2016 ESOO METHODOLOGY

METHODOLOGY FOR THE NATIONAL ELECTRICITY MARKET ELECTRICITY STATEMENT OF OPPORTUNITIES

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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 *2016 National Electricity Market Electricity Statement of Opportunities*, as at the date of publication.

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CONTENTS

TABLES

FIGURES

CHAPTER 1. INTRODUCTION

This document provides a high level outline of the methodology and assumptions used to develop the *2016 National Electricity Market Electricity Statement of Opportunities* (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 NEM ESOO modelling is an assessment of projected supply shortfalls and potential breaches of the NEM reliability standard.[2] The reliability standard specifies that the level of expected unserved energy should not exceed 0.002% of operational consumption per region, in any financial year.

The analysis is repeated for a range of scenarios, to determine the robustness of outcomes to changes in modelled assumptions.

The 2016 NEM ESOO is based on detailed modelling of the NEM and incorporates two models referred to as the “generation capacity outlook” and “time-sequential” models. Full details of the modelling process are contained in an accompanying document – *Planning Methodology and Input Assumptions.*[3]

1.1 Shared assumptions with other AEMO publications

The NEM ESOO is part of a comprehensive suite of annual AEMO planning publications for the NEM and eastern gas markets, an overview of which is shown in Figure 1. AEMO bases all its forecasting and analysis on the same set of assumptions and inputs, so there is a consistent basis for all its models and projections.

The NEM ESOO process begins with the annual *National Electricity Forecasting Report* (NEFR)[4], which produces electricity demand forecasts.

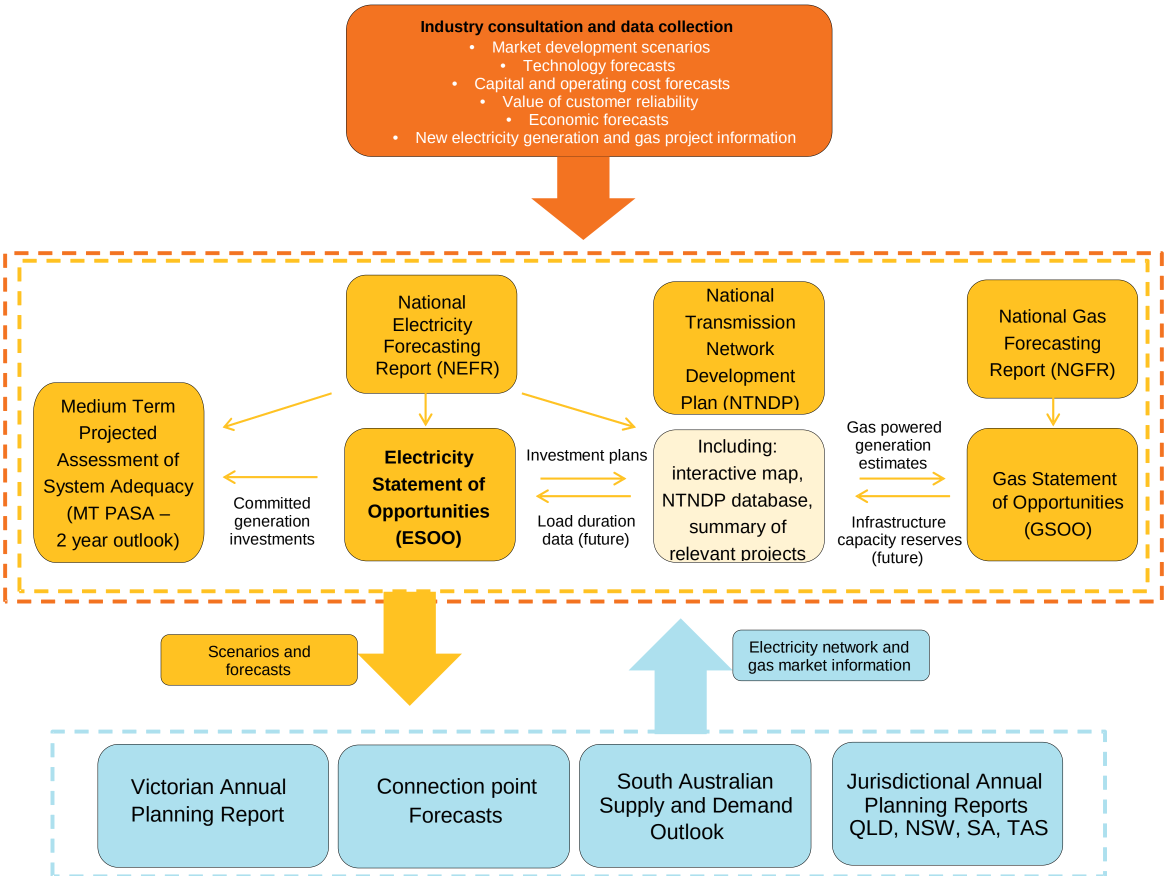
[1] AEMO. *2016 Electricity Statement of Opportunities*. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities.

[2] AEMC. *NEM Reliability Standard – Generation and Bulk Supply*. Available at: http://www.aemc.gov.au/getattachment/f93100d9-72d2-46fb-9c25-ac274a04ae58/Reliability-Standards-(to-apply-from-1-July-2012).aspx. Viewed 18 July 2016.

[3] AEMO’s models and common assumptions have been updated for 2016 forecasting and planning reports, and will be published in late 2016 to accompany the *2016 National Transmission Network Development Plan*. The previous version, *Planning Methodology and Input Assumptions, January 2014*, still provides some relevant detail and is available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/-/media/FBBF4E5174DF472DAAB429E57799F4F0.ashx.

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

Figure 1 AEMO's planning and forecasting publications – NEM and eastern gas markets



CHAPTER 2. MODELLING THE NEM

2.1 Methodology

NEM ESOO modelling incorporates two models of the NEM, referred to as the generation outlook and time-sequential models. Each 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 models, including the regional breakdown across the NEM regions, is provided in the *Planning Methodology and Input Assumptions* document.

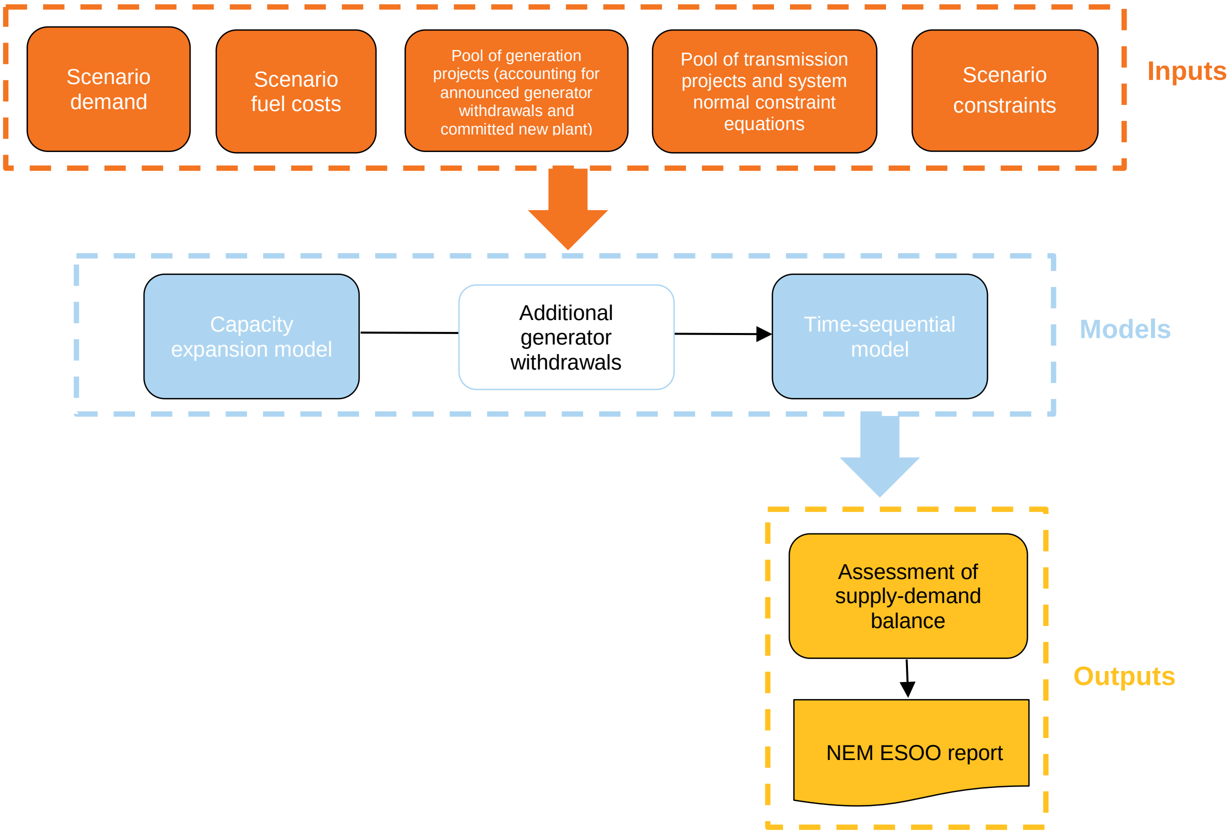
For the NEM ESOO, the two models interact as follows:

- The generation outlook modelling provides insight into future generation withdrawals and entry of new generation capacity that could occur, over and above current industry announcements, to efficiently meet future operational demand and climate change policies.
- The time-sequential modelling takes industry-announced new entry and generation capacity withdrawals and assessed future generation withdrawals from the generation outlook model, and runs 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 NEM ESOO time-sequential modelling does not include any new development in response to either potential supply shortfalls or government policy. Instead, it provides an assessment of supply adequacy in the absence of future development, to help stakeholders assess opportunities in the NEM.

Figure 2 summarises key input parameters and the interaction between the two models.

Figure 2 Overview of NEM ESOO models



2.1.1 Generation capacity outlook model

Generation capacity outlook modelling is the process of optimally adding new generation and transmission to the NEM, or removing existing generation, as future demand changes and constraints are applied to the system. The resulting set of generation and transmission facilities and the time at which they are implemented is referred to as the generation outlook.

In this context, "optimal" refers to the generation outlook that results in the lowest combined operating, capital, and reliability cost incurred to operate the NEM over the course of the modelled time horizon. Further details of AEMO's generation capacity outlook model are provided in the *Planning Methodology and Input Assumptions* document.

2.1.2 Time-sequential model

The time-sequential model takes a detailed look at the supply-demand balance at a much higher resolution, to provide an assessment of future supply adequacy. 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.

The following parameters are simulated for each NEM region:

- The availability of generation capacity, accounting for planned and unplanned outages.
- The intermittent nature of wind and solar generation.
- Demand-side participation activity.
- Transmission network limitations.
- Electricity demand projections under both moderate and extreme weather conditions.[5]

In total, 126 Monte Carlo simulations are run for each year in the modelled horizon, representing the variable nature of forced generator outages, intermittent generation, and demand patterns across regions. The breakdown of simulations is as follows:

- Demand under extreme weather conditions (10% probability of exceedance (POE)):
  - Six historical reference years to represent variables patterns of intermittent generation and demand (2009–10 to 2014–15).
  - 14 generator forced outage patterns.
- Demand under moderate weather conditions (50% POE):
  - Six historical reference years to represent variables patterns of intermittent generation and demand (2009–10 to 2014–15).
  - Seven generator forced outage patterns.

2.1.3 Assessing reliability standard breaches

A key output from the model is regional unserved energy (USE), enabling assessment of any projected reliability standard breaches.

Expected USE is 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.

The 2016 ESOO also includes charts showing the distribution of unserved energy in each NEM region, to inform stakeholders of the size of any potential supply shortfalls, and the frequency of occurrence, across the Monte Carlo simulations.

[5] Represented in the 2016 ESOO as 50% POE and 10% POE demand conditions.

2.2 Data sources

Full details of data sources required for the NEM models are in the *Planning Methodology and Input Assumptions* document. Table 1 summarises relevant inputs that have been updated since last year.

Table 1 Key sources of input data for NEM models

Input	Source	Website address
Demand projections	AEMO 2016 NEFR	http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report
Half hourly demand profiles[6]	AEMO analysis of NEFR annual demand projections, as outlined in section 3.3. Note: half hourly profiles are averaged to hourly profiles within the time-sequential model	http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Planning-assumptions
Fuel costs	Wood Mackenzie (coal prices), Core Energy Group (gas prices)	http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Planning-assumptions
Generator information	Industry participants	http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information
Generator withdrawal categories	Industry participants	2016 ESOO Appendix A, available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities
Emission factors	ACIL Allen 2016	http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Planning-assumptions
Network constraints	Analysis by AEMO and other TNSPs	http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Electricity-Statement-of-Opportunities

2.3 Scenarios

AEMO has updated its scenarios framework for forecasting and planning publications, and now considers a range of demand sensitivities that represent likely pathways for Australia across weak, neutral, and strong economic and consumer outlooks.[7]

Australia has set a target to reduce carbon emissions by 26% to 28% below 2005 levels by 2030, agreed at the 2015 Paris 21st Conference of Parties (COP21), and building on the 2020 target of reducing emissions by 5% below 2000 levels. For energy sector modelling, the Council of Australian Governments (COAG) Energy Council has agreed that the contribution of the electricity sector should be consistent with national emission reduction targets. COAG has stated that a 28% reduction from 2005 levels by 2030 is an appropriate constraint for AEMO to use in its ongoing forecasting and planning processes.

Four 2016 NEM ESOO scenarios have been modelled, combining the demand sensitivities with the COP21 commitment, as summarised in Table 2.

Table 2 Scenarios modelled in the 2016 ESOO

Scenario	Description
Weak Growth COP21	Weak scenario described in NEFR, achievement of COP21 emissions reduction target.
Neutral Growth COP21	Neutral scenario described in NEFR, achievement of COP21 emissions reduction target.
Strong Growth COP21	Strong scenario described in NEFR, achievement of COP21 emissions reduction target.
Neutral Growth	Neutral scenario described in NEFR, no emissions constraints.

6 Further information on the process for converting annual NEFR demand projections into half hourly profiles is contained in the *Planning Methodology and Input Assumptions* document.

7 Details of the sensitivities are provided in the *2016 National Electricity Forecasting Report*. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report.

CHAPTER 3. METHODOLOGY CHANGES FROM 2015

A number of improvements have been implemented since the 2015 NEM ESOO. These are summarised in the following sections.

3.1 Models

The generator capacity outlook model was not required for NEM ESOO modelling in 2015, since no generator withdrawals or new entrants (other than those announced by market participants) were considered. This year the generator capacity outlook model has been run to provide guidance on additional generator withdrawals that may be required to help meet emissions reduction targets. It is assumed that generator withdrawals would be one component of a number of changes to contribute to lowering NEM emissions, including changing patterns of demand and investment in new plant with zero or low emissions.

In previous years, the time-sequential model was implemented using Prophet software. PLEXOS software has been used for both the generation outlook and time-sequential modelling in 2016.

3.2 Reference years

In previous years, a single historical year was used to represent the pattern of demand and intermittent generation across the NEM, with 2009–10 deemed to be a representative year. In the 2016 NEM ESOO, demand and intermittent generation traces have been developed based on six reference years spanning 2009–10 to 2014–15. Expanding the number of reference years has allowed the model to better capture uncertainties in demand and intermittent generation profiles across the NEM.

3.3 Demand traces

The methodology for creating demand trace inputs for the NEM ESOO models has been updated. The process used for the 2016 NEM ESOO is summarised in Figure 3 and described below:

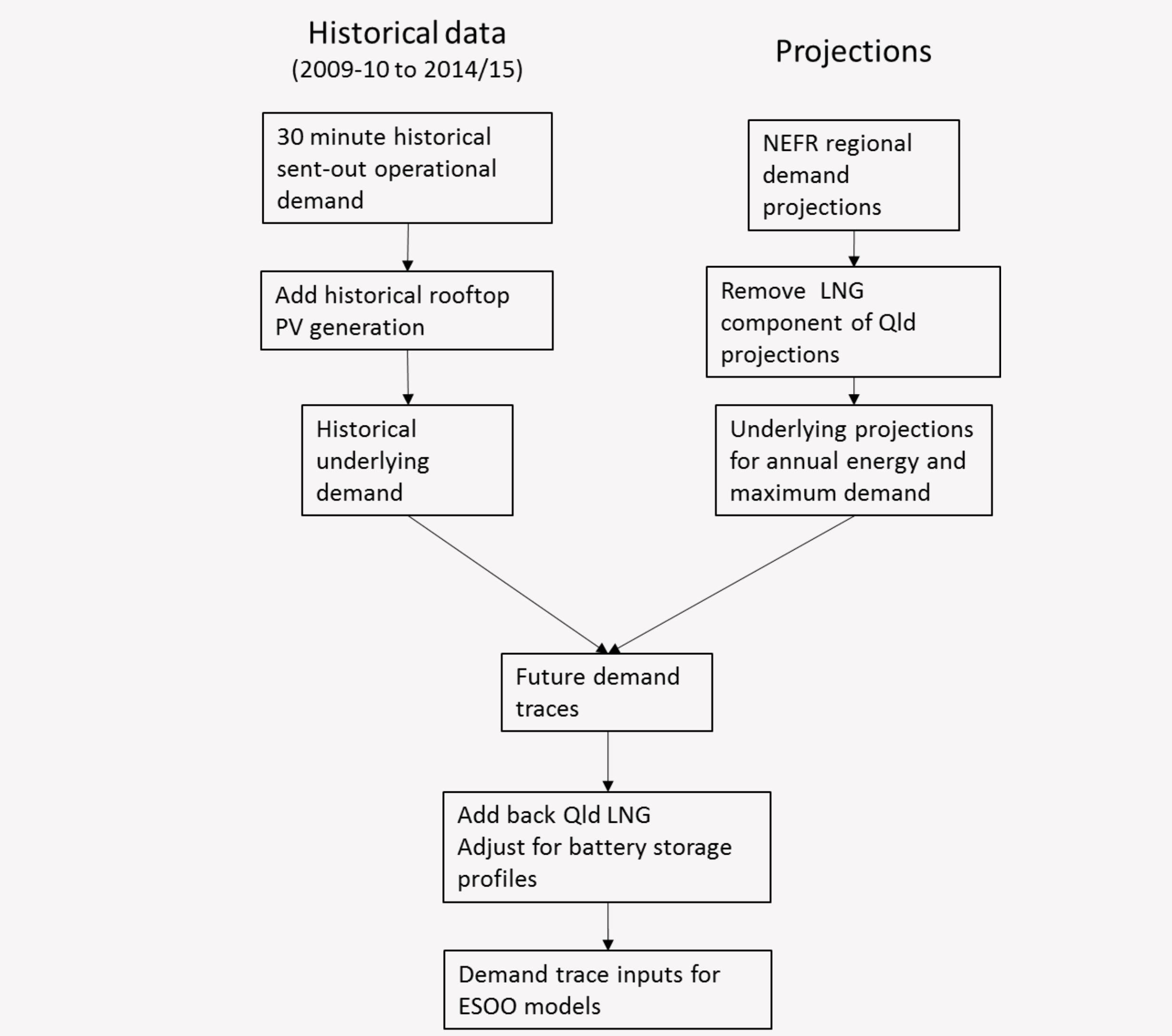
- Representative traces were obtained using historical data from 2009–10 to 2014–15.[8] Estimated production by rooftop PV generators over the same period was added to the demand traces to obtain historical traces representing total underlying demand. Rooftop PV is modelled explicitly as generation in the NEM ESOO modelling. Further details of the methodology used to obtain historical PV traces is provided in section 3.4.
- Projections of future levels of annual underlying energy consumption and maximum demand in each region were obtained from the 2016 NEFR. Projections of demand from the Queensland LNG export industry were subtracted from Queensland demand.[9]
- Derived underlying traces were “grown” to represent future energy consumption and maximum demand. Future LNG export demand was assumed to have a flat profile across the year and added to the future Queensland demand traces.
- Adjustments were applied to reflect changes in the shape of future demand traces due to increasing uptake of battery storage. A regional charging/discharging profile was assumed, representing the profile of all rooftop PV systems in each region. Charging was assumed to generally occur overnight and during the day, and discharging during the hours of evening peak demand. Further details of assumed battery storage operating profiles are available in the 2016 NEFR.[10]

[8] Based on 30 minute sent-out operational data. Available at: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Market-Management-System-MMS/Generation-and-Load.

[9] This step was necessary because historical traces do not include Queensland LNG demand. LNG demand is expected to have a flat profile across the year; this is different to other sources of demand and will change the shape of future Queensland demand traces.

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

Figure 3 Development of NEM ESOO demand traces



3.4 Intermittent generation

As discussed in section 3.2, intermittent generation traces have been developed based on six reference years spanning 2009–10 to 2014–15. 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.

For wind farms that were not operational across the full six reference years, a model was used to estimate what the output would have been in each hourly interval of the six-year reference period. 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 *Planning Methodology and Input Assumptions* document.

The output of large-scale and rooftop PV generators in the six reference years was estimated from a model developed as a collaborative project between AEMO and the University of Melbourne.[11] The

[11] AEMO. *Methodology summary – NEM rooftop PV generation model*, 2016. Available at: http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Electricity-Forecasting-Report.

model provided half-hourly normalised generation traces.[12] 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. Due to the deterministic nature of the PV traces obtained from the six reference years, there may be differences of up to 2% between the NEFR maximum demand projections and those implied in the NEM ESOO hourly simulation models.

There are plans to further refine the modelling of intermittent generation in future work, with the aim of ultimately implementing a stochastic model to represent variability in output.

3.5 Plant withdrawal categories

One of the inputs to the NEM ESOO models is the planned withdrawal of generation capacity from the market, based on announcements made by market participants. In previous years only a single category of withdrawal existed, which made no distinction about whether it was possible to ever return a generation plant to service. It was therefore assumed that if a generating unit was withdrawn, it remained withdrawn for the entire 10-year NEM ESOO horizon.

For the 2016 NEM ESOO, AEMO refined the categorisation of withdrawn generators to allow sensitivity testing around the potential reinstatement of withdrawn plant. After consultation with stakeholders, announced generator withdrawals are now classified as falling into one of the categories defined in Table 3.

Table 3 Classification of announced generator withdrawals

Category	Recall time
Removed	Not available for recall
Short-term withdrawal	Within three months
Seasonal withdrawal	Between three and six months
Long-term withdrawal	Generally between six and 12 months[a]

[a] Long-term storage may occasionally exceed 12 months.

It was anticipated that sensitivity testing of withdrawn generation would be conducted if reliability breaches were identified in the neutral scenario, however this was not observed in the 2016 NEM ESOO results. The new classification scheme will be retained to allow sensitivity testing in future work.

3.6 COP21 and emission factors

The inclusion of the COP21 emissions target in the generation outlook is a key change in the 2016 methodology. Emissions constraints were not considered in the 2015 ESOO.

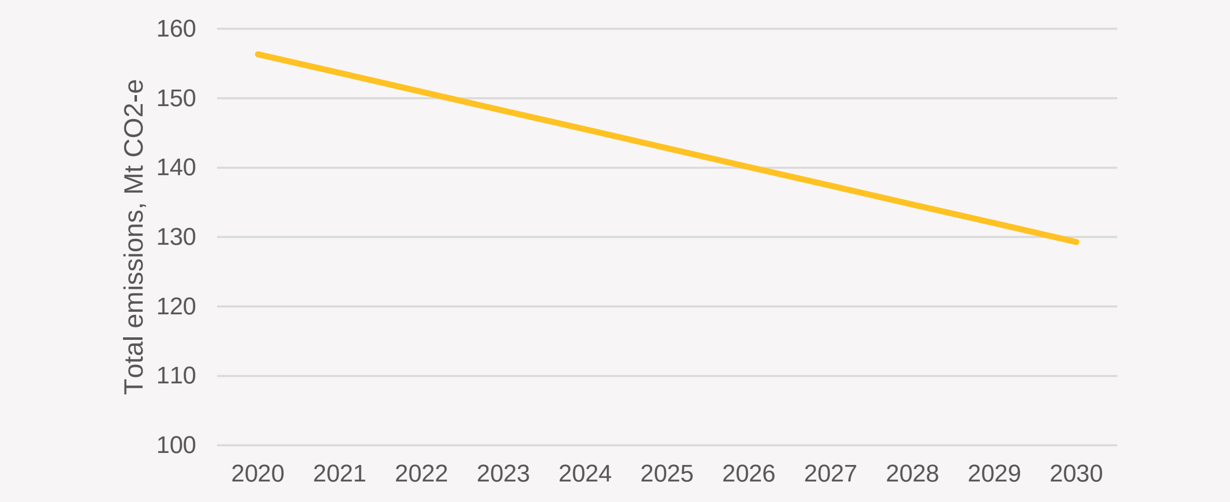
Total NEM emissions in 2005 have been estimated to be 179.5 million tonnes of carbon dioxide equivalent (Mt CO2-e), based on a review undertaken by ACIL Allen Consulting.[13] This translates to a 2030 target of 129.3 Mt CO2-e. Before 2020 no emissions constraint has been applied.

The trajectory of the emissions target between 2020 and 2030 has been assumed to follow a linear trend, as indicated in Figure 4.

[12] 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.

[13] ACIL Allen Consulting. May 2016. *Emission Factors Assumptions Update*. Available at: http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/NEM-Planning-assumptions .

Figure 4 NEM emissions target



ACIL Allen Consulting were also engaged to provide updated emission factors to accurately model emissions for each NEM generator, as indicated in section 2.2.