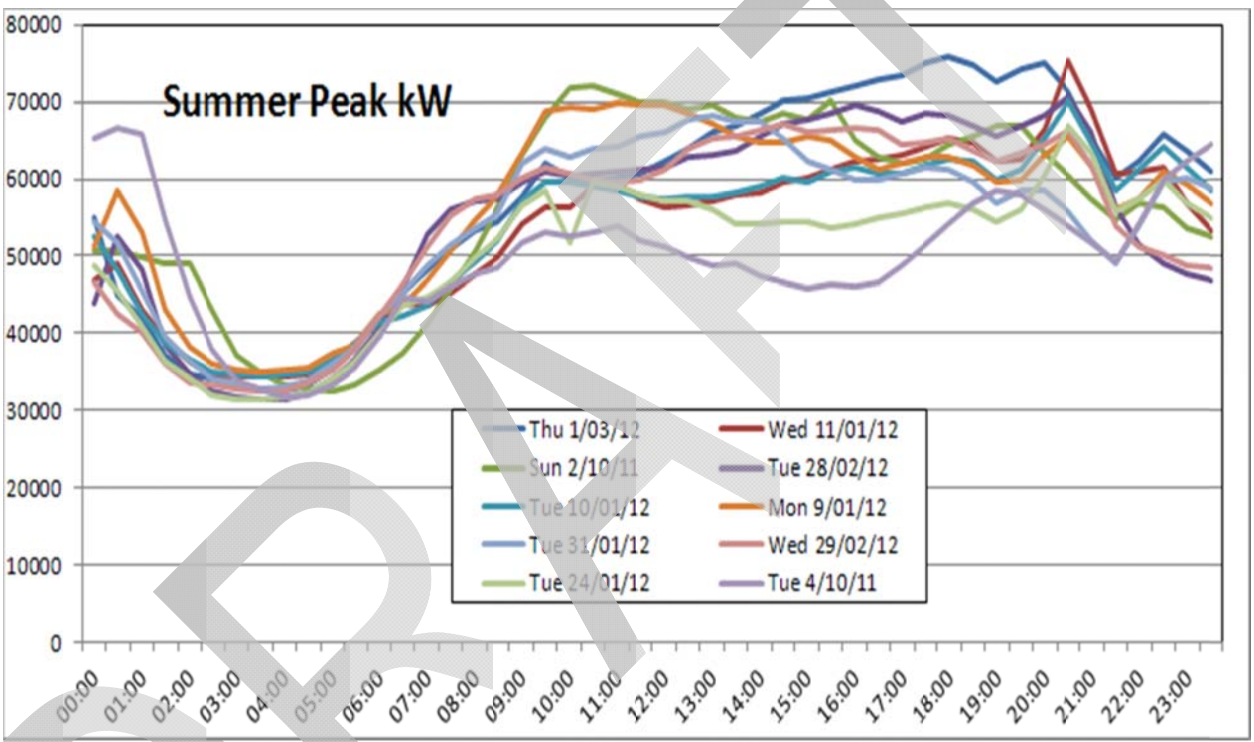
Guideline for Electricity Network Demand Forecasting



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essential energy

PREPARED BY: **MANAGER NETWORK FORECASTING AND REPORTING**

AUTHORISED BY:

ASSISTANCE:

DOCUMENT NUMBER: CEOP2084 - ISSUE 1

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PURPOSE

This document forms the basis of subtransmission and distribution network demand forecasting best practice for Essential Energy. It is to be used by Essential Energy's Network Planning and Design staff for planning augmentation of Essential Energy's electricity network.

INTRODUCTION

Essential Energy is currently undergoing a substantial transition in network forecasting from a relatively simplistic process (such as minimal weather correction and reconciliation between top-down and bottom up forecasts) which may vary somewhat depending on the individual undertaking the forecast to a more complex, repeatable process, closely aligned with the AEMO connection point forecasting methodology. Essential Energy strives to undertake the forecasting process as described in this document; however during this transitional period forecasts may be made available which do not entirely align with the process outlined in the document. It is anticipated that by January 2015 the transition in network forecasting will be complete.

On completion of the transitional period all relevant Network staff, particularly Regional and Central Network Planning groups will forecast network electricity demand in accordance with the philosophies, principles, criteria, guidelines and limits as set out in this document, and any other interrelated Essential Energy policy or procedure. Where and as required, appropriate staff training in the methods, applications, and tools used to achieve the objectives of this document shall be provided by Essential Energy.

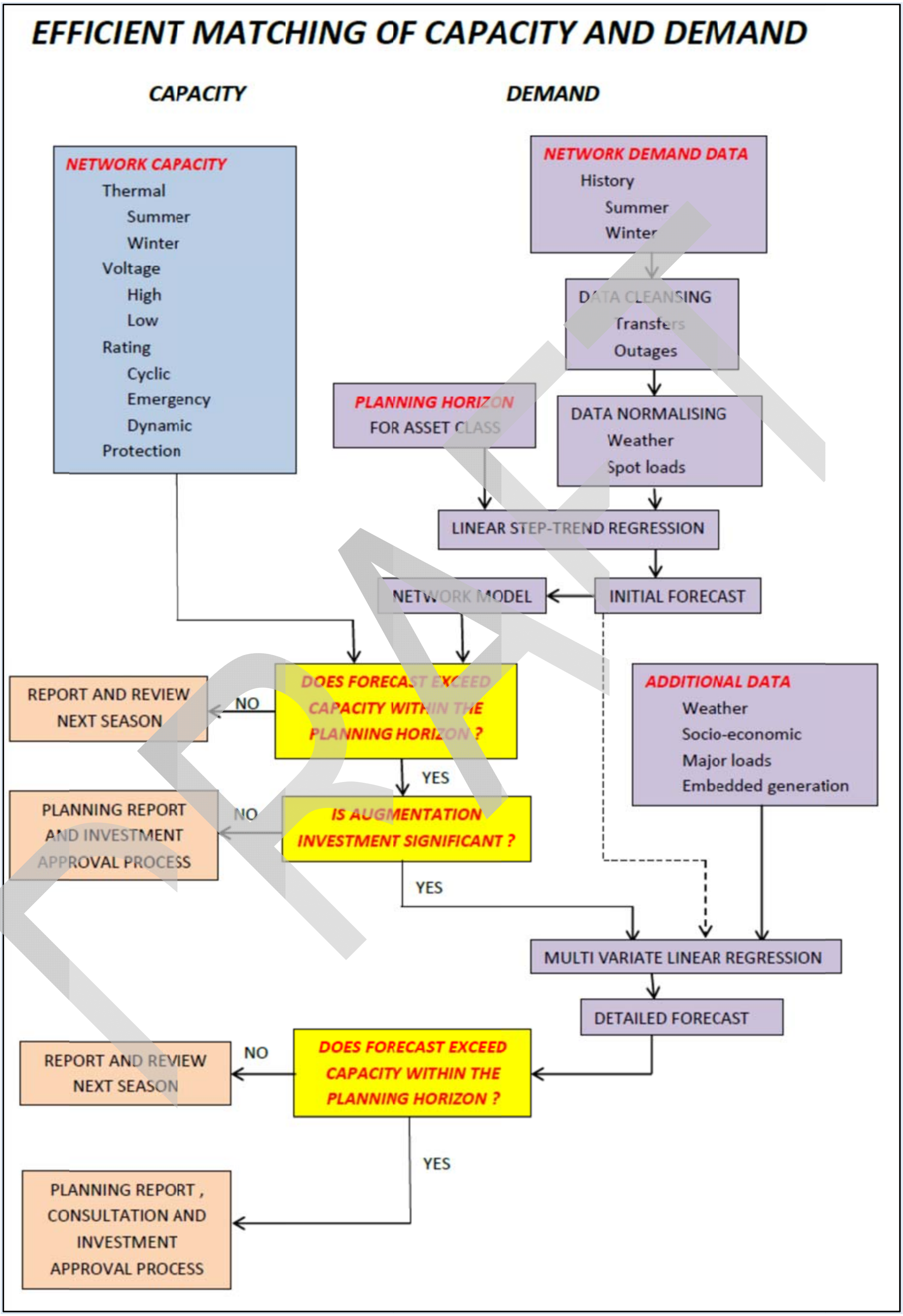
These guidelines will be revised at least annually to ensure they are consistent with Industry best practice. The Manager Asset and Network Planning is responsible for the revision and updating of the document, and will consult widely with all interested parties, both internal and external to the organisation, when carrying out the review.

Essential Energy's franchise covers 95% of NSW and has a total network customer base in excess of 800,000. The network extends into authorised supply areas of Queensland and Victoria.

The Essential Energy electricity network is one component of an integrated system by which electricity is generated and delivered to customers. Essential Energy's network has a large number of asset types across ten different voltage levels. Customers can be connected at any voltage level from 132,000 volts down to low voltage (230/400 volts). Most customers are supplied at low voltage.

Loads on the network range from large single customers such as: gold and coal mines, cotton gins, abattoirs, feedlots, irrigation pumps, shopping complexes, etc. to urban commercial and residential centres, to rural farms and villages, right down to remote Single-Wire-Earth-Return (SWER) connected customers.

NETWORK PLANNING PROCESS OVERVIEW



The development of the Essential Energy network is in accordance with the Electricity Supply Act 1995 as amended, National Electricity Rules (NER) and Essential Energy's Subtransmission and Distribution Network Planning Criteria and Guidelines (CEOP 8003).

The National Electricity Rules set out obligations and the required processes that Essential Energy must follow when evaluating strategies for the development of electricity supply. The Rules require Essential Energy to prepare and publish a Distribution Annual Planning Report (DAPR), which discloses zone substation and supply region forecasts and capacities, as well as identifying constraints in the subtransmission network over the planning horizon. For situations where constraints exist, Essential Energy is required to engage in the market-based development of options for electricity system support (including demand management, embedded generation and storage options) and their evaluation at the same time and in the same manner as network investments.

In general, Essential Energy plans the development of its network to ensure:

- Adequate network capacity to meet power transfer requirements;
- Electrical and thermal design ratings (normal and overload) of equipment are not exceeded;
- Supply reliability is in accordance with published standards, and as may be negotiated to meet the special requirements of individual major network customers;
- Quality of supply meets published standards and system voltage levels are maintained within acceptable standard limits;
- Standard and Conditions of connection for individual major customers is determined by negotiated connection agreements;
- Supply to customers is not adversely affected by other connected customers;
- Acceptable safety standards are maintained;
- Environmental constraints are satisfied; and
- The network is developed at least cost to meet the above requirements.

The need and timing for network augmentation is established by assessing the capability of the network to meet the requirements listed above. During the planning phase a number of options for addressing the reinforcement requirement are developed. The project options are then weighed against the project benefits. Generally, the benefits arise from the following main factors:

- Capacity improvement
- Avoided unserved energy
- System loss reduction, leading to reduction in greenhouse gas emissions
- Deferral of related capital expenditure
- Reduction in operation and maintenance costs
- Improvement in quality of supply
- Improvement in operational flexibility

Different network planning criteria are applied to network asset classes operating from 230 volts to 132,000 volts and specifically to individual connection points for customers with demands in excess of 10MW.

Essential Energy generally applies a deterministic network planning approach to asset classes but a probabilistic approach can be applied to the subtransmission network depending on the individual circumstance.

Network planning revolves around high level estimations of network loading patterns. It is generally not possible to forecast load patterns of individual small customers. Rather, forecasting takes place at an aggregate level. Demand and energy forecasts monitor total network load, transmission connection point loads, and zone substation and distribution feeder loads as necessary.
These forecasts, in conjunction with known customer step load changes are utilised to identify areas of future network constraint which may require attention. Through consultation with the customer/s, general community, interested parties, involvement of TransGrid and Powerlink at a transmission level, the least community cost option to accommodate the projected load is determined.

Planning Horizon

The long lead times required for major network augmentation projects mean that the planning horizon is medium to long term in nature. Subtransmission planning is carried out over a time frame of 3 to 5 years and also over a longer time frame of 5 to 15 years.

Forecasts are reviewed on a six monthly basis. This review increases the accuracy of the forecast in nearer years and adds an additional year to the end of the forecast series.

The nature of the forecasting process produces results that are less accurate the further out the forecast. Projects initially proposed from a medium term projection will be refined as forecasts improve in accuracy and their formal evaluation, approval and implementation approaches.

A planning horizon of five years is typically utilised for the formulation of firm capital expenditure plans on the subtransmission system. Forecasting horizons of at least 10 years are employed for long term forward identification and planning of potential major subtransmission line and zone substation works, and provide a framework for the orderly and economic development of the subtransmission network. Projects over the longer term are considered indicative as their timing and capital cost may vary as system conditions evolve.

Forecasts

A prime driver in the development of the network and the identification of specific augmentation projects is the forecast of electricity demand and energy.

To assist in the network planning process and to identify regional growth patterns, several levels of forecast are used by Essential Energy:

- Overall Essential Energy network forecast
- Regional TransGrid and Powerlink connection point forecasts
- Regional zone substation and associated subtransmission feeder forecasts
- Local distribution feeder forecasts as necessary

As changes in demand can impact on both source and supply side service delivery the forecasts at each level are reconciled with network levels above and below allowing for diversity between supply points and losses within the intervening network.

The regional and local modelling of loads and growth are utilised as a driver for determining the nature and timing of growth related network augmentations. Load modelling can also assist in determining the effect of demand management strategies for peak lopping and demand shifting. Assistance is sought from large customers in terms of input into the process.

Essential Energy will generally produce three forecast scenarios based on parameters provided as inputs into the model:

- A base or median projection
- A high growth projection
- A low growth projection

Inputs include historic demands, seasonal indicators and demographic factors such as expected future step loads and residential growth rates. Sensitivities to economic conditions, weather patterns, technology changes and regulatory variation are also assessed and taken into account where they are likely to have a significant influence on the forecast outcome.

To analyse conditions on the total network, a forecast will be developed which aligns the regional zone substation forecasts to provide a range of forecast demands which are coincident with the overall system peak demands, for both winter and summer. Similar analysis will be carried out to forecast demands coincident with the peak demands in the subsystem of the transmission network containing electrically adjacent transmission connection points.

To cater for regional and local needs, a forecast of the demand at each zone substation will be developed based on historical demands and information provided by major customers. Account will be taken of load diversity between connection points. The forecasts will generally cover both summer and winter demands, and extend over a planning horizon of five to ten years. Zone substation and local distribution feeder forecasts enable consideration of potential demand management programs and distributed generation developments.

Forecasts for connection point, zone substation and subtransmission line summer and winter demands are published by Essential Energy in the Distribution Annual Planning Report (DAPR) as a requirement of the National Electricity Rules.

Where there is known potential for the connection of major spot load developments such as mining loads, the forecast will take into account any reasonably firm step load increases in the medium term.

Existing and future embedded generation will be recognised and included in the forecast where it can provide firm capacity at the time of demand.

Load forecasts are also utilised as inputs into annual planning reviews and forecasts by TransGrid and Powerlink and the Electricity Statement of Opportunities as required by AEMO.

LOAD FORECASTING METHODOLOGIES

In order for a network to be operated economically and efficiently, it is necessary to have a long term network concept, which is oriented to the service life of the plant and equipment. A load forecast considers new construction, augmentation and energy requirements of the area. By analysing actual trends in load development for the individual supply sub-areas, planning for the distribution network is carried out as effectively as possible.

In an electricity network covering 70 transmission substations, 400 subtransmission lines, 350 zone substations, 1500 feeders and 140,000 distribution substations it is not practical to carry out in depth demand analysis and forecasting for all network assets. To ensure that planning resources are effectively utilised Essential Energy employs a two stage demand forecasting process:

- The first phase is an initial forecast which uses traditional linear step trending techniques to identify potential constraint points on the network within the planning horizon. Where it is clear that the network has adequate supply capacity within the planning time frame or the investment requirement is not material no further analysis is necessary.
- Where a constraint is likely to require significant investment in network augmentation or load management a more detailed analysis using multiple linear regression and expanded data sets can be undertaken to inform the planning report and refine the network support requirements and timing

At lower levels of the network where there are fewer customers with less diversity a statistical approach such as linear regression is unlikely to give enough correlation and the initial forecast should be upgraded using the best available information from local authorities and major customers.

The initial and detailed forecasting processes are outlined in the sections following

Initial forecast using linear step trend analysis

The initial load forecast is to be based upon the following information as appropriate:

- Actual normalised System Demand data (min 7 years – preferred 10 years)
- Actual normalised Energy data and load factor (min 7 years – preferred 10 years)
- Population demography and Local Council Land Use Strategy
- NSW Department of Planning and Infrastructure – Regional Planning Strategies
- Known future significant spot loads
- Known future significant developments
- Likely technology impacts
- Bureau of Meteorology historical weather data
- Relevant econometric model data
- Likely influences of Demand Side Management initiatives, Energy Efficiency
- Strategies and Alternative Energy sources or energy substitution

Data Sources

Preferred data sources are

- Demand and Energy data should be obtained by a combination of revenue/statistical metering, recording load survey instruments and spot checks.
- Population statistics may be obtained from a combination of Census statistics and the NSW Department of Planning and Infrastructure population demographic publications.
- Proposed land use may be established from Council Local Environmental Plans and land release strategies.
- Econometric data may need to be sourced from a credible institution.
- Consideration should be given to the influence of weather/climatic conditions or patterns, and allowed for in the upper and lower confidence limits of the forecast.

- Significant point load proposals should be included in determining confidence limits.

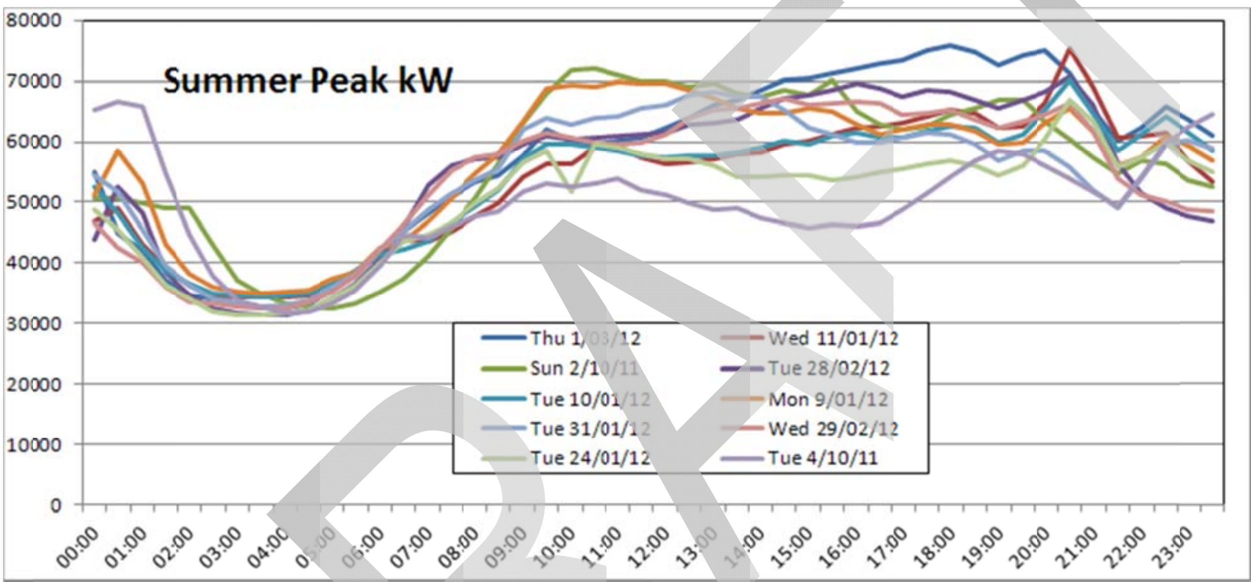
For the purposes of the initial forecast reasonable assumptions based on experience and local knowledge may be used where the preferred data cannot be readily obtained.

Calculations

Raw metering data for the prior season is "normalised" by removing anomalies due to network abnormalities and adjusting for any known load transfers.

Where interval data is available peak day profiles can be charted and examined for any significant departures. A spreadsheet based application has been developed to select, display and compare daily load profiles for half hour interval data

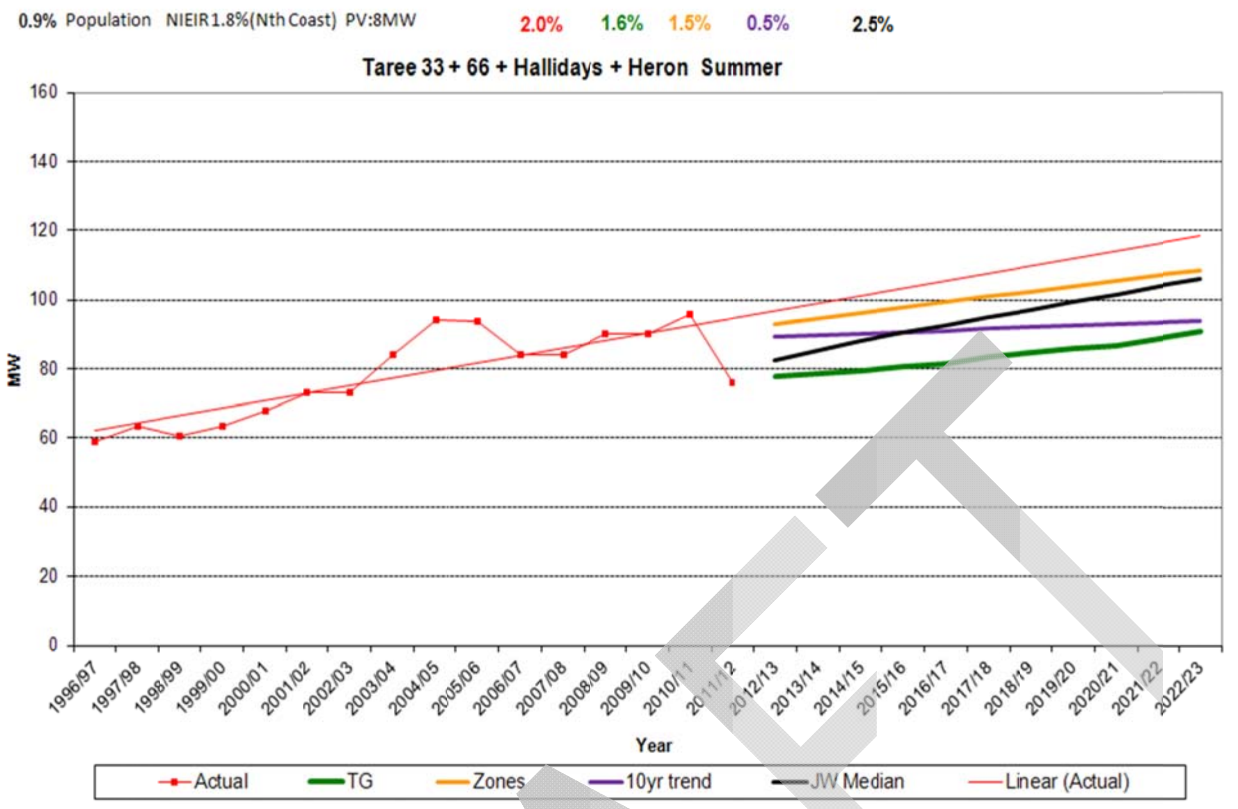
Temperature from the reference meteorological site is used to confirm weather conditions contributing to peak demand days.



If the forecaster is satisfied that a seasonal peak demand is legitimate it is added to the historical record of previous annual season peaks.

Forecasting calculations are performed on the updated demand series using linear regression/projection methodology for long term influences and appropriate adjustments for any significant short term influences that may be identified for the load under consideration.

The forecast load is estimated having regard to the historic trend and aligned with projections for other network levels.



Separate Demand trends for Summer and Winter forecasts are given, based on known 'normalised' monthly peak demands ('normalised' infers peak demand was not 'artificial' due to load transfer, miscalculation or other non-standard variances).

Summer months: October, November, December, January, February, March.

Winter months: April, May, June, July, August, and September.

Forecasts should be updated six monthly, following the last month of both Summer and Winter periods.

Presentation

Summer and Winter Forecast trends are derived and projected for all transmission connection points, subtransmission feeders, zone substations and distribution feeders, where regular information is available.

Where necessary, the forecasts shall be presented as a bandwidth between upper and lower confidence limits about a median.

Demand trends should be displayed in either MVA or in MW at actual power factor

Detailed forecast using multiple linear regression techniques

Note that this section is intended for persons familiar with the concepts of network demand modelling. It assumes knowledge of Essential Energy's information systems and a high level of technical understanding.

This section outlines an independent and repeatable method of forecasting electricity demand. It is to be used to further inform electricity network planning in situations where emerging network constraints are expected to require significant investment in either network augmentation or load management.

The level of demand forecasting analysis undertaken should be commensurate with the financial impact of the network constraint solution, and in particular the timing of that investment. The detailed analysis should be used to establish a more accurate time line for implementing an appropriate constraint solution when the initial screening test has identified network assets where peak demand is approaching supply capacity.

The accuracy of a forecast is affected by the randomness of the input data used to derive the forecast model and any uncertainty around the estimated forward predictor variables. The detailed forecast will normally be given as the median value with high/low figures to indicate this level of uncertainty. The values used in network planning should reflect a level of risk that is acceptable to Essential Energy.

This process will be modified when appropriate to include additional data sets and analytic enhancements to improve the effectiveness of the forecasting process and provide:

- A consistent approach to the estimation of future loads on the network for the purpose of network planning.
- Process transparency and credibility for both internal and external stakeholders
- Alignment with current industry best practice in electricity demand forecasting

CHALLENGES

The forecasting methodology is intended to:

- Align with accepted industry practises.
- Be an easily applied method (multivariable linear regression that can be performed in Excel or other standard statistical packages).
- Use independent sources of data where available (BoM, ABS, NSW government, ABARE, ...) and monitor available data to ensure that the most effective data sets are utilised.
- Include consideration of:
    - Abnormal network conditions,
    - Weather variability,
    - Special customer loads,
    - Effect of embedded generation,
    - Potential large connections,
    - Socio economic influences, and
    - Technology impacts

These factors are considered to be broad (complicated) enough to cover the diverse nature of load in Essential Energy's network but practical (simple) enough to apply across an electricity network covering 70 transmission substations, 400 subtransmission lines, 350 substations and 1500 feeders.

THE PROCEDURE

General Data Requirements

There is a large range of data that could be included in forecasts however the main criteria for selecting variables are that they need to:

- have an independent source for historic data, and
- not be highly correlated to other variables used (the predictors are linearly independent, i.e. it is not possible to express any predictor as a linear combination of the others).

The generic data sources in this section may be supplemented with data sets representing localised or emerging factors that are likely to have a material impact on network demands.

Internal Data Sources

Load Data

Load data will have been downloaded and normalised as part of first stage forecasting but this may need to be supplemented.

The preferred source is statistical metering data stored in EDDIs, maintained by MDA and extracted using DAWEB and/or IMDR.

Where statistical metering is not available SCADA data can be used. Data is stored in ENMAC and retrieved using TrendSCADA.

Recloser data is also available for some locations. This is stored in WSOS and retrieved using internal resources.

Customer Data

Customer meter data is stored in EDDIs and maintained by the MDA. Data is extracted using DAWEB and/or IMDR.

Embedded Generation

Large generation (>10 kW) meter data is stored in EDDIs and maintained by the MDA. Data is extracted using DAWEB and/or IMDR.

Small generation (roof top solar) data, including installed system capacity, is stored in Energy.

External Data Sources

Weather Data

Historic weather data is obtained from the Bureau of Meteorology (BoM) using a sample of 48 weather stations across the state (see appendix 1).
Where available, data includes:

- station_number
- tran_date
- global_solar_exposure
- precipitation
- precipitation_type
- max_temp
- min_temp
- 0900_temp
- 1500_temp
- 0900_humidity
- 1500_humidity
- sunshine_hours

- max_wind_gust
- max_wind_direction
- wind_run_above_3m
- wind_run_below_3m
- occurrence_snow
- occurrence_hail
- occurrence_thunder

In the absence of actual metered data 'global solar exposure' is used to model solar generation.

Calendar Data

This contains day of week and holiday information which influences customer usage patterns. For supply areas with a diverse customer base the seasonal maximum demand will generally occur on a working weekday outside holiday periods.

Population Data

Population history is obtained from the Australian Bureau of Statistics (ABS) and divided into Statistical Local Areas ('Population Estimates by Statistical Local Area' from: http://www.abs.gov.au).

Population Growth is forecast by NSW planning also at a Statistical Local Area ('New South Wales Statistical Local Area Population Projections Detailed Summary' from NSW Department of Planning. Population growth should be considered in conjunction with any variation in housing occupancy rates as this will impact directly on customer numbers.

High and Low growth scenarios can be generated by applying a 20% variation to the base rate.

Electricity Price Data

Electricity price increases and CPI data history are obtained from a weighted historic cost of retail and business electricity bills for our network area and the ABS (data series A2328141J).

Based on the assumption that there will be no network price increase above CPI in the future a reduction in real prices of 1.5% for financial years 2013/14 and 2014/15 has been used. Price rises are then assumed to be equal to CPI so the price index is assumed to be 0%.

The price index is calculated by looking at the change in electricity price relative to the change in CPI each year.

For example for 1999:

Financial Year	Weighted electricity annual cost	Annual CPI	Electricity Delta	CPI Delta	Electricity Price Increase
1998	$4,260.71	120.500			
1999	$4,173.76	122.475	0.9796	1.0164	-3.76%

Space Cooling Data

An estimate of installed air conditioning load has been obtained from the Department of Climate Change and Energy Efficiency – End use in the Australian residential sector 1986 – 2020.
This contains historic and forecast energy consumption by state for space cooling.

Tourism Data

The ABS records quarterly tourist accommodation data for hotels, motels and serviced apartments with 15 or more rooms by 'tourist region'. Parameters recorded include guest arrivals, guest nights and nights occupied. Nights occupied has been used in places were tourism has a material impact on load.

Locations particularly affected by tourism include the north and south coast and snowy mountains. For example the Forster Tuncurry area can approximately double in population over summer.

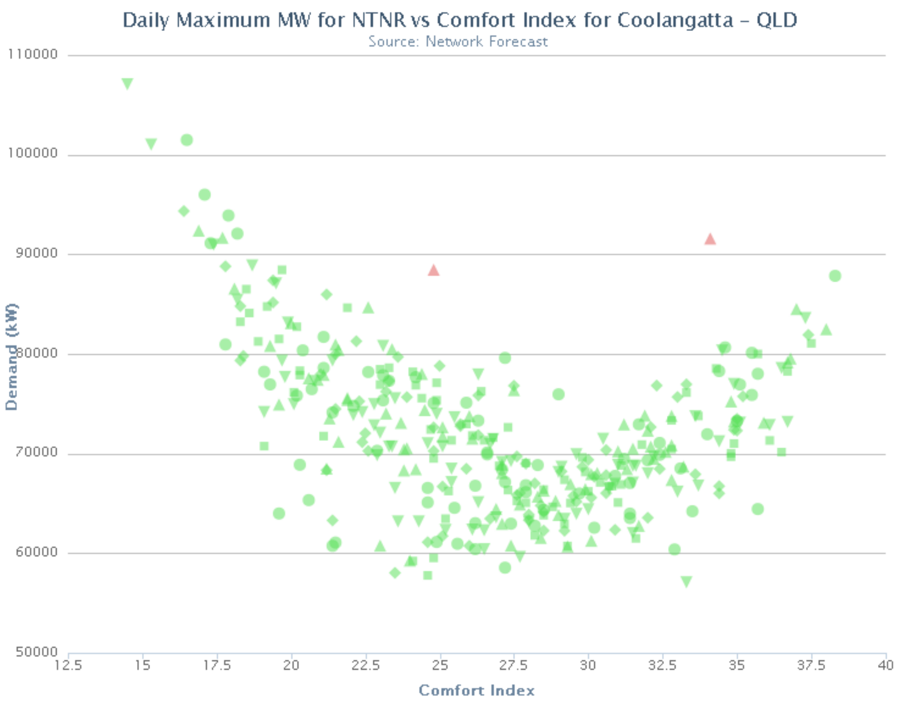
DATA PREPARATION

Data Cleansing

Meter Data

After the meter data is aggregated any obvious anomalies will have been corrected during the preliminary forecast process. As a further check the daily maximum demand can be plotted against the location's comfort index. This makes it easier to identify days where meter data may be missing or load transfer to or from another region may have occurred.

For example in 2008 at Terranora TNI: NTNR there were two days when load in QLD also appears to have been supplied (coloured red in chart below). These would either be excluded or the load adjusted when modelling the demand.



Load Transfers

When large blocks of load are transferred away or added to a supply point the load growth at this point will become distorted. When data is available to model the transferred load it should be backed out of the data used for forecasting

Special Customers

Special customers (customers whose load is not correlated to any known variables) are forecast separately. These are identified through local knowledge or by extracting large customer interval meter readings and correlating it to the total load

Typical special customers include but are not limited to:

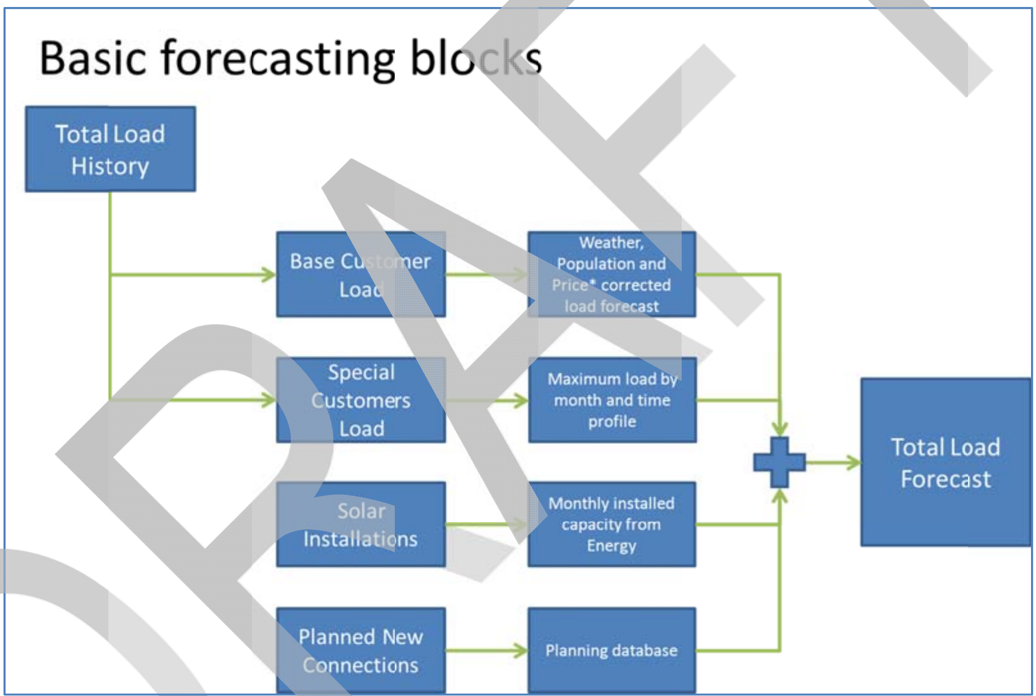
- Irrigators,
- Rice Mills,
- Cotton Gins,
- Water pumps, and

- Mines

Demand Models

Forecasting demand has been split into four blocks.

- **The base load** is the normal weather dependant load that grows over time with population.
- **Special customers** are modelled separately as their behaviour is not generally weather dependent or may be driven by other factors that are hard to forecast over a long period of time - For example water for irrigation.
- **Solar demand/generation** is a relatively new issue. Gross metered solar installations are treated as a supply point. Net metered solar installations are modelled by creating a supply point based on the installed capacity and a customer load based on the difference between the installed capacity and the net metered energy. This is to show demand hidden from the supply point. Although relatively small at present this could potentially become quite significant.
- **New connections** are sourced from the planning database and local knowledge where available.



Base Load

Weather dependent demand is assessed in accordance with the principles of AEMO's published methodology "Connection Point Forecasting – a nationally consistent methodology for forecasting maximum electricity demand (26th June 2013)".

Base load raw data is derived from the overall meter data for the supply point under study less any known significant loads that are not temperature dependent and any known embedded generation.

After the base load raw data is normalised for the effects of switching or load transfers the data set is truncated to remove days when load patterns are typically lower. In most cases this would be weekends and holiday periods although special consideration may need to be given to atypical areas such as tourist resorts.

A further truncation removes "mild" days where the temperature influence is minimal. The threshold temperatures can be estimated through examining a scatter plot of demand versus maximum daily temperature. Across Essential Energy's supply area this would typically be above 25 degrees Celsius for summer and below 22 degrees Celsius for winter but will vary slightly with each location.

It is important that there are enough data points remaining in the truncated series to establish a robust relationship between demand and weather. A minimum of 30 for each season of interest is recommended.

Multiple linear regression is used to establish the relationship between daily weather variables and maximum demand for the latest season of interest. A sufficiently accurate regression model can usually be derived from daily maximum and minimum temperatures but if correlation is poor (the regression model has an R-squared value of less than 0.3) consideration could be given to including other parameters such as prior day temperatures or humidity. If the latest season has been extremely mild and temperature correlation low it may be necessary to examine data from previous seasons to make the regression model more robust

Available historic weather data is applied to the regression model to establish equivalent maximum seasonal demands in previous years. From these calculated annual maximum demands further values are simulated by adding an error drawn from a normal distribution with mean zero and standard deviation equal to the standard error of the regression model. When sufficient simulated values have been generated the relevant probabilities of exceedance can be derived.

Special Customer Load

Special customers are typically large customers whose demand is not weather dependent. As a guideline their demand will be 5% or more of the overall demand. They are identified by the forecaster and the relevant interval data is extracted to derive the historic base load at each supply point.

Where special loads are highly intermittent (as can be the case for agricultural or extraction activities which are sensitive to climate and/or economic conditions) duration curves of the historic data can be used to help choose an appropriate value for forecasting.

Solar Generation

A base (no cloud) profile is constructed for each location based on its latitude, longitude, altitude and the day of the year using a solar position and radiation calculator.

Solar generation can be estimated based on the time of day and the day's 'global solar exposure' combined with the installed PV capacity in the supply area.

New Load

Known material spot loads need to be included (or excluded if for example a mine is going to shut down). Local planners will be the main source of this information as they are monitoring load at the distribution level. and the Network Connections division will be aware of connections to the subtransmission system for larger installations.

Forecast

Base Forecast

A base load demand forecast can be generated by applying appropriate growth factors (from expected econometric, technical and legislative influences on electricity demand) to an estimated starting point demand.

The starting point demand would ideally be a weather corrected value for the latest season at the designated probability of exceedance. However this should be checked against the time trend regression of historic demands and may need to be empirically adjusted to a best fit value based on the forecaster's judgement.

An appropriate growth path should be derived from the best available information on future trends in factors that are likely to contribute to growth in electricity demand.

While population growth rate is a key driver this should be guided by consideration of a range of socioeconomic issues including finance availability, commodity prices, government policy, emerging technology and incentive programs that will also influence electricity demand. Advice can be obtained from various credible economic institutions to assist.

Special Customer Forecast

A forecast is generated by sorting the historic daily maximum demand and selecting the load corresponding to an appropriate probability of exceedance. The value used should reflect the potential for the load to be present at the time of network peak demand and take into account likely fluctuations in economic and climatic factors (such as low commodity prices or prolonged droughts) that influence the level of demand.

Solar Forecast

Forecast solar generation will be based on the total connected capacity in the supply area and global solar exposure adjusted for the relevant peak time of day and time of year

New Load Forecast

New loads may be included when a substantive tangible commitment has been made by the project proponent. Where loads are prospective rather than firm a judgement will need to be made on the likelihood that the load will eventuate. For planning purposes a "contingent" forecast may be generated.

Total Forecast

The total forecast is generated by combining data as required. In most cases it will be a combination of the forecast base load, major customers and firm spot load increases with allowance for the impact of embedded generation