DEMAND TRACE DEVELOPMENT FOR THE 2015 NATIONAL TRANSMISSION NETWORK DEVELOPMENT PLAN

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AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information about the methodology used to create the demand traces for the 2015 National Transmission Network Development Plan (NTNDP).

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CHAPTER 1. INTRODUCTION

Electricity demand is the main driver for National Electricity Market (NEM) investment. This paper outlines the methodology used to create demand traces for the 2015 National Transmission Network Development Plan (NTNDP).

The 2015 NTNDP examines two scenarios affecting demand over the next 20 years. The ‘Gradual Evolution’ scenario reflects a future where there are no major cost reductions or additional incentives to drive the uptake of new technology. The Rapid Transformation scenario is designed to reflect a future where new embedded technologies experience rapid uptake, possibly driven by significant cost reductions and/or new policy incentives.

Both scenarios were developed using operational consumption and maximum demand projections from the 2015 National Electricity Forecasting Report[1] (NEFR) scenarios as a starting point. The ‘Gradual Evolution’ scenario was based on the NEFR medium scenario, together with forecasts for the hourly impact of residential storage and electric vehicles on consumer demand profiles in the 2015 Emerging Technologies Information Paper (ETIP).[2] The ‘Rapid Transformation’ scenario is based on the NEFR low scenario, and applies greater penetrations of residential storage and electric vehicles to the same methodology in the ETIP.

The 2015 NEFR forecast was extrapolated to produce an additional five years of forecasts from 2035–36 to 2040–41, using each region’s growth rate over the last five forecast years (from 2029–30 to 2034–35). This 25-year forecast of annual energy and maximum demand then underwent five major development steps (see Chapter 2 below) for the creation of hourly regional demand traces.

The hourly demand traces are applied in the NTNDP’s PLEXOS least-cost modelling simulation that is used to facilitate power system analysis.

[1] AEMO. http://www.aemo.com.au/Electricity/Planning/Forecasting/~/media/Files/Electricity/Planning/Reports/NEFR/2015/Detailed%20summary%20of%202015%20electricity%20forecasts.ashx.

[2] AEMO. http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report/~/media/Files/Electricity/Planning/Reports/NEFR/2015/Emerging%20Technologies%20Information%20Paper.ashx.

CHAPTER 2. DEMAND TRACE DEVELOPMENT

Demand traces for the NTNDP represent the trace of supply 'sent out'. The supply sent out is the electricity supplied to the market by the scheduled, semi-scheduled and some non-scheduled generation, and excludes generator auxiliary load.

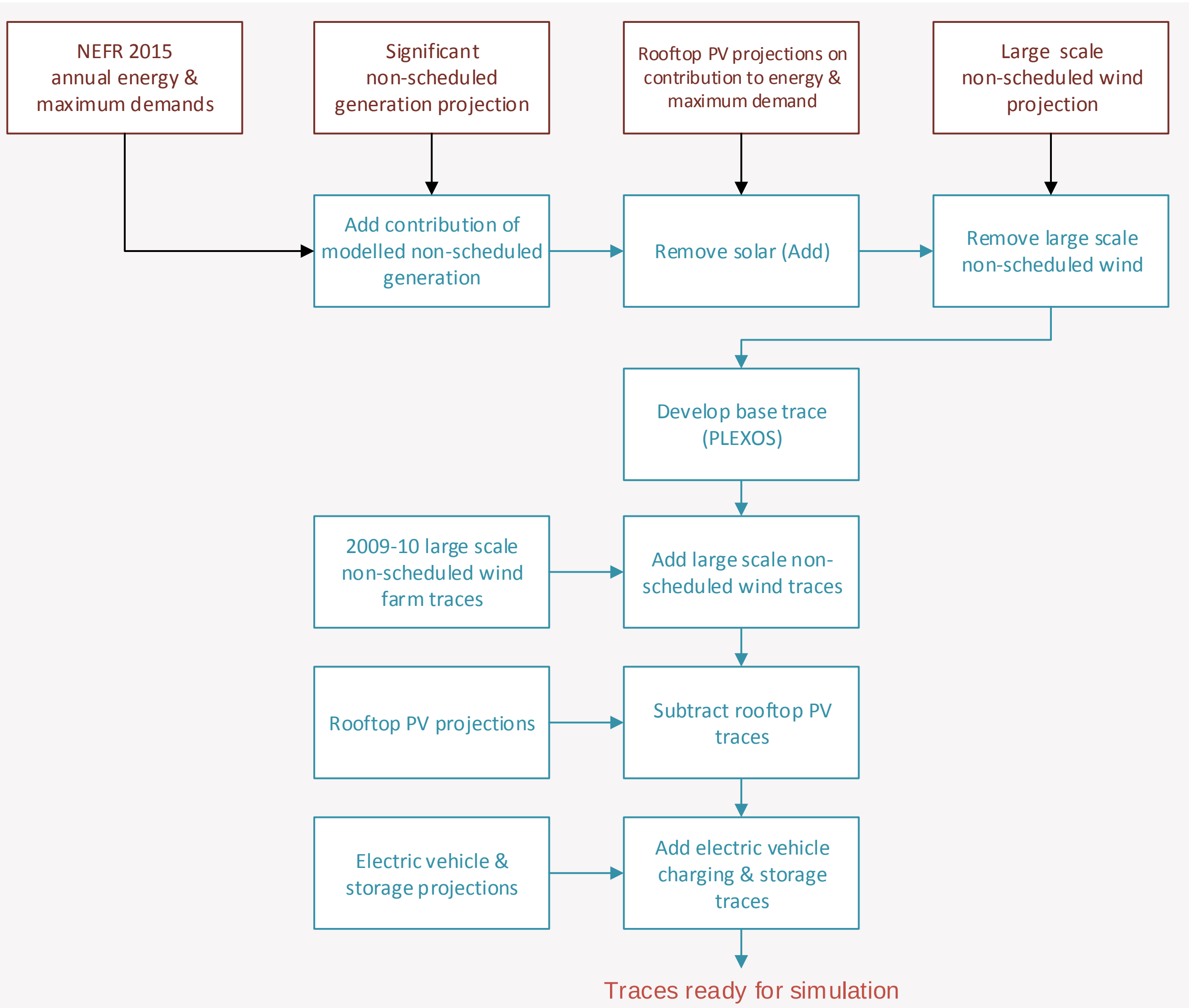
Starting with the 2015 NEFR projections, there are five major demand trace development steps:

- Adjusting the NEFR projections to account for modelling assumptions.
- Producing an hourly base demand trace using the adjusted NEFR projections.
- Adding contributions from large-scale non-scheduled wind generation.
- Subtracting hourly contributions from rooftop photovoltaic (PV) generation.

Adding hourly contributions from electric vehicles (EV) and battery storage.

shows the process for developing the demand traces, and the following sections explain each of these steps in more detail.

Figure 1 Demand trace development



2.1 Step 1: Adjustments to NEFR

The 2015 NEFR provided projections of operational[3] consumption and maximum demand for summer and winter periods to be met by scheduled, semi-scheduled, and some non-scheduled generation[4].

The 2015 NEFR demand projections considered the contribution of rooftop PV to reducing underlying demand. In contrast to these single annual values of total PV energy generated and the assumed contribution to maximum demand, the modelling process for the NTNDP required a full set of hourly demand traces. To allow a realistic solar output profile to be used, the contribution of rooftop PV in the NEFR projections was removed, and included as an hourly solar trace in a later step (see Section 2.4).

Similar to rooftop PV adjustment, assumptions of energy and peak demand contribution from large scale non-scheduled wind have been removed from the forecasts, and hourly wind traces for those wind farms added back (see Section 2.3).

Adding back the contribution of some non-scheduled generation (that is explicitly modelled) and removing the contribution of rooftop PV and large scale non-scheduled wind from the NEFR projections created the annual operational consumption and maximum demand targets that form the basis for developing the demand trace.[5]

2.2 Step 2: Develop base hourly demand trace

Demand traces were developed using PLEXOS, a market simulation platform capable of developing a demand trace that matches a historical reference trace while meeting predetermined energy and maximum demand targets (both summer and winter).

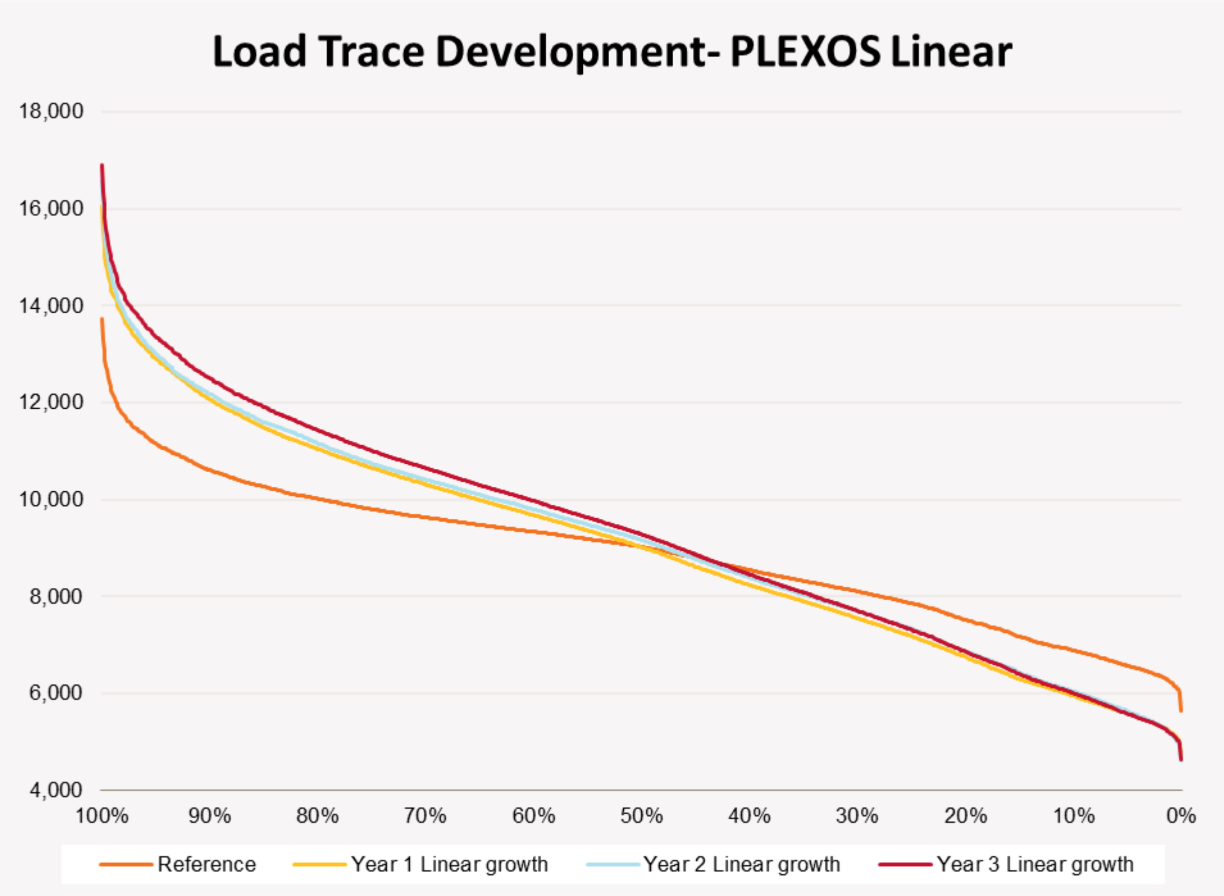
In the 2015 NTNDP, the 2009–10 financial year was chosen as the reference trace. This selection was based on an assessment of the demand diversity across adjoining regions[6] and the wind energy output within subregion[7], targeting a year that was representative of average outcomes.

PLEXOS load growth has two distinct modes: Linear or Quadratic. Both methods calculate a continuous growth rate function that gets applied to each point of the reference demand shape.

In Linear growth mode, the growth rate function is a straight line – points at the top of the demand duration curve are scaled by a factor that is linearly greater than points at the bottom of the demand duration curve. This gives a reasonable result if energy and maximum demand grow at similar rates. However, it can lead to negative growth for low demand periods if maximum demand is growing faster than annual energy, as shown in Figure 2.

[3] A definition of 'operational' can be found at: http://www.aemo.com.au/Electricity/Planning/~/media/Files/Other/planning/Use%20of%20Operational%20Consumption%20and%20Demand.ashx. Viewed: 10 November 2015.
[4] The NEM model used for the NTNDP represents some non-scheduled generation explicitly to capture their impact on network constraint equations.
[5] To capture the 2009–10 historical profile, forecast electricity consumption from LNG projects were accounted for when growing the trace for the Queensland region.
[6] AEMO has previously published an analysis of the coincidence of regional maximum demands: http://www.aemo.com.au/Electricity/Planning/Related-Information/Historical-Market-Information-Report.
7 AEMO has previously published an analysis of the variation in wind availability between 2002–03 and 2009–10: http://www.aemo.com.au/~/media/Files/Other/planning/0400-0057%20pdf.ashx.

Figure 2 PLEXOS Line

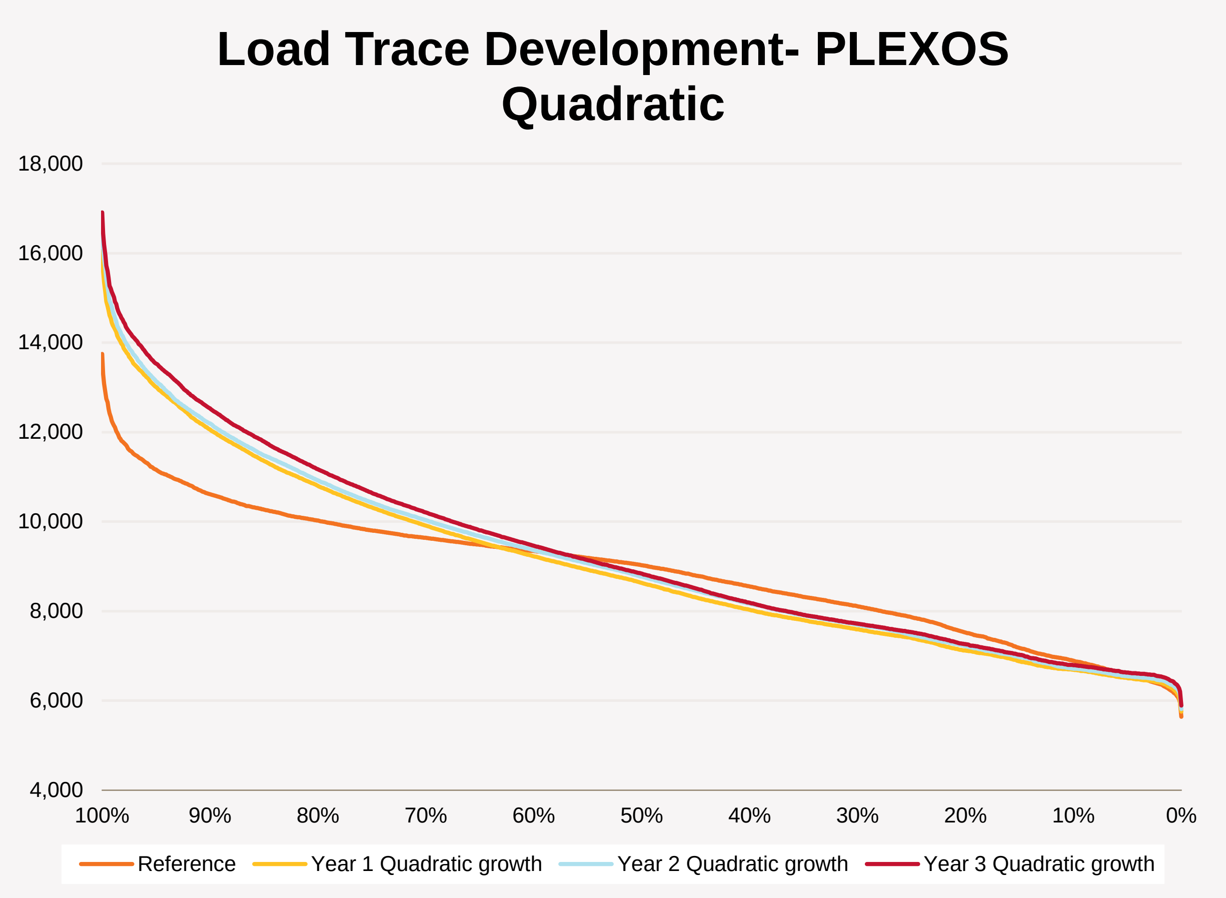


In Quadratic growth mode, the growth rate function is quadratic – points at the top of the demand duration curve are scaled by a factor that is quadratically higher than points at the bottom of the demand duration curve. This method allows a more realistic fit when maximum demand grows much faster than annual operational consumption.

The quadratic growth function also provides two additional tuning parameters to improve the flexibility of this approach. A “Relative Growth at Min” parameter specifies the amount of energy growth that will be applied to the tail of the load duration curve, and a “Max Shape Distortion” parameter controls the energy distribution across the middle of the load duration curve.

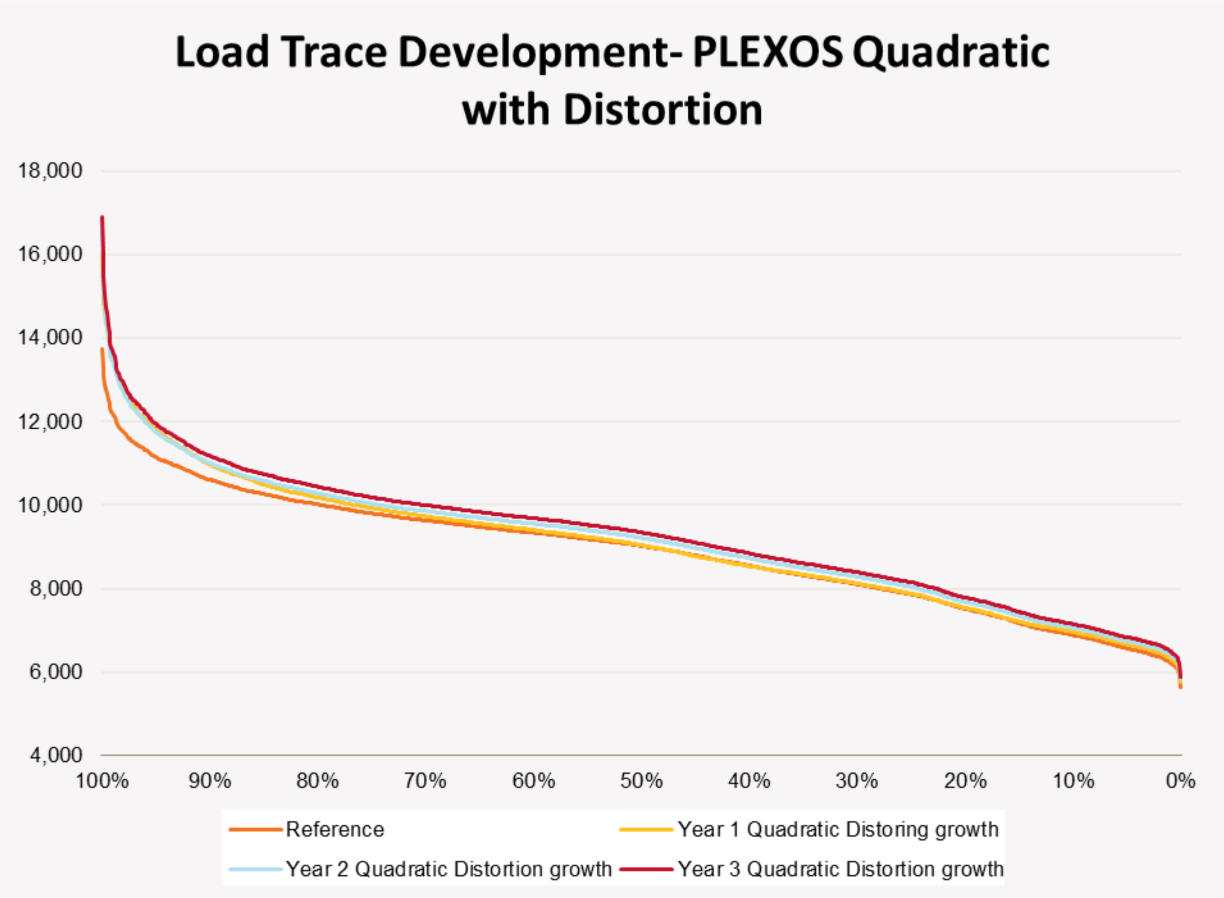
Figure 3 below shows the results of quadratic growth using a relative growth at minimum of 10% (of the annual operational consumption growth), and no distortion. This resulted in a better match than the linear method, but does not put enough energy in the mid-low demand range.

Figure 3 PLEXOS Quadratic



By also including a distortion factor, additional energy could be moved from the mid-high demands, into the mid-low demand range. The final result is shown in Figure 4 below.

Figure 4 PLEXOS Quadratic Distortion tuned



There is no one-size-fits-all set of parameters for these two quadratic parameters. A manual tuning process is undertaken during the demand growth process to ensure the parameters yield appropriate results for each region, and across simulation years.

2.3 Step 3: Adjust demand to account for large-scale non-scheduled wind generation

Table 1**Error! Reference source not found.** lists the large-scale non-scheduled wind farms that have been modelled explicitly to capture the impact of their variability on hourly demand, and their impact on network constraint equations. Because these units are modelled explicitly on the supply side, their contribution is removed from the output of step 1 (Section 2.1) must be reversed out of the demand side. This is done using wind traces based on the 2009–10 historical wind profile for each unit.

Table 1 Large-scale non-scheduled wind generation

Region	Wind farm
New South Wales	Capital
	Cullerin Range
Victoria	Challicum Hills
	Waubra
	Portland
	Yambuk
	Oaklands Hill
South Australia	Cathedral Rocks
	Canunda
	Lake Bonney 1
	Mt Millar
	Starfish Hill
	Wattle Point
Tasmania	Woolnorth

2.4 Step 4: Adjust demand to account for hourly rooftop PV generation

Rooftop PV traces were developed based on the published NEFR forecasts.[8] The original 20-year forecast was extended to 25 years to cover the NTNDP's outlook period.

A normalised solar PV irradiation profile for the 2009–10 year was overlayed with the NEFR projections on annual PV generation to create an hourly profile for each NEM region.

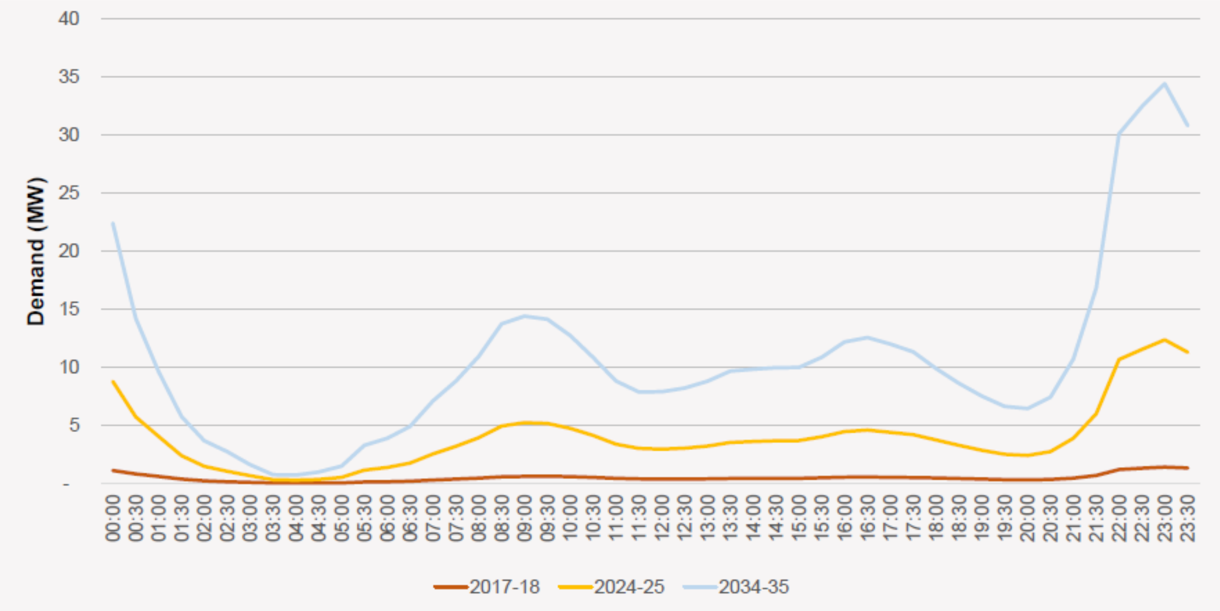
The total contribution from rooftop PV was treated as negative demand, and was subtracted from the demand traces developed in step 3 (see Section 2.1).

8 AEMO. Available http://forecasting.aemo.com.au/.

2.5 Step 5: Adjust demand to account for electric vehicle charging and battery storage

Electric vehicle charging profiles were developed, based on a forecast of the number of electric vehicles entering the Australian vehicle market, and applied to a daily charging profile for electric vehicles. For example, Figure 5 shows the electric vehicle charging profile used for New South Wales over a sample of years. The hourly regional electric vehicle charging demand was added to the demand traces produced in Section 2.4.

Figure 5 Median electric vehicle charging profiles (NSW)

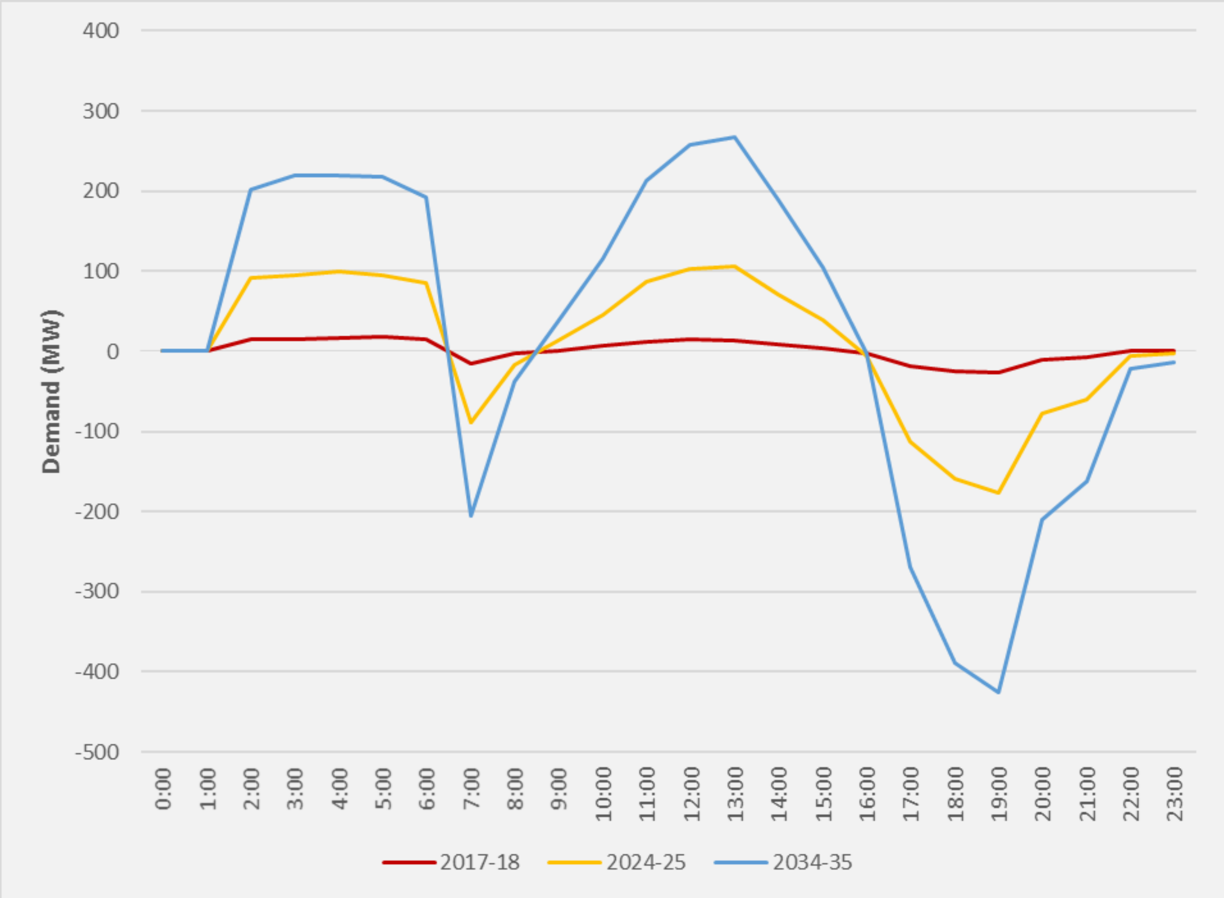


Battery storage profiles were forecast using an economic model that optimised integrated PV and Storage Systems (IPSS). For example, Figure 6 shows the median profile for New South Wales over a sample of years. Similar to electric vehicles, the profile is added to the demand trace.

For more information about electric vehicle charging or battery storage profiles, see AEMO's 2015 Emerging Technologies Information Paper.[9]

9 AEMO. http://www.aemo.com.au/Electricity/Planning/Forecasting/National-Electricity-Forecasting-Report/~/media/Files/Electricity/Planning/Reports/NEFR/2015/Emerging%20Technologies%20Information%20Paper.ashx.

Figure 6 Median battery storage profile (NSW)



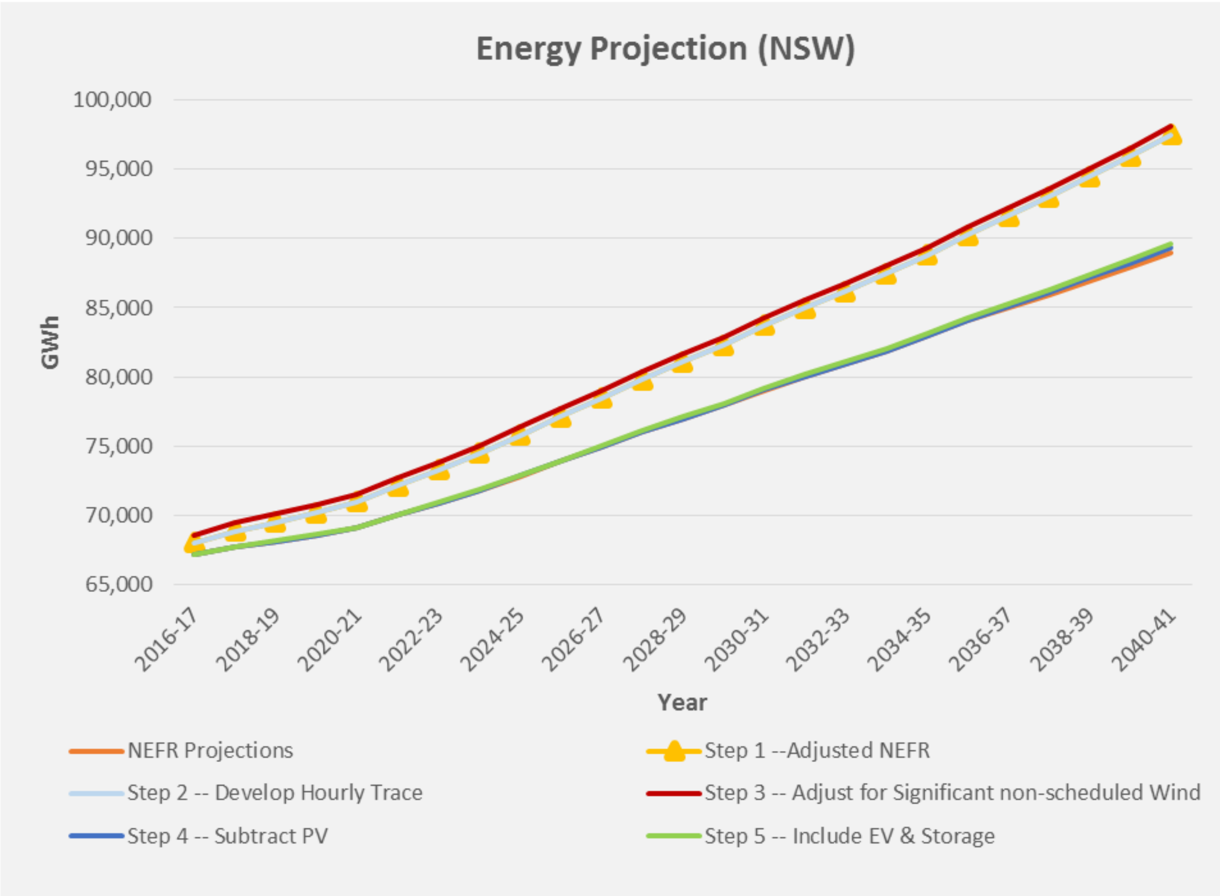
CHAPTER 3. THE IMPACTS ON DEMAND

This section graphically presents the results of the adjustments described in Chapter 2, to show the impacts on demand. All the data used in the following illustrations are based on the medium scenarios from the 2015 NEFR and 2015 Emerging Technologies Information Paper.

3.1 Energy projection

Figure 7 shows the impact from adjustments to the original energy projections in developing the NTNDP demand traces.

Figure 7 2015 NEFR energy projections for NSW



The hourly demand traces grown in PLEXOS (light blue) show the same energy profile as the adjusted NEFR forecasts (yellow). After the subsequent adjustments (some positive, some negative) the resulting modelled demand (green) is marginally higher than that presented in the NEFR. These values are consistent with each other, however modelled demand is expressed on a different basis that makes it appropriate for use in AEMO's least-cost and time-sequential modelling.

3.2 Regional maximum demand projection

As an example, Figure 8 and Figure 9 illustrate the impact of the adjustments detailed in Chapter 2, on the New South Wales summer and winter maximum demand projections under the medium scenario.

The impact of the adjustments described in Chapter 2 on the summer maximum demand projections is similar to that for the energy projections. The exception is rooftop PV generation, which shows a larger proportional contribution to lowering maximum demand (based on hourly output profiles) than the single-point value assumed by the 2015 NEFR. In addition, the assumed charging profiles of electric vehicles lead to a smaller contribution to peak demand than was seen in the energy projections. Together these effects result in the NTNDP modelled maximum demand being smaller than the NEFR maximum demand values.

The 2015 NEFR forecasts that the contribution of rooftop PV is minor during times of maximum demand in winter. Therefore, the adjustment has only a minimal effect until later in the outlook period.

Figure 8 New South Wales summer maximum demand projections

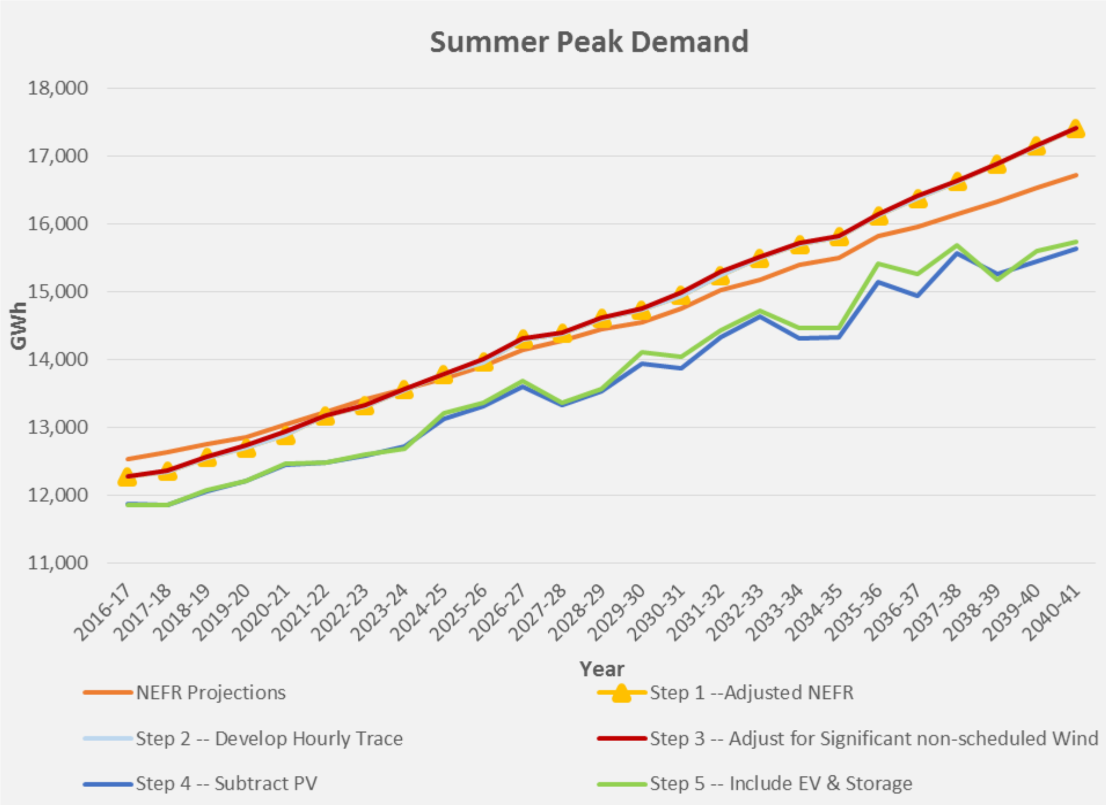
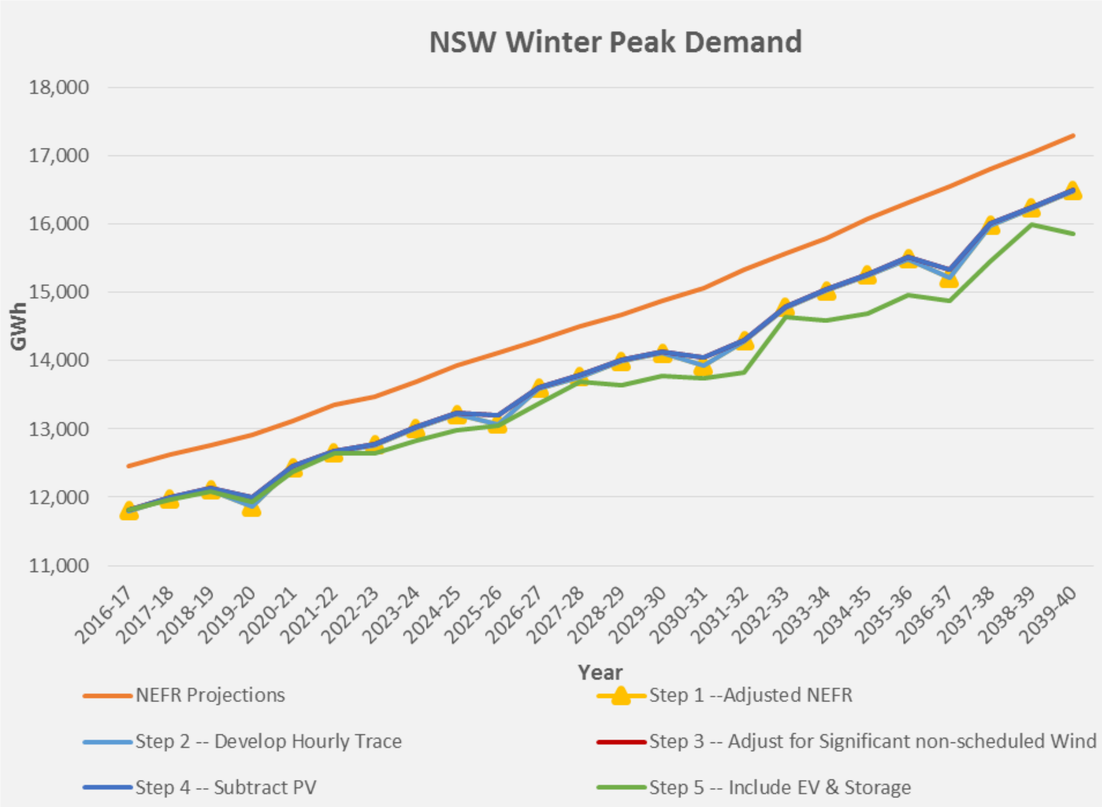


Figure 9 New South Wales winter maximum demand projection



3.3 Regional demand trace

The regional demand traces were developed using a single historical demand trace (2009–10), providing a reference profile for future demand.

Figure 10 and Figure 11 show the summer 3-day demand projections for New South Wales in 2020–21 and 2030–31, respectively. These figures show rooftop PV having the dominant impact on the shape of demand, in transitioning maximum demand times to later in the day, resulting in reductions on the overall level of demand.

Figure 10 Summer 3-day demand for New South Wales in 2020–21

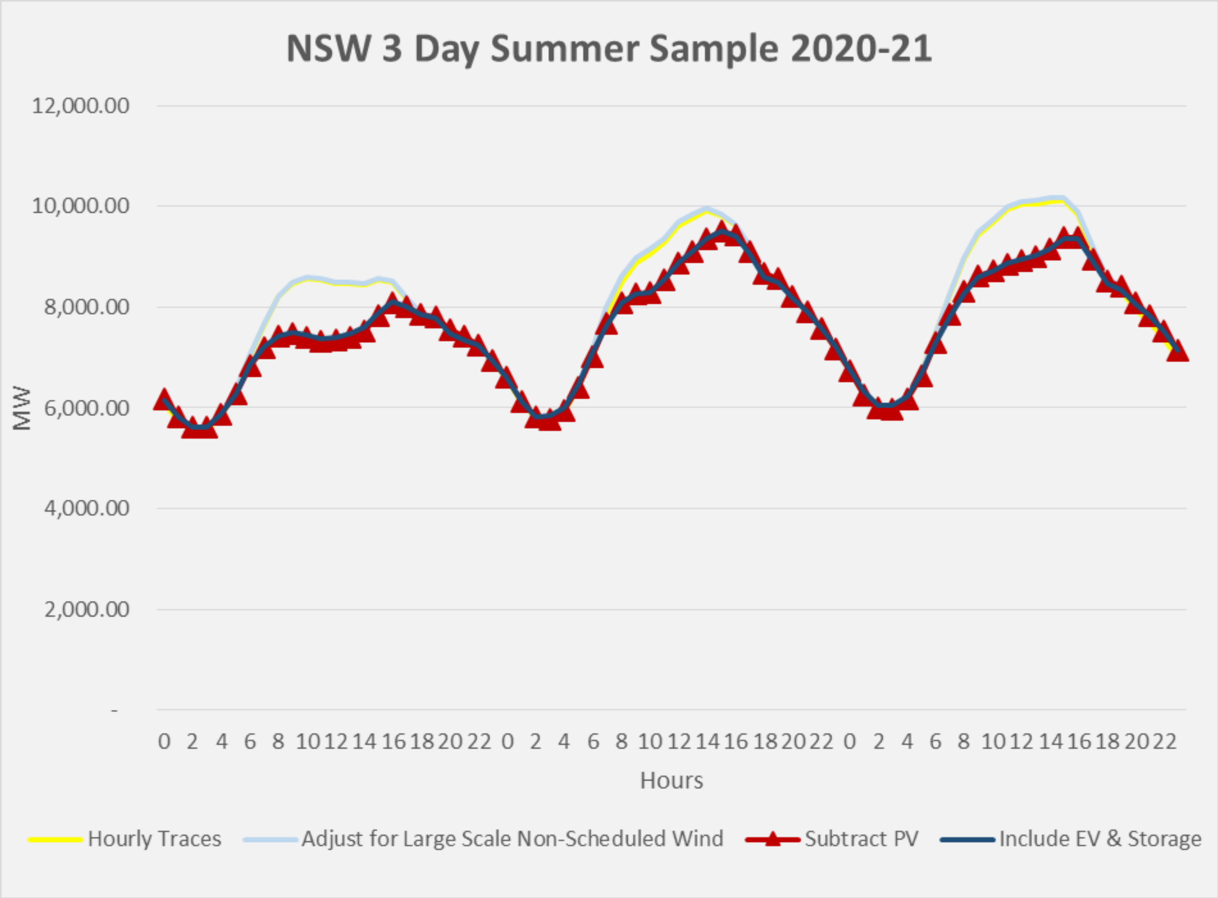


Figure 11 Summer 3-day demand for New South Wales in 2030–31