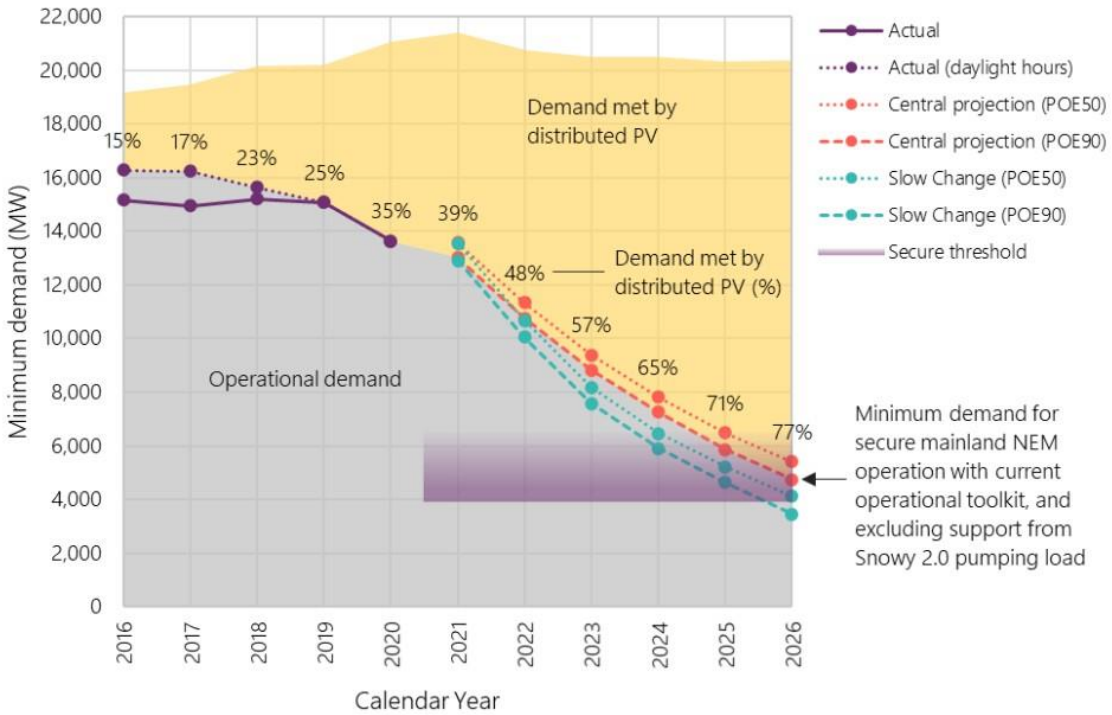
PS2 Q1: How are short, shallow, and frequent events distinguished from long, deep, and rare (low probability high impact) events and factored in the resource adequacy studies? How are fuel adequacy, fuel transportation and transmission issues factored in the resource adequacy studies? Considering the large amount of data associated with resource adequacy studies, how are visualization and stakeholder communication challenges handled?

The constitution of the Australian National Electricity Market (NEM) generation supply has changed remarkably quickly over the past 15 years. The approximately 50,000 MW power system was supplied by conventional coal and gas with modest hydro resource system for the past 40 years. This is moving to a grid which is fast approaching potential for periods of 100% instantaneous renewable generation sources. A significant contributing factor to the rapid change is massive uptake of residential rooftop PV, large scale solar PV and wind generation. Rooftop PV in aggregate is now by far the largest single source of daytime generation. Somewhat ironically, the high quantities of rooftop PV have led to system security challenges resulting from operating the grid with decreasing minimum daytime demand and fewer synchronous generation facilities on-line. An excellent visualisation of this challenge is presented in Figure 2 and Figure 3 in the AEMO 2021 Electricity Statement of Opportunities[1].

Figure 2 Minimum demand on the NEM mainland (excluding Tasmania)

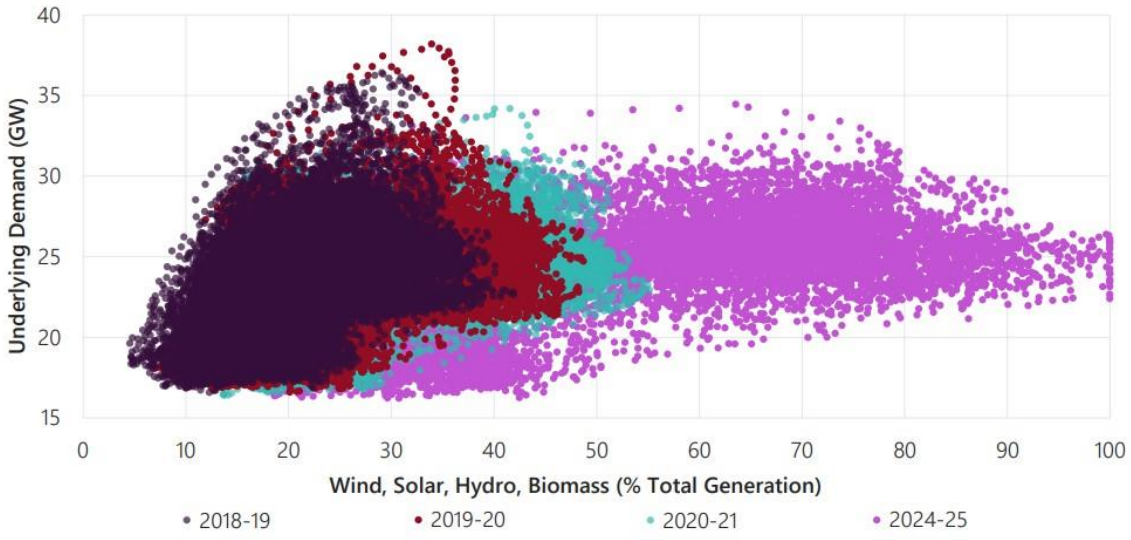


Notes: 90% probability of exceedance (POE) means demand is expected to be lower than forecast one year in 10; 50% POE means demand is expected to be lower one year in two. Forecasts are "as generated", meaning they are measured at each generating unit's terminal point and represent the unit's gross electrical power output, including power "sent out" to meet demand and power used to operate the generating unit.

[1] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2021/2021-nem-esoo.pdf?la=en

Figure 2 above shows the observation and projection of decreasing minimum demand which is surely contributing to financial pressure and technical challenges leading to retirement and closure of conventional coal fired generation facilities. Figure 3 below presents a forecast of the rapid increase in observed and forecast expectation of the proportion of underlying demand that is met by renewable generation sources. As renewable generation sources become more dominant, forecasting reliability metrics must necessarily be enhanced to study the availability patterns of intermittent renewable generation resources and at the same time be cognisant of the increased stress and age of existing facilities leading to higher unplanned outage rates.

Figure 3 NEM-wide penetration of renewable resources (large-scale and distributed), 2018-19 to 2020-21, with indicative resource potential forecast for 2024-25 based on existing, committed, and anticipated projects and distributed PV forecasts



In direct response to the changing dynamic of the NEM supply resources, forecast adequacy assessment has radically evolved from static pre-computed capacity reserve levels (regional Minimum Reserve Levels) to massively computational Monte Carlo simulation. By moving to hourly or half-hourly time sequential simulation, the potential impact of unplanned outages of individual generation facilities can be captured along with coincidence of underlying demand, wind and solar generation availability through a “weather reference year” approach. As such, Monte Carlo simulations are capturing variability in:

1. Underlying time-series demand driven by economic growth (High, Medium, Low) and probability of exceedance peak demand driven by weather (10%, 50%, 90%)
2. Location specific resource availability of large scale wind and solar generation facilities and the aggregate rooftop PV portfolio
3. Electricity transmission network capability captured through dynamic constraint equations which change over time to reflect major network augmentations assumed to be commissioned in future years

To support development and interpretation of supply adequacy assessment AEMO have published *Reliability Standard Implementation Guidelines*[2] (RSIG). The RSIG brings together a description of the range of supply adequacy assessment applications for the NEM, the data sources, methodologies and instructions on how to interpret outcomes. The most relevant assessment to this PS2.1 question are as follows:

Application	Description
Short term projected assessment of system adequacy (STPASA)	7 days ahead projection of availability vs demand on 30-minute time resolution
Medium term projected assessment of system adequacy (MTPASA)	2 years ahead projection of availability vs demand on 30-minute time resolution
Energy Adequacy Assessment Projection (EAAP)	2 years ahead projection of energy availability considering hydro inflows, cooling water for thermal and thermal fuel availability on 30-minute time resolution
Electricity Statement of Opportunities (ESOO)	10 years ahead projection of the risk of unserved energy considering multiple weather reference years for wind/solar generation and Monte Carlo simulation of unplanned generation outages on 30-minute time resolution
Integrated System Plan (ISP)	20 years ahead projection of an ideal, least cost generation and transmission network expansion plan, supplemented by power system studies to assess operability and security considerations
Gas Statement of Opportunities (GSOO)	The GSOO leverages the ESOO and ISP to combine projected demand for gas for power generation with projected demand for residential, commercial and industrial and LNG export industry. This gross demand is then assessed against production/supply and pipeline capacity

AEMO has undertaken significant stakeholder engagement and consultation in relation to the preparation of forecast input data[3] and outcomes interpretations[4]. Through forecasting unserved energy (USE) events in Monte Carlo simulation the full distribution of events are available to be interrogated, analysed and reported to industry stakeholders and market participants. The nature of USE events are forecast to remain as a mix of high impact low probability (HILP) and more frequent shallow supply shortfall risks. With the benefit of planning, consultation and publication of the modelling the market is seeking stronger contribution from the demand side, identifying opportunities for both shallow and deeper long duration storage, and valuing the beneficial aspects of transmission network investment. A number of key visualisations are provided in the accompanying contribution presentation.

[2] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/rsig/reliability-standard-implementation-guidelines.pdf?la=en

[3] https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp/get-involved

[4] https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2021/2021-esoo-launch-day-briefing-presentation.pdf?la=en