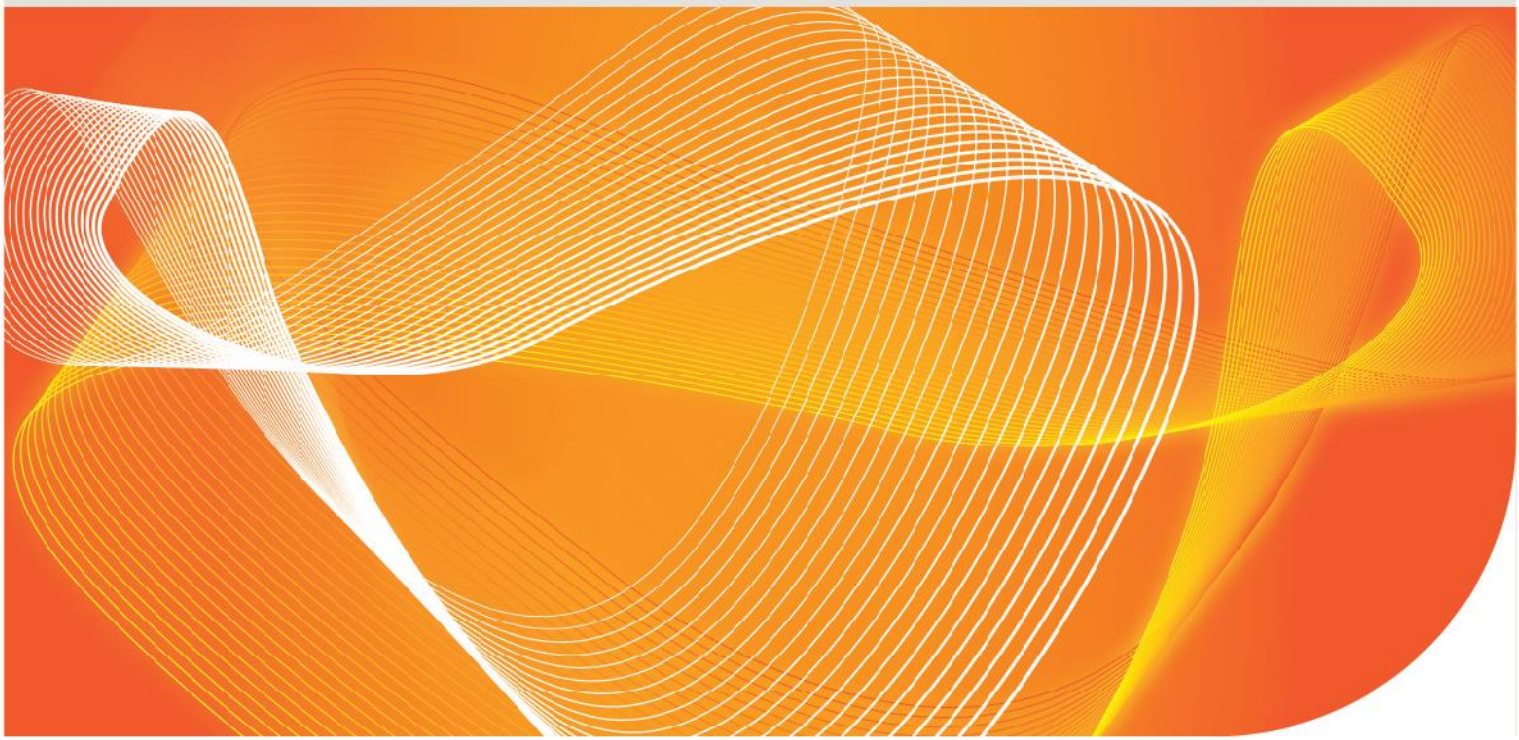
2017 ESOO METHODOLOGY

METHODOLOGY FOR THE NATIONAL ELECTRICITY MARKET ELECTRICITY STATEMENT OF OPPORTUNITIES

Published: **October 2017**



AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

IMPORTANT NOTICE

Purpose

AEMO has prepared this document to provide information about the methodology and assumptions used to develop the 2017 Electricity Statement of Opportunities for the National Electricity Market, as at the date of publication.

Disclaimer

This document or the information in it may be subsequently updated or amended. This document does not constitute legal or business advice, and should not be relied on as a substitute for obtaining detailed advice about the National Electricity Law, the National Electricity Rules, or any other applicable laws, procedures or policies. AEMO has made every effort to ensure the quality of the information in this document but cannot guarantee its accuracy or completeness.

Accordingly, to the maximum extent permitted by law, AEMO and its officers, employees and consultants involved in the preparation of this document:

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this document; and
- are not liable (whether by reason of negligence or otherwise) for any statements or representations in this document, or any omissions from it, or for any use or reliance on the information in it.

Version control

Version	Release date	Changes
1	16/10/2017	

CONTENTS

TABLES

FIGURES

CHAPTER 1. INTRODUCTION

This document provides a high level outline of the methodology and assumptions used to develop the *2017 Electricity Statement of Opportunities* for the National Electricity Market (NEM ESOO).[1]

The NEM ESOO provides technical and market data that informs the decision-making processes of market participants, new investors, and jurisdictional bodies as they assess opportunities in the NEM over a 10-year outlook period.

The key output of the NEM ESOO is an assessment of projected supply adequacy in the NEM and in each region, and of potential breaches of the NEM reliability standard.[2] The current reliability standard specifies that the level of expected unserved energy (USE) should not exceed 0.002% of the total energy demanded[3] per region, in any financial year.

The analysis is repeated for a range of scenarios, to indicate the robustness of outcomes to changes that may impact the market in future years. The assessment of supply adequacy to meet forecast demand is performed by probabilistic modelling, on a time-sequential basis, at an appropriate granularity, using a collection of assumptions to reflect the scenarios under investigation.

Full details of the modelling process are contained in an AEMO publication – *Market Modelling Methodology and Input Assumptions.*[4]

1.1 Shared assumptions with other AEMO publications

The 2017 NEM ESOO is part of a comprehensive suite of AEMO planning publications for the NEM and eastern gas markets. AEMO bases all its forecasting and analysis on a common set of assumptions and model inputs. AEMO's planning scenarios define key drivers behind electricity demand, generation costs and policy assumptions.[5] They outline different plausible futures and cover Neutral, Strong, and Weak outlooks for economic growth, population, and consumer sentiment.

[1] AEMO. *2017 NEM Electricity Statement of Opportunities*. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.
[2] AEMC. *Final reliability standard and settings guidelines published*. Available at: http://www.aemc.gov.au/News-Center/What-s-New/Announcements/Final-reliability-standard-and-settings-guidelines. Viewed 24 August 2017.
[3] See rule 3.9.3C of the National Electricity Rules for the full meaning of the term "unserved energy" in relation to the current reliability standard.
[4] AEMO. *2016 Market Modelling Methodology and Input Assumptions.* Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database.
[5] For more information about AEMO's scenarios, see https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2017/Draft-2017-Planning-and-Forecasting-scenarios.pdf.

CHAPTER 2. MODELLING NEM SUPPLY ADEQUACY

2.1 Methodology

Traditionally, the NEM ESOO modelling, in accordance with 3.13.3(q) of the National Electricity Rules, has focused on supply developments to meet forecast demand, including existing generators as well as those generators that satisfy AEMO's current commitment criteria.[6] It therefore provides an assessment of supply adequacy in the absence of uncommitted future development, to help stakeholders assess opportunities for additional supply connections in the NEM.

For 2017 ESOO modelling, AEMO has increased the number of scenarios modelled, to capture a broad range of possibilities that could occur in the NEM in the next 10 years. This includes demand projections, generation assumptions, and contingency events.

Three paths for renewable generation builds in the NEM have been modelled. The first renewable pathway modelled committed and existing capacity. There is currently a significant disparity between the capacity of renewable capacity connection requests in train (21,721 megawatts (MW)) versus the capacity that currently satisfies AEMO's commitment criteria (1,331 MW). Two alternative renewable pathways have therefore been included in the 2017 NEM ESOO to assess supply adequacy with additional renewable developments beyond the level committed (see Section 2.2).

The 2017 NEM ESOO modelling also included these announced government initiatives:

- The Victorian Government Energy Storage Initiative's battery.[7]
- The market-operated component of the South Australian Energy Plan's battery.[8]

It did not, however, include all government policy proposals and announcements. Proposals and announcements not considered include:

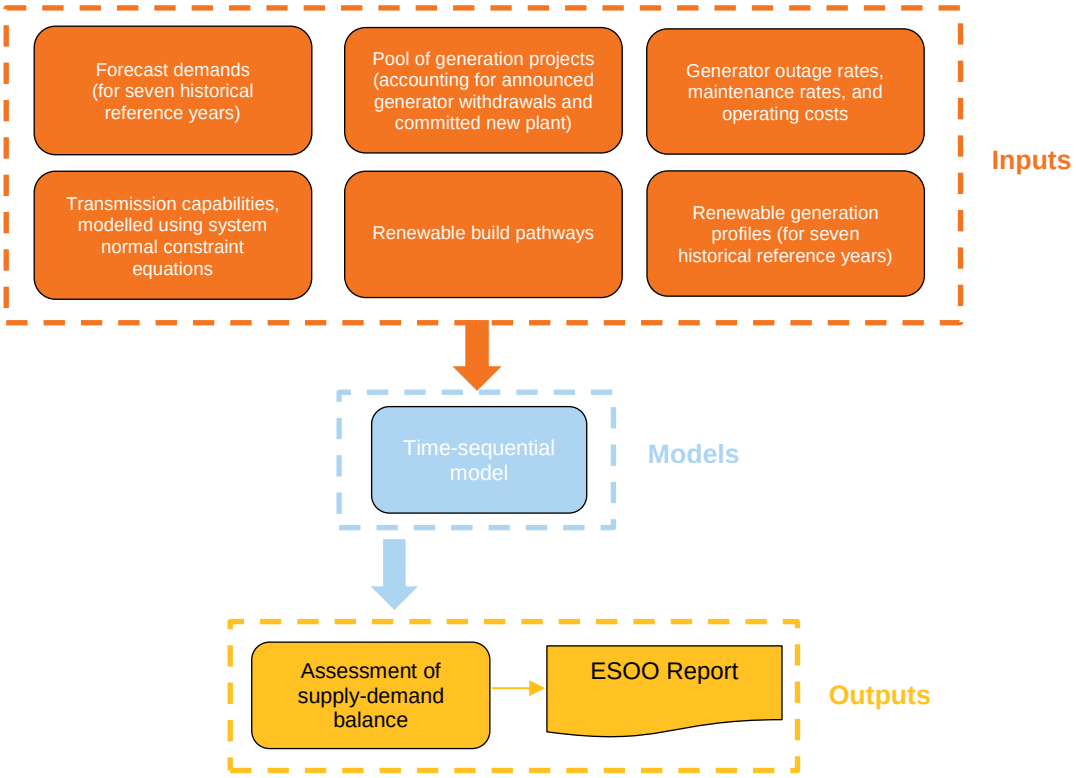
- Snowy Hydro 2.0.
- Powering Queensland Plan's 100 MW battery.[9]
- Powering Queensland Plan's 300 MW of renewable generation.
- South Australia's power purchase agreement for 150 MW of solar thermal generation.
- ElectraNet's 30 MW battery in South Australia.

The 2017 NEM ESOO also did not consider non-market operated actions through AEMO's Reliability and Emergency Reserve Trader (RERT) function or South Australia's Energy Plan, including, for example, diesel generation in South Australia and the joint AEMO and Australian Renewable Energy Agency (ARENA) Demand Side Participation (DSP) project.

Figure 1 summarises key input parameters used in the 2017 NEM ESOO modelling. The approach is explained in more detail below.

[6] AEMO's commitment criteria for generation are published in each regional spreadsheet on its Generation Information web page: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.
[7] Victorian Government media statement. "*Large Scale Energy Storage: An Investment In Jobs, Reliability And Affordability*", 14 March 2017. Available at: http://www.premier.vic.gov.au/large-scale-energy-storage-an-investment-in-jobs-reliability-and-affordability/.
[8] South Australian Government Energy Plan for Battery. Available at: http://ourenergyplan.sa.gov.au/battery.html.
[9] Queensland Government Powering Queensland Plan. Available at: https://www.dews.qld.gov.au/electricity/powering-queensland-plan.

Figure 1 Overview of key inputs into ESOO modelling



Calculating unserved energy

The NEM ESOO is based on probabilistic, time-sequential modelling. It models each scenario's specific demand and generation assumptions, and simulates hourly Monte Carlo simulations to determine potential future supply shortfalls.

These simulations capture the impact of key uncertainties, such as generator outage patterns, weather sensitive demand, intermittent generation availability, and coincidence of demand across regions.

The model performs optimised electricity dispatch for every hour in the modelled 10-year horizon, with the aim of minimising system costs incurred in meeting operational consumption across the NEM, subject to generation capability, fuel availability, and transmission constraints. In cases where there is insufficient generation or DSP to meet forecast demand, it results in USE.

For the 2017 NEM ESOO, the following parameters were simulated for each NEM region:

- The availability of generation capacity, accounting for planned and unplanned outages, and storage capabilities.
- The intermittent nature of wind and solar generation.
- DSP.
- Transmission network limitations.
- Electricity demand projections under a range of weather conditions, including the impact of rooftop photovoltaic (PV) systems.

In total, 210 probabilistic simulations were run for each year in the modelled horizon for each scenario, representing the variable nature of forced generator outages, intermittent generation, and demand patterns across regions.

The breakdown of simulations was as follows:

- Demand under extreme weather conditions (10% probability of exceedance (POE)[10]):
  - Seven historical reference years to represent variable patterns of intermittent generation and demand.
  - 20 generator forced outage patterns per reference year (Monte Carlo).
- Demand under moderate weather conditions (50% POE):
  - Seven historical reference years to represent variable patterns of intermittent generation and demand.
  - 10 generator forced outage patterns per reference year (Monte Carlo).

Assessing reliability standard breaches

The key output of the model is regional USE, enabling assessment of whether the current reliability standard is expected to be met.

Expected USE was derived by applying the following weightings to results from the moderate and extreme demand scenarios:

- 30.4% for 10% POE.
- 69.6% for 50% POE.

Where the expected USE is above the reliability standard, the NEM ESOO flags that the standard is not expected to be met. The year that happens is referred to as the Low Reserve Condition (LRC) point.

2.2 Key assumptions

Electricity demand

The scenarios cover different demand outlooks, which are inputs into the NEM ESOO. Rapid changes to energy technology, policy, the economic and societal drivers of consumption, the increasing interrelation between the electricity and gas sectors, and the tight supply-demand balance in both sectors have prompted a considerable increase in scrutiny on energy projections and risks.

AEMO is responding with more frequent forecast updates, including integrated energy system studies that consider the dynamics between gas and electricity and supply and demand, including the projected effect of international developments on an increasingly globally connected domestic gas market.

For the 2017 NEM ESOO, AEMO updated its forecasts of consumption and maximum demand.

Prior to the 2017 NEM ESOO projections, AEMO's most recent forecasts were:

- 2016 *National Electricity Forecasting Report* (NEFR) in June 2016 (used in the 2016 NEM ESOO, published August 2016).
- 2016 NEFR Update in March 2017 (used in AEMO's June 2017 *Energy Supply Outlook* (ESO)).
- 2017 *Electricity Forecasting Insights* (EFI) in June 2017 (informing DSP assumptions in the 2017 NEM ESOO).

Compared with these reports, the 2017 NEM ESOO used updated forecasts for annual consumption and maximum demand for all three scenarios: Neutral, Strong, and Weak. The updates included:

- Reviewing how rising energy prices may impact energy demand, and how this can be best accounted for in modelling methods. Of particular concern to AEMO is how the demand forecasting system should account for near-term supply-demand tightness, and the impact on shorter-term dynamics on peak demand that may be less transparent to AEMO. This includes

[10] Probability of Exceedance (POE) means the probability, as a percentage, that a maximum demand forecast will be met or exceeded (for example, due to weather conditions). For example, a 10% POE forecast is expected to be met or exceeded, on average, only one year in 10, so considers more extreme weather than a 50% POE forecast, which is expected to be met or exceeded, on average, one year in two.

competition dynamics, contractual terms in energy supply agreements, and operational responses to short-term supply scarcity.

- The findings of interviews with large industrial consumers in each region to update price response assumptions, including short-term behavioural responses by industry and households as well as long-term structural responses via investments in energy efficiency and rooftop PV.
- Recalibrating annual consumption forecasts, to have the starting point reflect actual demand levels observed in 2016–17. This accounts for more up-to-date information regarding major industrial production shifts, including, for example, the long-term outage impacting the Portland Aluminium smelter, as well as dynamics since January 2017 (which formed the basis of the 2017 EFI starting point).

The updated forecasts are presented in the 2017 NEM ESOO report and are available in detail on AEMO's demand forecasting portal.[11] The DSP forecast in AEMO's 2017 EFI was used in all scenarios.

Renewable Pathways

The 2017 NEM ESOO considered a number of generation pathways to capture a broad range of possibilities in the next 10 years. The pathways are:

- **Committed and existing generation** – including existing generation in the NEM and committed generation that meets AEMO's commitment criteria, in accordance with industry advice.[12]
- **Concentrated renewables** – assumes development after 2020 continues to be uncoordinated nationally, and concentrated particularly in Victoria, underpinned by the Victorian Renewable Energy Target (VRET).
- **Dispersed renewables** – assumes developments are driven by national targets that deliver a more even geographic spread of renewable generation across the NEM, leading to a greater penetration of renewables than is achieved if they are geographically concentrated.

Network

The model implements a simplification of the physical energy network, to manage the problem size while capturing sufficient resolution to produce meaningful results. A description of the topology of the network model, including the regional breakdown across the NEM regions, is provided in the *Market Modelling Methodology and Input Assumptions* document.

NEM ESOO scenarios

Combining the demand by scenario and generation pathways, the 2017 NEM ESOO modelled five scenarios summarised in Table 1.

Table 1 Scenarios modelled in the 2017 NEM ESOO

Scenario	Description
Committed and existing generation	Neutral demand forecast, committed and existing generation, DSP based on 2017 EFI.
Concentrated renewables	Neutral demand forecast, committed and existing generation PLUS concentrated renewables, DSP based on 2017 EFI.
Dispersed renewables	Neutral demand forecast, committed and existing generation PLUS dispersed renewables, DSP based on 2017 EFI.
Strong economic growth	Strong demand forecast, committed and existing generation PLUS dispersed renewables, DSP based on 2017 EFI.
Weak economic growth	Weak demand forecast, committed and existing generation PLUS dispersed renewables, DSP based on 2017 EFI.

[11] Demand forecasts available in detail at: https://forecasting.aemo.com.au.
[12] AEMO's commitment criteria for generation are published in each regional spreadsheet on its Generation Information web page at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

2.3 Data sources

Full details of data sources required for the NEM models are in the *Market Modelling Methodology and Input Assumptions* document. Table 2 summarises relevant inputs that have been updated since the 2016 NEM ESOO.

Table 2 Key sources of input data for 2017 NEM ESOO model

Input	Source
Demand projections	AEMO Updated Demand Forecast for 2017 NEM ESOO introduced in main ESOO document. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities. Detailed data available at https://forecasting.aemo.com.au.
Half-hourly demand profiles*	AEMO analysis of 2017 ESOO annual demand projections, as outlined in Section 3.2 of this report. Half-hourly profiles are averaged to hourly profiles within the time-sequential model. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities
DSP	AEMO 2017 EFI. Available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights/Key-component-consumption-forecasts/Demand-side-participation.
Fuel costs	As informed by consultants: • ACIL Allen (liquid fuel prices). • Core Energy Group (gas prices). • Wood Mackenzie (coal prices). Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database.
Generator information	As provided by industry participants. Available at: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.
Concentrated renewables	Renewable expansion plan, informed by analysis performed by AEMO. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.
Dispersed renewables	Renewable expansion plan, informed by analysis performed by AEMO. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.
Emission factors	ACIL Allen. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database.
Network constraints	Analysis by AEMO and other transmission network service providers (TNSPs). Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

* Further information on the process for converting maximum demand, minimum demand, and annual consumption projections into half-hourly profiles is contained in the *Market Modelling Methodology and Input Assumptions* document.

CHAPTER 3. METHODOLOGY CHANGES FROM 2016

AEMO has implemented a number of improvements since the 2016 NEM ESOO. These are summarised in the following sections.

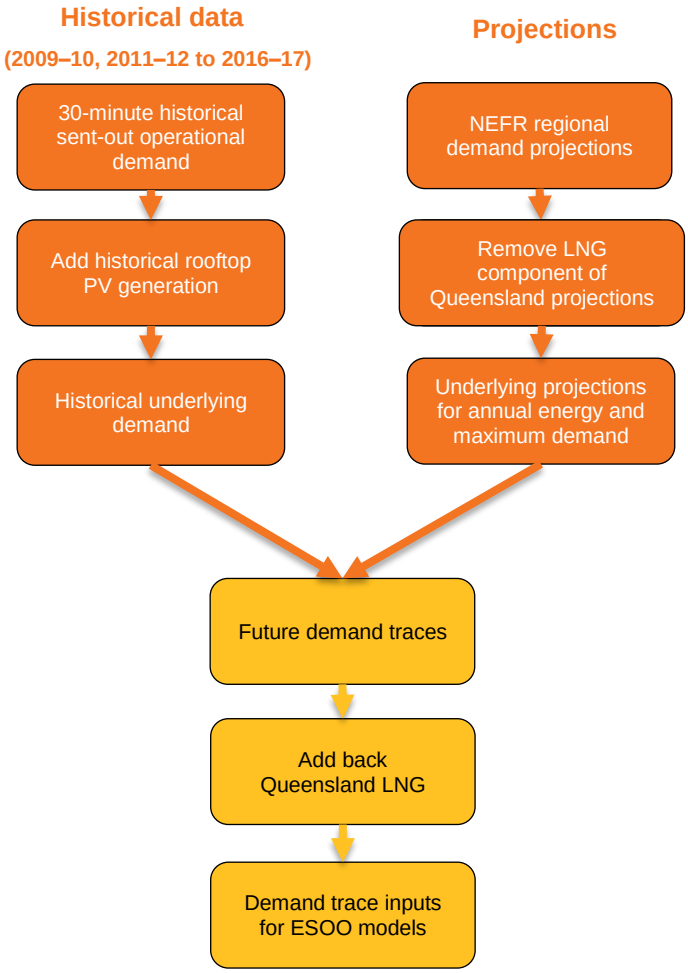
3.1 Reference years

In 2016, AEMO used hourly traces for demand and intermittent generation based on six reference years spanning 2009–10 to 2014–15. [13] For the 2017 NEM ESOO, AEMO added the 2015–16 and 2016–17[14] reference years, which captures recent extreme weather outcomes as experienced in February 2017. In total, seven reference years have been modelled.

3.2 Demand traces

The algorithm for creating demand traces for the different historical reference years for this ESOO used the same overall flow as explained in *Market Modelling Methodology and Input Assumptions* document.

Figure 2 Development of 2017 NEM ESOO demand traces



[13] The 2010–11 reference year has not been included, because the demand trace methodology used to grow historical years into future years did not preserve the shape of the historical demand sufficiently well, and could cause incorrect conclusions if used for forecasting.

[14] The 2016–17 reference year was constructed before the completion of the 2016–17 financial year. As such, it reflects the conditions observed from July 2016 to March 2017, with April, May, and June conditions reflecting those observed in 2016. As supply shortfalls are most likely during summer demand conditions when temperatures are highest, it was considered more prudent to include this partial year in the 2017 GSOO methodology than to hold it until 2018 when the full year's data would be available.

To cover more up-to-date information on demand conditions, such as major industrial production shifts, AEMO updated its forecast for maximum demand and recalibrated its projected annual consumption for the 2017 NEM ESOO. Discussion on the demand forecast update and approach is presented in the 2017 NEM ESOO.[15]

3.3 Intermittent generation

As discussed in Section 3.1, AEMO developed intermittent generation traces based on seven reference years spanning 2009–10 to 2016–17. Expanding the number of reference years allowed the model to better capture the varying contributions of wind and solar output to total supply, which is particularly important at times of high demand.

Wind

For wind farms that were not operational across the full seven reference years, a model was used to estimate what the output would have been in each hourly interval of those reference years. The model used historical correlations and geographic proximity to synthesise missing data points for existing and committed wind farms. Further details are provided in the *Market Modelling Methodology and Input Assumptions* document.

Rooftop PV

The output of rooftop PV and non-scheduled PV generators[16] in the seven reference years was estimated from a model developed as a collaborative project between AEMO and the University of Melbourne.[17] The model provided half-hourly normalised generation traces.[18] These were multiplied with estimates of installed capacity across the reference years to obtain historical generation traces.

Rooftop PV has been modelled as a generator in the time-sequential model, rather than a reduction in operational demand.

Large-scale PV

Large-scale PV generation is simulated using the System Advisor Model (SAM)[19], a computer model developed at the National Renewable Energy Laboratory (NREL) that calculates the hourly generation output of solar generators.

To calculate these outputs, input data for SAM includes project characteristics such as the panel technology type (fixed flat plate, single axis, or dual axis tracking) and nameplate capacity, solar irradiance data, and weather conditions.

Irradiance and weather data were based on historical information from the closest Bureau of Meteorology (BOM) weather station to the latitude and longitude of each project. The model generated hourly generation traces in seven reference years, correlated to demand and wind generation profiles.

[15] AEMO. *2017 Electricity Statement of Opportunities.* Available at: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2017/2017-Electricity-Statement-of-Opportunities.pdf.

[16] This includes PV installations larger than 100 kW but smaller than 30 MW in capacity.

[17] AEMO. *2016 Forecasting Methodology Information Paper*. Available at: http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report.

[18] The normalised trace has values between 0 and 1 for each half-hourly interval. A value of 1 indicates the system is operating at rated capacity, and 0 indicates no output.

[19] NREL. *System Advisor Model (SAM)*. Available at: https://sam.nrel.gov/.

Battery storage

The 2017 NEM ESOO modelling included the following large-scale battery storage projects:

- The reliability portion of the 129 megawatt hour (MWh)/100 MW battery (120 MWh/30 MW) from the South Australian Energy Plan.
- The Victorian Government Energy Storage Initiative's battery storage.[20]

These batteries have been modelled in the 2017 NEM ESOO to provide emergency backup during periods of supply shortfall. They were assumed to be used after all DSP has been exhausted in the region in which they are installed.

Given the purpose of the NEM ESOO is an assessment of supply adequacy, potential operation to target arbitrage opportunities was not included, and the batteries were modelled to ensure maximum availability during periods of supply shortfall.

The 2017 NEM ESOO has not modelled ElectraNet's 30 MW battery,[21] or the proposed Powering Queensland Plan's 100 MW battery.

Small-scale (residential or commercial "behind-the-meter" battery storage installations, on consumers' premises) have not been accounted for. These customer installations are expected to operate to minimise customer exposure to retail costs and network tariffs. The reliability of the installations being available to meet peak demands is not certain.

AEMO is considering how this may be better captured in modelling in future years, including considering how storage optimisation may change if aggregated to provide DSP at time of system peak.

[20] Available at: https://www.energy.vic.gov.au/batteries-and-energy-storage.
[21] *ElectraNet's Battery Storage Project*. Available at: https://arena.gov.au/blog/southaustraliabattery/.