 2014**



SOURCE: AUSTRALIAN BUREAU OF STATISTICS

Air conditioner penetration in Victoria has risen substantially between 1994 and 2014 (see Figure 4.2). In 2014, 78.4% of Victorian households had air conditioners installed. While it isn't possible to determine with certainty when saturation is going to occur, penetration rates in South Australia suggest that there may be more to come.

FIGURE 4.2 – **PROPORTION OF ALL DWELLINGS WITH AIR CONDITIONERS**



SOURCE: AUSTRALIAN BUREAU OF STATISTICS

ACIL Allen considers that the AusNet Services methodology could be improved by linking its spatial forecasts to a top down independently produced system forecast which models the impact of macroeconomic drivers on maximum demand across AusNet Services' network.

The independent system wide maximum demand forecast should be used to reconcile the spatial forecasts. A simple reconciliation would be simply to apply a proportional adjustment to the spatial forecasts to equalize them to the system forecast, after making sure all losses are accounted for.

Another advantage of reconciling to a system level forecast, is that the higher level maximum demand data is smoother, with fewer discrete jumps. This means that smoother and more stable relationships can be estimated statistically. This is particularly suitable for the purposes of weather correcting the observed maximum demand to the 10 and 50 POE levels.

To some extent, AusNet Services' use of independent population forecasts may offset the need for a top down demand forecast. We also note that the value of a top down forecast is strongest when economic activity is expected to change. If economic growth continues in the forthcoming regulatory period at a similar rate to the period for which AusNet Services' data are available (i.e. from 2002 for demand and 2008 for customer numbers) the impact of a top down forecast would be reduced.

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