Appendix A4. System Operability

December 2025

Appendix to the 2026
Integrated System Plan for the
National Electricity Market

We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO is proud to have launched its first Reconciliation Action Plan in May 2024. 'Journey of unity: AEMO's Reconciliation Path' was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation – a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Important notice

Purpose

This is Appendix A4 to the Draft 2026 Integrated System Plan (ISP) which is available at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp. AEMO publishes the Draft 2026 ISP pursuant to its functions under section 49(2) of the National Electricity Law (which defines AEMO's functions as National Transmission Planner) and its supporting functions under the National Electricity Rules. This publication is generally based on information available to AEMO as at 1 December 2025 unless otherwise indicated.

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Version control

Version	Release date	Changes
1	10/12/2025	First release
1.1	21/04/2026	Amended Figures 21 and 24 to correct pumped hydro load and Figure 22 to correct water volume units.

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Executive summary

AEMO's ISP is a roadmap for the NEM's transition, and outlines an 'optimal development path' (ODP) for generation, storage and network investments to meet Australia's future energy needs.

The Draft 2026 ISP reaffirms that renewable energy, connected by transmission and distribution, firmed with storage and backed up by gas, presents the least-cost way to supply secure and reliable electricity to consumers as coal plants retire, while meeting government policies through to 2050.

This appendix contributes to the Draft 2026 ISP by providing detailed assessments of system operability as the NEM transitions to higher shares of variable renewable energy (VRE). It details how, in the *Step Change* scenario:

- **The way consumers use electricity will continue to evolve.** It will evolve significantly with the continued uptake of consumer energy resources (CER), the electrification of industry, businesses, homes, and transportation, and the expansion of data centres. More of that growing consumption will be self-supplied by their own devices, and increased flexibility of demand is expected. Operational demand, being the electricity supplied from the transmission system, is expected to continue to exhibit deep daytime troughs as rooftop and other small-scale solar grows.
- **Variable renewable energy (VRE) penetration increases operational complexity.** Operating the power system reliably with more VRE and fewer synchronous generators will present daily, weekly and seasonal challenges requiring material changes in operational approach to managing power system reliability and security. Investments in network and storage assets will firm VRE, enabling surplus energy to be used to meet demand where and when renewable resources are less available. Solar generation will become the main energy source during daylight hours, complemented by wind energy across the day and night, and the charging and discharging of storages and the use of hydro will be important to firm supply and shape supply to demand. In various circumstances flexible gas and other dispatchable resources will back up this diverse resource mix. Geographic and technological diversity of the supply mix will help reduce the energy adequacy risks of poor weather conditions.
- **Periods of renewable potential that exceed 100% of demand forecast increase operational complexity.** These periods have already been experienced and are expected to become more frequent in the future. Some level of VRE curtailment (either economic offloading[1] or network curtailment[2]) is expected to be more efficient than building sufficient network investments and storage to allow all excess generation to be used or stored for future use. Modelling indicates that forecast NEM-wide annual curtailed VRE remains below 20% across the horizon, with most unused potential energy resulting from economic offloading rather than transmission limits.
- **'Renewable lulls' of longer, dark and still weather conditions increases operability** complexity**.** From time to time, the power system will experience extended long, dark and still weather patterns over a wide geographical area, meaning VRE output is low for several consecutive days. These extended VRE 'lulls' covering wide areas are, over the longer term, extremely difficult to predict in duration and intensity. Resource diversity – particularly geographical diversity – will help mitigate the effects of localised low VRE conditions associated with adverse weather in a single

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[1] Economic offloading refers to a generator being dispatched below its maximum availability, because some or all of its output was bid into price bands greater than the regional reference price. May also be referred to as economic 'spill' as generators reduce output due to low market prices or lack of available demand.

[2] Network curtailment refers to a generator being dispatched below its economic availability (output available at offer prices below the regional reference price) due to the operation of network- or security-related constraints.

area, but occasionally weather systems across larger areas of the NEM can reduce overall availability. During an extended VRE lull event, storages are heavily relied upon to shift energy to when it is most required, and demand flexibility is also important (such as shiftable charging patterns for electric vehicles). Existing hydro schemes, whose reservoirs store rainfall as potential energy, will also help in shifting energy over weeks or months (seasonal shifting) and cover extended VRE lulls. In addition, flexible gas generation, and surplus generation from regions less affected by poor weather conditions transmitted through the transmission and distribution networks will support ongoing reliability during these conditions.

A4.1 Introduction

This appendix contributes additional analysis on the operability of the ODP. It presents a granular assessment of operational dynamics and reliability challenges as the power system transitions to much higher levels of VRE.

This appendix presents the NEM-wide view of detailed analysis to assess the operability of the power system given the forecast demand conditions, the generation and storage developments, and network developments that are identified in the proposed ODP of this Draft 2026 ISP. In this appendix:

- A4.2 examines how demand profiles will continue to evolve and the impacts on power system operations.
- A4.3 provides forecasts and analysis for VRE penetration and curtailment.
- A4.4 analyses the requirement for resource flexibility to manage increased variability in supply and demand.
- A4.5 investigates the role of storage technologies in firming VRE.
- A4.6 examines the operational resilience of the ODP during extended long, dark, and still weather conditions.
- A4.6 investigates the role of storage technologies in firming VRE.
- A4.7 summarises preliminary insights regarding the types of seasonal risks facing the power system.

The content in this appendix is complemented by Appendix A7, which quantifies NEM system security requirements and provides insights into the nature, timing, and geography of the services needed to address them.

Key changes from the 2024 ISP

Key changes since the 2024 ISP that have impacts on the system operability outcomes in this appendix are:

- The time sequential model underpinning the analysis in this appendix has been calibrated to reflect recent market bidding strategies and real operational behaviour of generators.
- The implementation of hydro generators and their associated reservoirs has been improved[3].
- Imperfect foresight methodology described in the updated *ISP Methodology* has been implemented to better reflect the challenges storages face in meeting unforeseen changes in weather and demand conditions[4].

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[3] The 2025 *Inputs, Assumptions and Scenarios Report* (IASR) contains details of the improved hydro generation implementation. At https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2025-iasr-scenarios/final-docs/2025-inputs-assumptions-and-scenarios-report.pdf?rev=63268acd3f044adb9f5f3a32b6880c27&sc_lang=en.

[4] The 2025 *ISP Methodology* provides an overview of the imperfect foresight methodology for storage technologies. At https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2026-isp-methodology/isp-methodology-june-2025.pdf?rev=e88a1f1bbeef447ba27692b785069a0a&sc_lang=en.

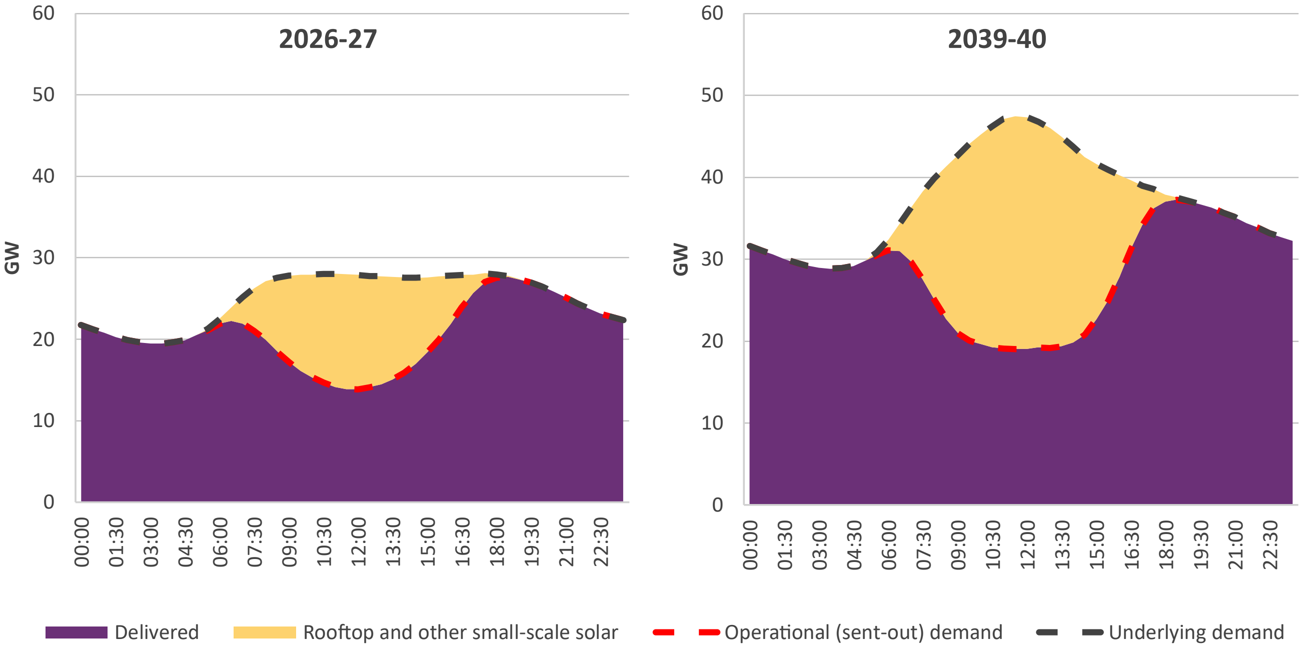
A4.2 The NEM's demand profiles will continue to evolve

As Australia transitions to a net zero emissions future, electricity consumption and demand will continue to change and the NEM will need to adapt appropriately to meet the needs of consumers. There are several key drivers of change impacting the forecast demand profile:

- Consumers will increasingly influence the demand profile of the NEM through investments in consumer resources such as rooftop PV, batteries and electric vehicles (EVs), investments that improve energy efficiency, and also through behaviorial choices that change the way they interact with the grid.
- Increasing demand for digitalisation, AI uptake and cloud-based computing adoption is driving a forecast expansion of data centres, which is projected to increase electricity consumption despite increases in computational energy efficiency.
- Households and businesses seeking to reduce emissions are projected to electrify fossil fuel loads, such as natural gas used for space heating, leading to a rise in electricity consumption and peak demand.
- Population growth and increased economic activity are projected to continue increasing demand across the power system, and major industrial loads face the need to reduce emissions, potentially leading to increased use of electricity in manufacturing, mining and other major industrial processes.

Figure 1 illustrates how demand patterns in the NEM are projected to evolve over time. By 2039-40, overall consumption and the evening peak demands are higher, while operational demand through the middle of the day increases much more slowly due to growing rooftop and other small-scale solar offsetting the underlying demand. This results in a projected demand profile with a wide, deep trough when rooftop and other small-scale solar generation is the highest and sharper changes in demand for the morning and evening peaks.

Figure 1 Projected time-of-day average demand profile for the NEM, 2026-27 and 2039-40, *Step Change* (GW)



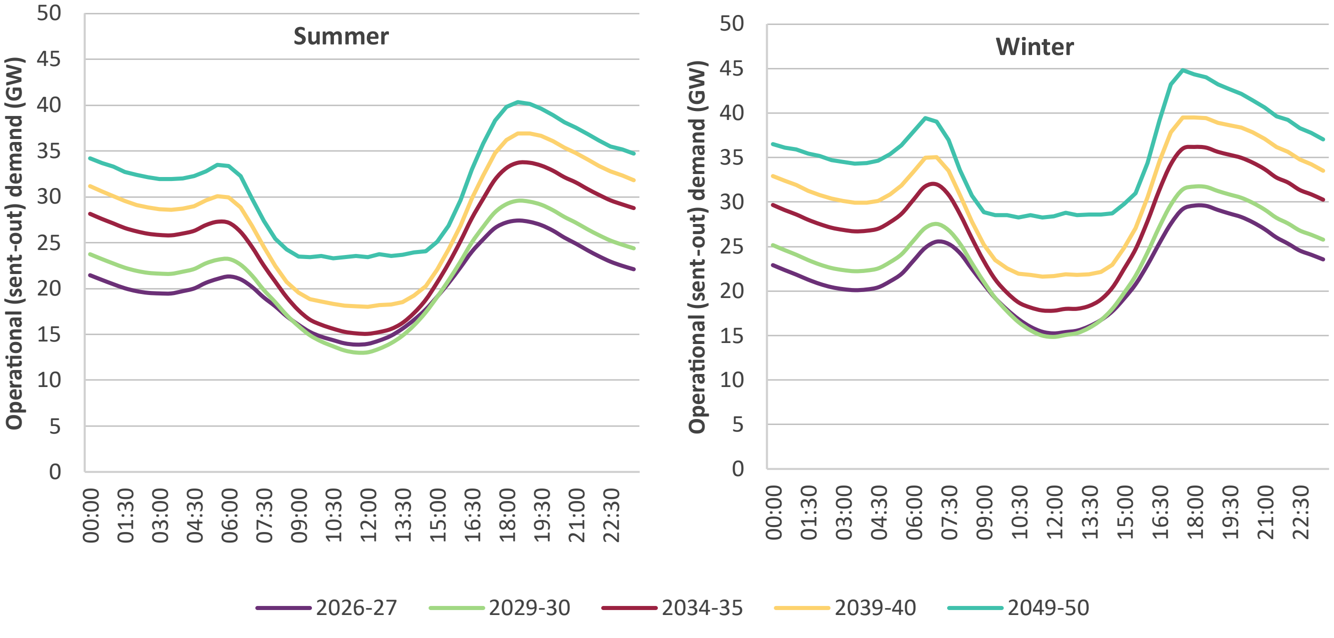
This shift underscores the growing influence of CER and emerging technologies on grid demand, alongside the continuing challenge of managing evening peaks and minimum system load conditions (that is, when high output from rooftop solar combines with low underlying demand, resulting in extremely low operational demand).

Demand definitions used in this appendix

- **Operational (sent-out) demand** refers to demand supplied from the national power system (or grid).
- **Minimum operational demand** means the lowest level of demand from the grid in any day, week or year.
- **Underlying demand** encompasses all the electricity used by consumers, including electricity sourced from the grid and other sources including consumers' rooftop PV and battery storage.
- **Residual demand** refers to the operational demand left over after generation from grid-scale VRE is removed; that is the operational demand remaining to be met from fully scheduled generation sources.

Figure 2 illustrates the projected average time-of-day demand profiles for summer and winter seasons. The upward trend in both seasonal curves reflects forecast strong growth in electricity consumption driven by electrification, EV uptake, population growth, data centre expansion and hydrogen demand. Heating and cooling devices are significant influences on seasonal load patterns, and particularly drive up demand for electricity during extreme temperature days, as customers use their energy devices to improve their thermal comfort.

Figure 2 **Forecast time-of-day average half-hourly NEM operational demand profile, summer and winter, *Step Change*, 2026-27 to 2049-50 (GW)**



Over time, summer peaks are forecast to rise due to higher cooling demand and electrification impacts. Winter profiles show steeper growth, consistent with ongoing adoption of electrified space and water heating as customers shift away from energy forms such as gas and wood heaters, supported by commercial decisions by consumers when replacing end-of-life assets, and various government policies.

During summer, the deepening midday trough, particularly noticeable between now and 2034-35, highlights the influence of rooftop and other small-scale solar, whereas winter retains a flatter midday curve due to reduced solar contribution. Both seasons' midday troughs are expected to be offset by additional load from EV and battery charging over time, and while batteries will discharge in the evenings, driver preferences for vehicle charging may increase evening peaks, increase overnight demand and increase daytime charging. Weather and behavioural patterns are hard to predict and are significant influences on the needs to develop infrastructure that is resilient to weather variations to support customer load. This underscores the challenge of managing increasing peak demand and greater supply and demand variability during the energy transition.

A4.3 VRE penetration and curtailment

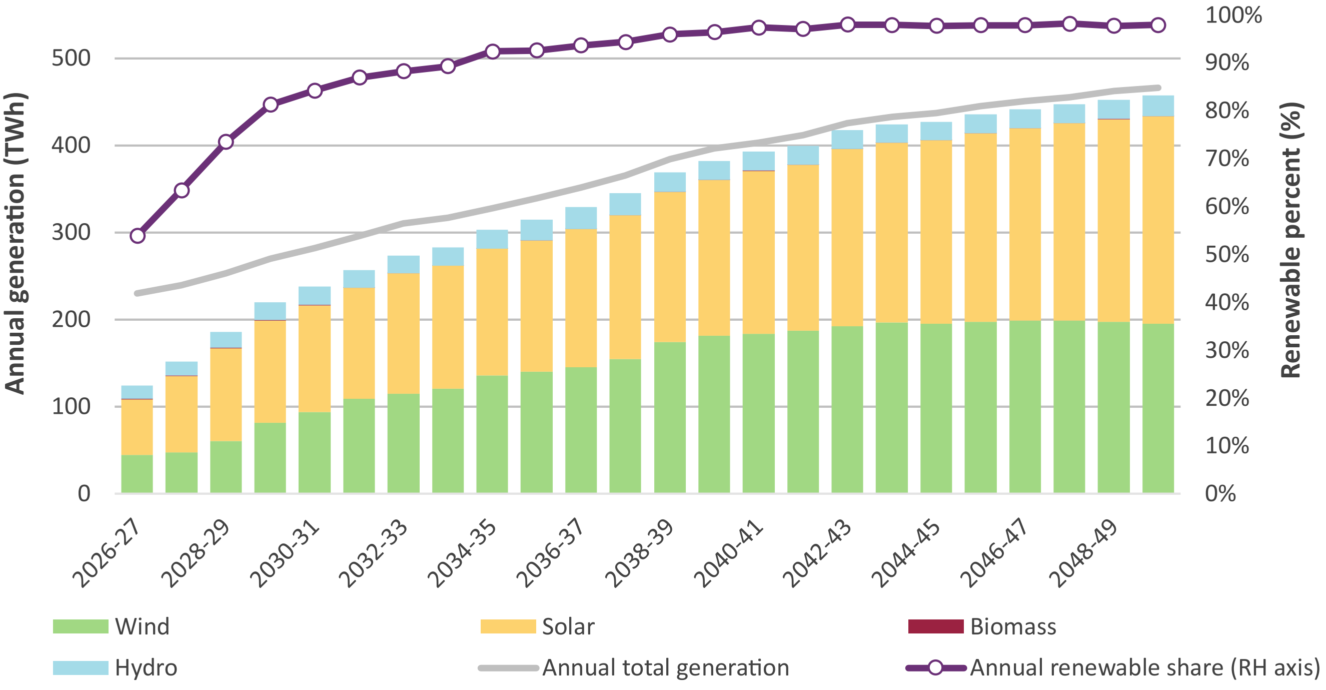
The replacement of coal-fired generation with new forms of electricity generation, particularly VRE, is not a like-for-like replacement and will need a significantly more diverse energy mix to ensure reliable supply than has been the case with coal capacity. AEMO's *Transition Plan for System Security*[5] details the plan for system security needs in the next 10 years to support the energy transition, and operate a system with a large proportion of VRE, including large quantities of CER.

The changing technology mix and shift to a more decentralised power system introduces new challenges. Minimum operational demand continues to decline across all NEM mainland regions, driven by strong consumer uptake of rooftop and other small-scale solar. Operating the NEM through these periods of very low operational demand results in periods where demand may need to be maintained above certain thresholds. This will ensure that synchronous generation is able to be maintained online to provide essential system services (such as system strength). In the long term, other technologies will be critical to deliver system security services that have been traditionally provided by fossil fuel generators.

Investments in storage will be essential in the future NEM to enable surplus VRE generation to be stored and allow this energy to be used when solar production drops later in the day or at another future time. Projected storage capacity is unlikely to be sufficiently sized or located to capture all VRE generation, and so some generation will experience network curtailment when there are constraints in the network or there will be economic offloading when there is over-abundant renewable energy supply.

Figure 3 shows projected levels of annual total generation, annual renewable generation, and renewable share of total generation to 2049-50, including contribution from CER (aggregated within the Solar data series).

Figure 3 Projected annual NEM generation (TWh), annual renewable generation (TWh), annual renewable share of total generation, *Step Change*, 2026-27 to 2049-50



TWh: terawatt hours.

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[5] At https://www.aemo.com.au/energy-systems/major-publications/transition-plan-for-system-security-tpss.

VRE penetration

The current record maximum renewable resource potential[6] in the NEM was set on 14 September 2025, reaching 110.3% of demand across a 30-minute period[7]. As renewable energy increases, the renewable resource potential in the NEM becomes higher and more concentrated, and greater than 100% renewable potential will occur more frequently at increasingly higher underlying demand levels. **Figure 4** shows the projected changes to renewable resource potential relative to underlying demand from 2026-27 to 2049-50 in *Step Change*.

Periods where there is greater than 100% renewable resource potential will not necessarily result in 100% instantaneous renewable penetration. Instantaneous renewable penetration levels are restricted by market behaviours, network constraints, and system security requirements. Records for instantaneous renewable penetration, or share of total energy supplied from renewable sources, have already surpassed 77%[7], and reached 79% for a half-hour on 11 October 2025.

Figure 4 Projected renewable resource potential, *Step Change*, 2026-27 to 2049-50 (GW)

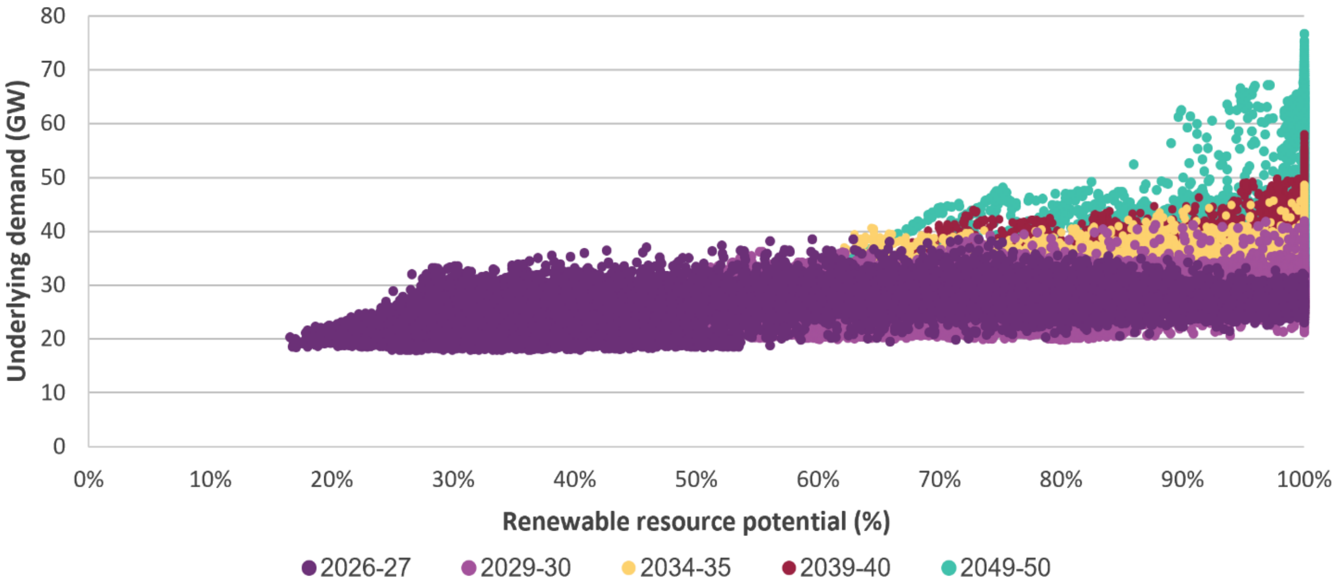

Figure 5 shows the distribution of renewable resource potential and penetration for every half-hour in 2019-20 (historical) and in forecast years 2026-27, 2029-30, 2039-40 and 2049-50, as well as the current NEM-wide records for instantaneous potential and penetration (as of September 2025). Renewable resource potential is projected to be sufficient to meet all demand occasionally from the start of the modelling horizon, and around 25% of the time in 2029-30.

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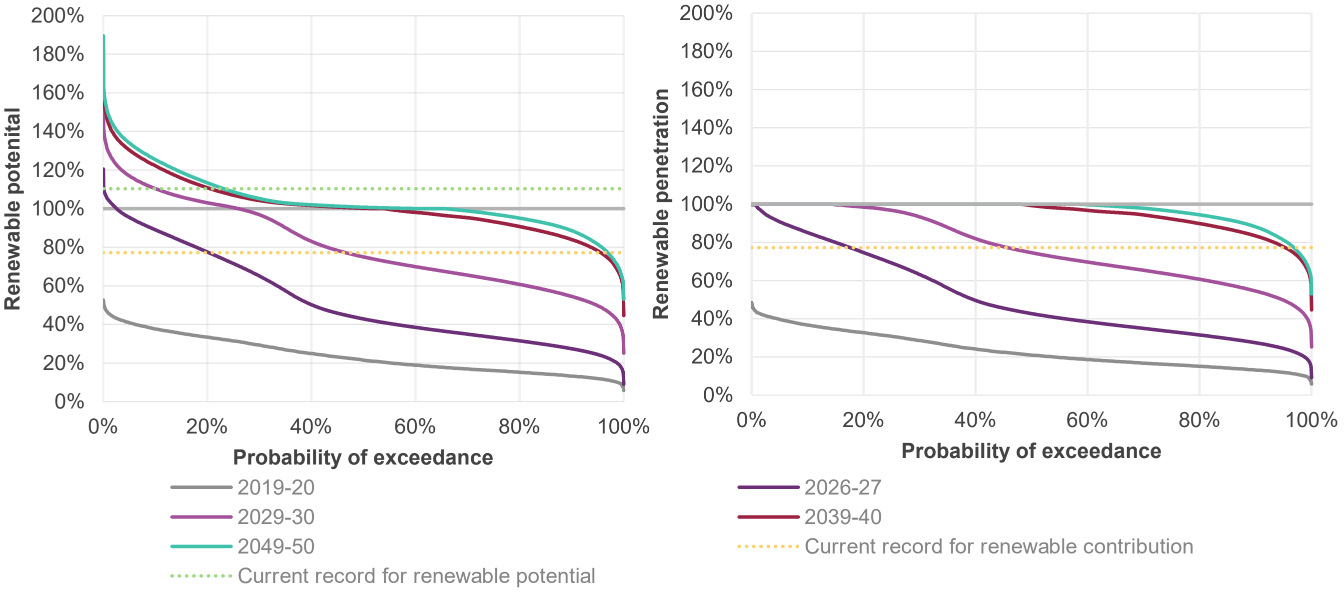
[6] Renewable resource potential is defined as total available power from CER and utility-scale VRE, even if not necessarily dispatched, plus actual generation from dispatchable renewables, expressed as a percentage of the total NEM supply requirement.

[7] See AEMO *Quarterly Energy Dynamics* Q3 2025, at https://www.aemo.com.au/-/media/files/major-publications/qed/2025/qed-q3-2025.pdf?rev=7436be91333e4603bc59158b0bf095a1&sc_lang=en.

Figure 5 Distribution of actual and projected renewable potential (left) and penetration (right), including current NEM records for instantaneous renewable potential and penetration (records as of September 2025), *Step Change*, 2019-20 (actual), 2026-27 to 2049-50 (projected)



Geographical diversity of VRE resources is delivered through developing new resources across the NEM, many of which will be within new renewable energy zones (REZs), and connecting these new developments with customers across the grid through network expansion. As a result, renewable resource potential is projected to rise across nearly all half-hour periods during the year. Increased use of storage technologies will help shift excess daytime generation from periods of renewable energy surplus to times of lower VRE availability, which will rely on appropriate storage management and storage depth to achieve this.

Modelling for the Draft 2026 ISP assumed that some coal generators will be able to operate flexibly, and stop generating for periods of no less than four hours, so while 2026-27 is not projected to reach 100% renewable penetration, by 2029-30 the NEM is projected to be capable of 100% renewable penetration around 14% of the time. This modelling did not account for system security requirements and actual renewable penetration will not be able to reach 100% until other technologies can provide these requirements and minimum system load thresholds are removed.

System security requirements will limit the actual maximum VRE penetration

The highest levels of instantaneous penetration of VRE will be limited by the availability of sufficient power system services to maintain security of supply. During low load conditions, AEMO may set minimum system load (MSL) thresholds, which are determined by the minimum combination of thermal units that need to remain online to provide system security services. These thresholds change dynamically depending on real-time system conditions. Over time, MSL thresholds will decrease as system security parameters are decoupled from synchronous fossil fuel generating units and these services are delivered by alternative technologies.

VRE curtailment

The Draft 2026 ISP identifies frequent instances where VRE generators will not be able to operate to their maximum potential, either due to:

- periods when VRE resource potential exceeds demand (including the additional capacity to store excess generation), particularly at times of low operational demand,
- insufficient transmission capacity to transport VRE to demand centres, or
- system security requirements that require synchronous generation to be dispatched to maintain a secure power system (until such time as alternative technologies can provide these critical services).

These conditions may lead to economic offloading of energy when generators reduce output due to low market prices or lack of available demand, or to network curtailment where insufficient transmission capacity exists for generators to continue to operate.

The Draft 2026 ISP projects that it is uneconomic to develop sufficient network and/or storage capacity to accommodate all peak VRE generation potential, meaning some degree of economic offloading or network curtailment is inevitable to keep total system costs as low as possible. As the seasonal load profiles diverge, generation is increasingly needing to be developed to meet the energy consumption requirements of winter when consumption is high and VRE production is reduced, and therefore summer periods may exhibit increased periods of economic offloading or network curtailment when renewable resources are higher.

Hydrogen electrolyser developments in the proposed ODP are projected to play a role in reducing curtailment by absorbing excess VRE generation. Electrolysers co-located with renewable generation developments may reduce network curtailment by accessing renewable energy generation before network limitations.

Figure 6 shows the total VRE potential that is projected to be utilised (generation) or not (economic offloading and network curtailment) out to 2049-50. As coal generators close and transmission is expanded, the NEM-wide level of available VRE curtailed annually is projected to remain below 20% across the horizon. The majority of unused VRE potential is the result of economic offloading, rather than network curtailment due to transmission limits[8].

Figure 7 shows the projected monthly distribution of instantaneous economic offloading in 2039-40 across a range of weather reference years, and illustrates the months with excess renewable generation potential.

The large majority of economic offloading is projected to occur during daylight hours on sunny and windy days, particularly in summer months more than in winter. The seasonal trend of VRE economic offloading indicates the role long-duration storages could have in firming energy on a seasonal basis.

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[8] See Figure 6 in Draft 2026 ISP Appendix A3.

Figure 6 Projected NEM-wide VRE generation, economic offloading and network curtailed energy, *Step Change*, 2026-27 to 2049-50 (TWh)

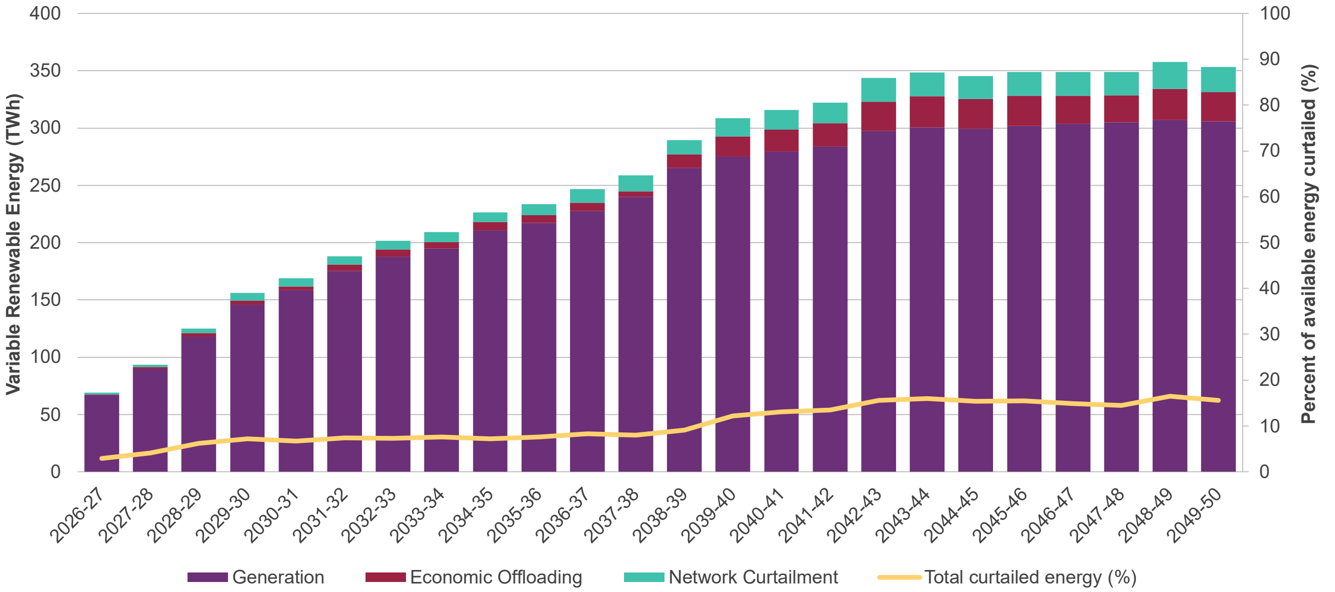
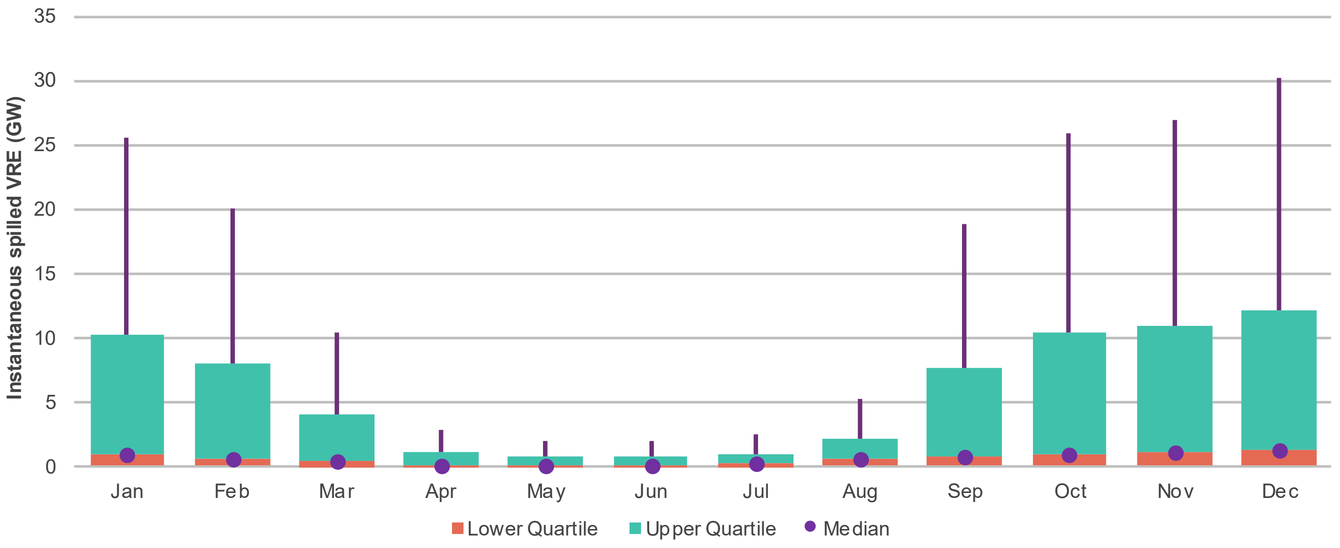


Figure 7 Projected NEM capacity of VRE subject to economic offloading, *Step Change,* 2039-40 (GW)



A4.4 System flexibility manages increased variability

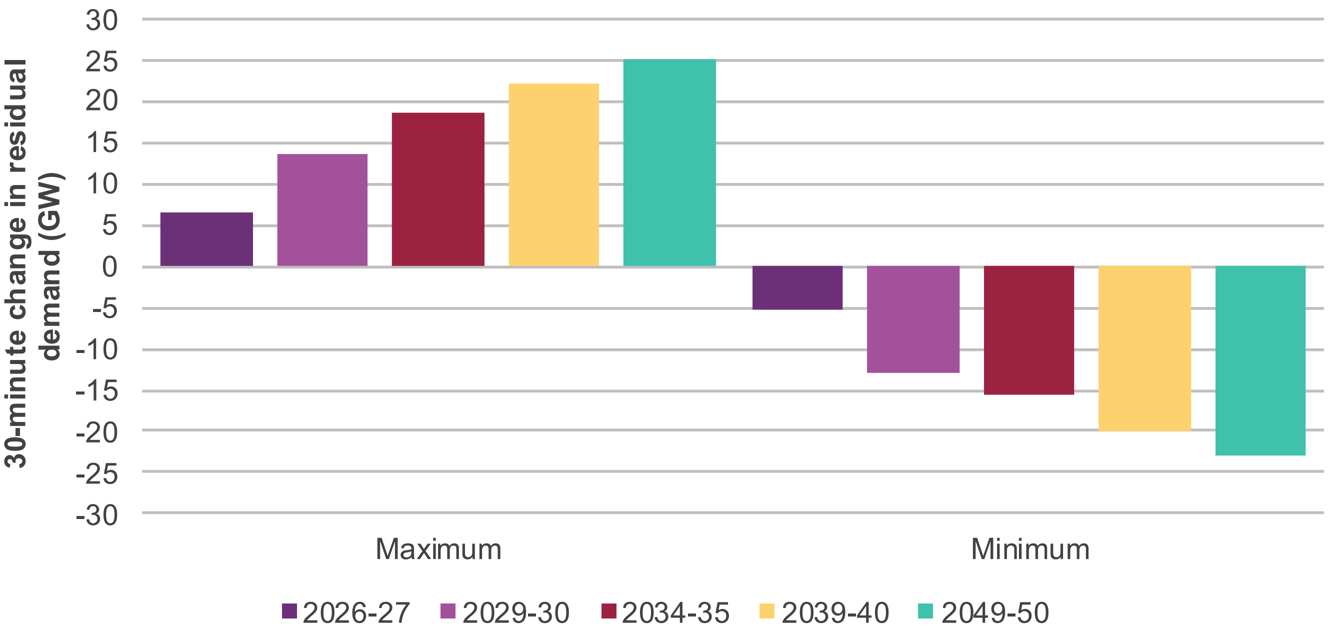
Resource flexibility is required to manage increased variability of electricity generation and demand. Residual demand in this appendix refers to the electricity demand that is met by dispatchable generation, or the demand that is net of VRE generation. Rapid and more frequent changes to residual demand across the power system will require firm resources to have sufficient ramping capability across all operational timeframes. Increased ramping requirements are typically associated with local wind speed fluctuations, daily diurnal solar profiles, and much faster, less predictable ramps from clusters of rooftop solar and other small-scale solar due to localised cloud movements.

Managing the operational requirements of firming technologies, including consideration of real-time ramping requirements to accommodate the variability of VRE and operational demand, will be important to operating the NEM securely and reliably.

Analysis in this section is based on modelled dispatched outcomes that reflect operational conditions, taking into account factors such as economic offloading, network curtailment and operational dispatch due to generator bidding behaviour.

During the period to 2049-50, residual demand is projected to reduce significantly but also become much more variable. **Figure 8** below shows the maximum and minimum changes projected in half-hourly NEM-wide residual demand over a year in *Step Change*.

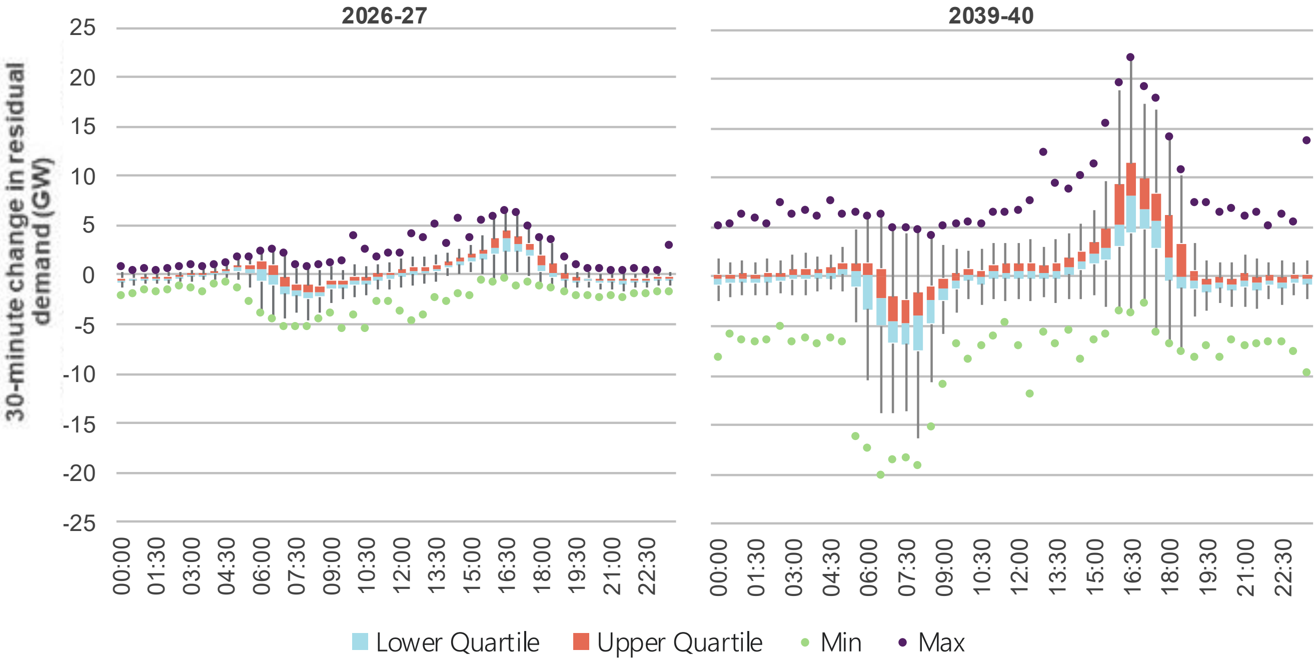
Figure 8 Projected maximum and minimum changes in half-hourly NEM-wide residual demand, *Step Change*, 2026-27 to 2049-50 (GW)



Residual demand fluctuations become more extreme as the capacity of utility solar and rooftop and other small-scale solar grows. While variations in wind generation also contribute to the need for ramping, wind speed fluctuations tend to be more localised, and therefore less impactful when considering a geographically diverse generation mix developed across multiple REZs. The periods of greatest residual demand change are projected to be at dawn and dusk as it follows the solar generation profile, which is highly predictable and thus less challenging for NEM operations. However, ramping requirements at other times that are less predictable are expected to present a more significant challenge to future NEM operations. A record coincident half-hourly ramp up occurred on 26 November 2025, with operational demand increasing by nearly 2.5 GW in New South Wales and 2 GW in Queensland over 30 minutes as bands of fast-moving cloud cover crossed Sydney and Brisbane at approximately the same time.

Figure 9 shows the projected distribution of residual demand changes for each half-hourly period over the course of a day in 2026-27 and 2039-40.

Figure 9 Projected time-of-day distribution of half-hourly NEM residual demand changes, *Step Change*, 2026-27 (left) and 2039-40 (right) (GW)

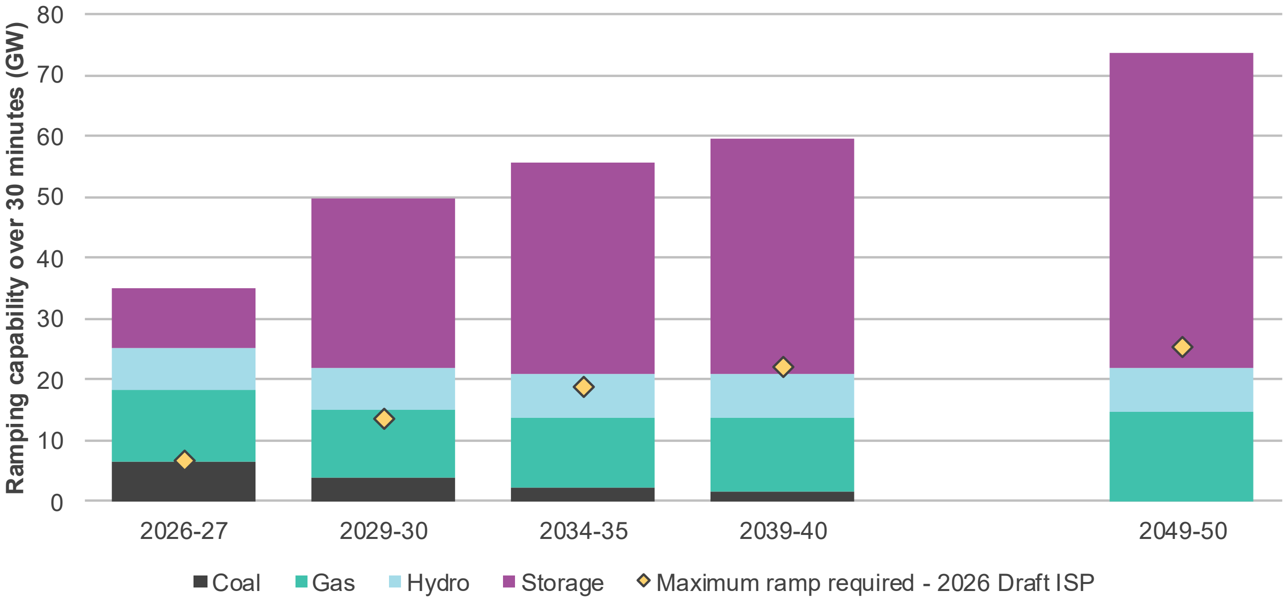


In the future, utility storage (including pumped hydro) and coordinated CER storage are projected to become the primary providers of system flexibility, but flexible gas and hydro will continue to provide significant ramping capacity.

Figure 10 shows the projected maximum ramp up capability in gigawatts (GW) for each 30-minute period across the dispatchable generation fleet. This represents the combined flexibility across all units operating in the system.

It is important to note that during daily operation, the actual ramping capacity at a unit will vary according to its online status, current generation, and, in the case of storage, the level of stored energy at that time. The Draft 2026 ISP's proposed ODP develops firm capacity throughout the planning horizon to match growing demand and balance VRE intermittency and availability.

Figure 10 Forecast maximum ramping capability of dispatchable generation, *Step Change*, 2026-27 to 2049-50 (GW)



Note: Dispatchable generator categories include coal (black and brown coal generators), gas (flexible gas, mid-merit gas, biomass and diesel generators) and storage (utility storage, coordinated CER storage).

Figure 11 presents the projected NEM generation mix during a day in 2034-35 when a peak 18 GW ramp up, equivalent to 50% of underlying load, is required at approximately 1700 hrs due to significant generation reduction from solar while load remains relatively high.

Storage technologies contribute most of the ramping required by rapidly discharging stored energy, with hydro and coal generators[9] providing the rest of the ramping requirement. In cases where stored energy and other dispatchable generation is insufficient to meet demand, demand side participation (DSP) including demand response may need to be deployed.

Storage dispatchability is projected to become crucial to the reliability and security of the power system. Further discussion on the role and needs for storage firming is in Section A4.5.

This assessment does not address the need to maintain grid security and the provision of critical frequency and voltage control services. Appendix A7 and the 2025 *Transition Plan for System Security* provide more detail regarding system security and engineering requirements for secure operation of the power system.

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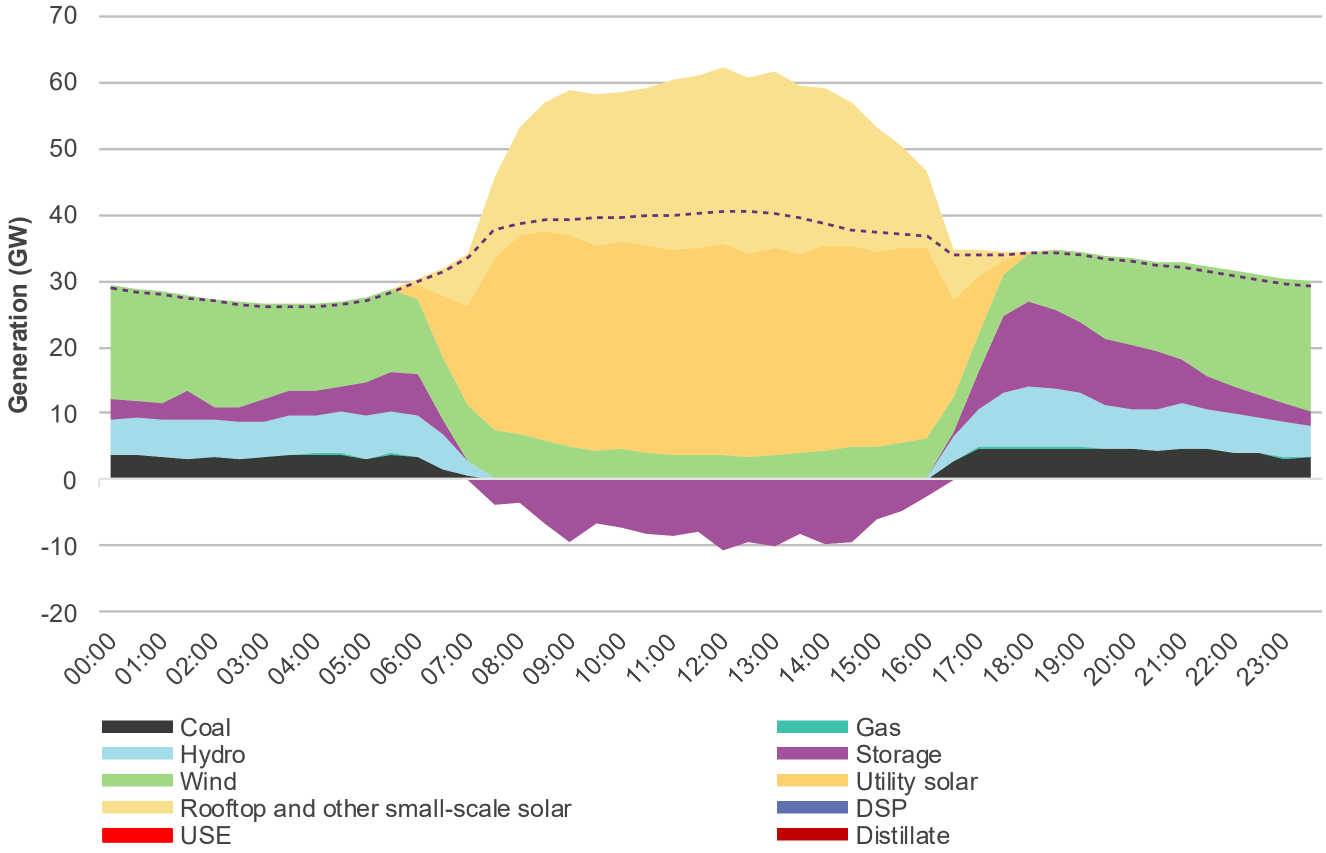
[9] In this modelling, coal generators can operate flexibly, including stopping generation for periods of no less than four hours.

Figure 11 Projected NEM generation mix on a day with maximum ramp, *Step Change*, 2034-35 (GW)



A4.5 Storage technologies will firm renewables by firming energy

Storages in the NEM currently play several roles including providing energy firming, system balancing and active power reserves, in addition to advanced power system services such as synthetic inertia and system strength support (by providing a stable voltage waveform). Though storages will continue to provide system security services, storage operators are expected to rely less on system services revenue and increasingly develop their operational strategies around energy arbitrage. As VRE penetration increases, larger quantities of all forms of storage will be required across the NEM to accommodate the peaks and troughs in renewable generation and match energy supply to demand.

The Draft 2026 ISP projects the storage capacities needed to firm the NEM's VRE developments. The development of medium and deep storage technologies is important to complement flexible gas and hydro generators, providing the capacity to store energy and dispatch it over long periods.

Storage definitions used in this appendix

- **CER storage** – behind-the-meter household and business storage, including EVs that may be able to send electricity back into the grid. Coordinated CER storage is managed as part of a VPP (enabling a response to market signals); passive CER storage is not, operating to service the household's needs in isolation.
- **Shallow storage** – utility storage, connected to either the transmission or distribution network, to dispatch electricity for less than four hours, valued for both its provision of system services and stored energy.
- **Medium storage** – utility storage with the capability to dispatch electricity for four to 12 hours. This includes batteries and pumped hydro (or other emerging technologies in future) which can shift large quantities of electricity to meet evening or morning peaks.
- **Deep storage** – utility storage that can dispatch electricity for more than 12 hours, to shift energy over weeks or months (seasonal firming) or cover periods of low sunlight and wind (renewable lulls), backed up by flexible gas.

Intra-day storage

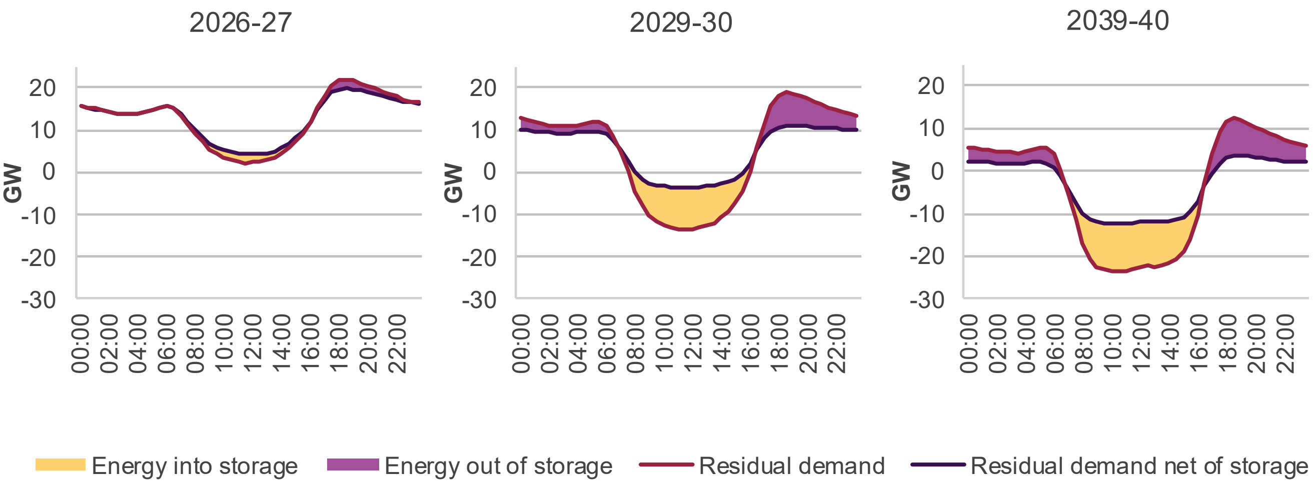
The NEM will increasingly rely on all forms of storage to shift available energy supply within a 24-hour period to match instantaneous demand. Shallow and medium storages will provide much of this function, with daily shifting of surplus daytime VRE generation to meet evening peak demand and overnight surplus wind energy stored to meet morning peak demand. Future operational strategies for storages are also expected to include the use of storage to create a corresponding load, through battery charging or pumping of water, for thermal generators operating near minimum stable levels during periods of low system demand.

Coal generators typically bid in their minimum stable levels at the market price floor during low system demand levels to ensure dispatch and remain online to be available for evening peak demand. A number of owners are constructing utility-scale batteries at the sites of existing coal-fired generation to capture energy through low operational demand conditions, introducing a local load (battery charging) during these periods at market floor price.

Storages will typically charge when low-cost, surplus daytime VRE is plentiful, and store and discharge that energy when prices are higher during peak demand periods. This reduces dependence on traditional peaking technologies such as flexible gas. In some instances, operating hydro and gas generators to pre-charge shallow and medium storages can be an effective strategy to improve the reliability of supply, provided these lulls can be anticipated in advance, although this would impact overall emissions outcomes, and would need high prices to compensate for charging during periods of VRE scarcity.

Figure 12 shows the projected evolution of time-of-day average profiles of residual demand and the growing impacts of storage technology. As the penetration of VRE increases, coal-fired generators retire and more storage capacity is developed, the daytime residual demand is projected to decrease and feature deeper troughs. Storages will enable greater volumes of surplus energy to be time-shifted to service evening demand peaks. Storages will also help smooth the evening residual demand peak, allowing generators with less flexibility to operate at a flatter profile. As the penetration of VRE increases across the ISP horizon, negative residual demand net of storage (as indicated in the figure) during the middle of the day is still projected. This indicates that not all the VRE generation can either serve prevailing customer load, or be stored, leading to some economic offloading or network curtailment. These outcomes are driven by market dynamics and system conditions, such as a finite amount of storage capacity and network constraints, that limit the ability to capture all excess generation.

Figure 12 Projected time-of-day average profile of residual demand, *Step Change*, 2026-27, 2029-30 and 2039-40 (GW)



Intra-week storages balance short-term VRE variability

Longer duration storage, including medium and deep storages, play a critical role in smoothing out larger variations in VRE generation over multiple days. The depth of these facilities, in conjunction with the operational forecasting capabilities of AEMO and storage operators, is critical for storing available energy production ahead of sustained periods of low VRE output with relatively short notice.

To maximise the reliability of the power system, deep storage operators may need to store several days' worth of energy, including using thermal and hydro generation if available, ahead of periods of low forecast VRE potential to ensure sufficient dispatch capacity (and energy) is available during protracted periods of extremely low VRE. This will enable improved reliability outcomes during sustained low VRE output (see Section A4.6).

Seasonal storage provides critical reliability in low VRE conditions

Deep storage is critical to shifting surplus VRE energy between seasons and provide resilience for longer periods of sustained low VRE generation. This is increasingly important as coal generators retire.

The NEM currently relies on deep water reservoirs to store energy season-to-season with water outflows balanced between generation needs and water licence release requirements, depending on the reservoir. Stored energy can be used directly during periods of sustained low VRE output but can also provide a source of energy to charge shallow and medium storages prior to, and during, extremely low VRE events. It is therefore important to ensure these deep storages are filled prior to these sustained low VRE events. Operators of longer duration storages will need operational strategies that balance intra-day load firming operations with strategically preserving energy for intra-week or seasonal storage arbitrage. These deep storages are also a critical sink for surplus VRE energy and are essential to reducing VRE curtailment.

The type of reservoir, water release requirements, and whether the water stored is used for other purposes will influence the role that hydro generation can play in storing energy. For some hydro generators, the needs and water rights for irrigation and other water uses may reduce the ability to conserve water specifically for electricity generation, and the multiple uses of water storages may also dictate operating behaviours.

AEMO's modelling of water storages includes different hydro configurations for run-of-river, irrigation and other reservoir types to attempt to capture these potential influences, and increase alignment between simulated outcomes and the operational contribution these assets are likely to provide in real-time.

Long duration storages provide seasonal firming

Figure 13 shows that the projected monthly generation mix and maximum instantaneous residual demand in 2039-40 has strong seasonal dependence:

- Solar output is higher on longer bright summer days with seasonality most prominent in southern regions.
- Wind output is greater on average during winter months but typically has greater volatility, particularly in early winter.
- Residual demand is higher during winter, due to higher underlying heating load and reduced solar output.
- Operation of seasonal energy storages and flexible and mid-merit gas are projected to become increasingly important during winter to support lower solar output and more volatile wind output. All storages will also have a critical contribution during extreme demand days in summer, especially in earlier years when the coordination of CER is projected to be more limited.
- Storage cycling[10] is maximised during periods with greater daily fluctuations in residual demand which create stronger arbitrage opportunities.
- Available coal and gas generation may operate throughout the year, but higher output is important to complement VRE and storage during winter months.

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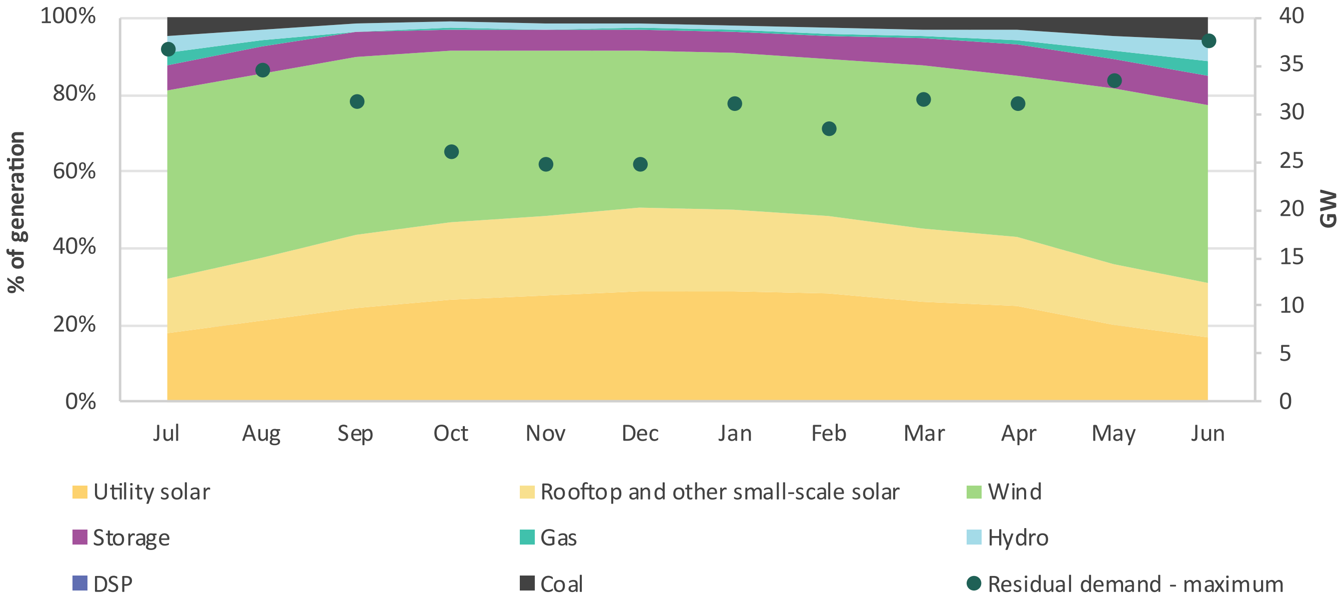
[10] As batteries and pumped hydro charge and discharge electricity, the level of stored energy cycles between low and high levels.

Figure 13 Generation mix and maximum monthly residual demand, *Step Change*, 2039-40



Impact of imperfect foresight of battery operation

Storage operators must conduct charging and discharging activities with imperfect foresight for the expected market conditions each day. AEMO's market modelling includes different levels of foresight to enable efficient utilisation of energy storages, while attempting to reduce the degree of storage management perfection that can apply in simulation models.

To reduce the management performance of stored energy in the ISP models, AEMO has introduced a margin of energy at the upper and lower states of charge that is accessible to the system only during conditions that would otherwise result in unserved energy (effectively reducing the storage depth of typical operating conditions)[11]. These reserves act as a proxy for operational risk mitigation strategies, preserving the option for storage devices to respond flexibly - either charging or discharging – should unforeseen events arise. This approach restricts storage devices from using its full capacity of stored energy on a daily basis[12].

Assessing the impact of planning errors in the operation of battery storage

AEMO has also analysed circumstances whereby a deliberate energy planning error approach is applied to assess system operability under alternative conditions than forecast in pre-dispatch. In this approach, storage devices plan their states of charge based on alternative renewable energy availability, demand conditions and generator outages, creating a charge profile that then can be tested under other system conditions (effectively emulating outcomes where forecasts in pre-dispatch deviate from real-time operation).

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[11] For more detail on the limitations on storage devices that AEMO has applied, see the *ISP Methodology*: https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2026-isp-methodology/isp-methodology-june-2025.pdf?rev=e88a1f1bbeef447ba27692b785069a0a&sc_lang=en.

[12] The headroom and footroom reservation were implemented as soft constraints, with the cost of violation priced below the market price cap, to enable discharge if required to avoid a low energy reserve outcome.

Figure 14 compares the modelled dispatch profile of shallow and medium storage from the base operability model against the profile of storages operating with a deliberate planning error approach during 2039-40. The lack of foresight introduced by implementing imperfect energy targets reduces the amount of energy dispatched, particularly during the evening peak.

Figure 14 Impact of deliberate planning error on the average hourly dispatch profile of energy storage, *Step Change*, 2039-40 (GW)

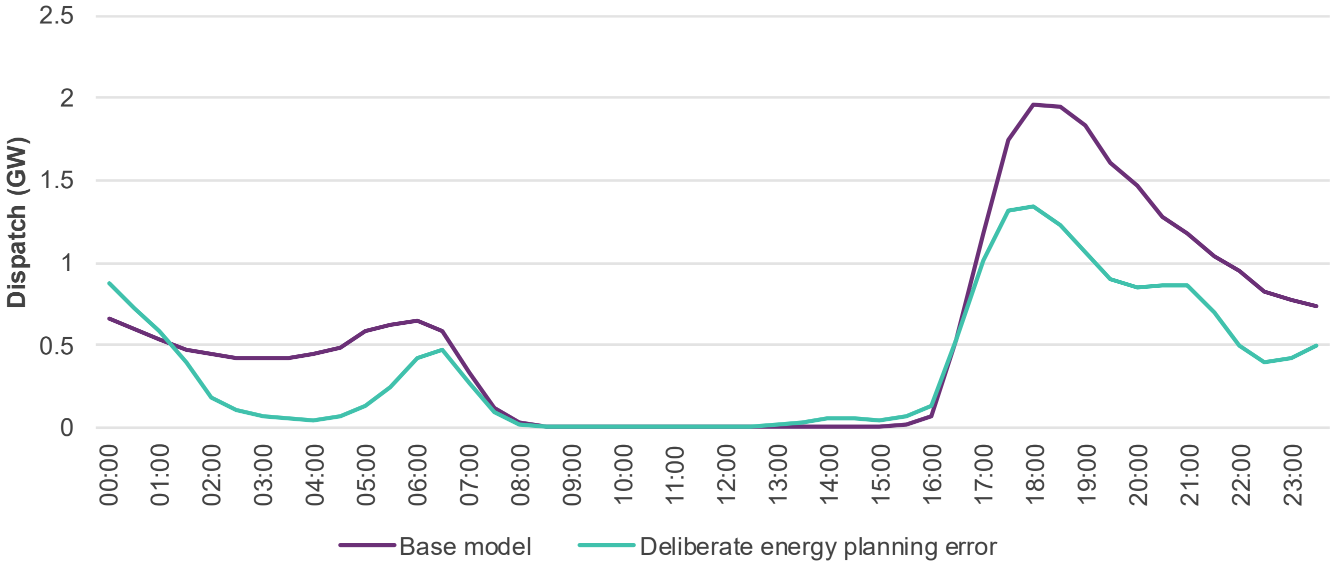
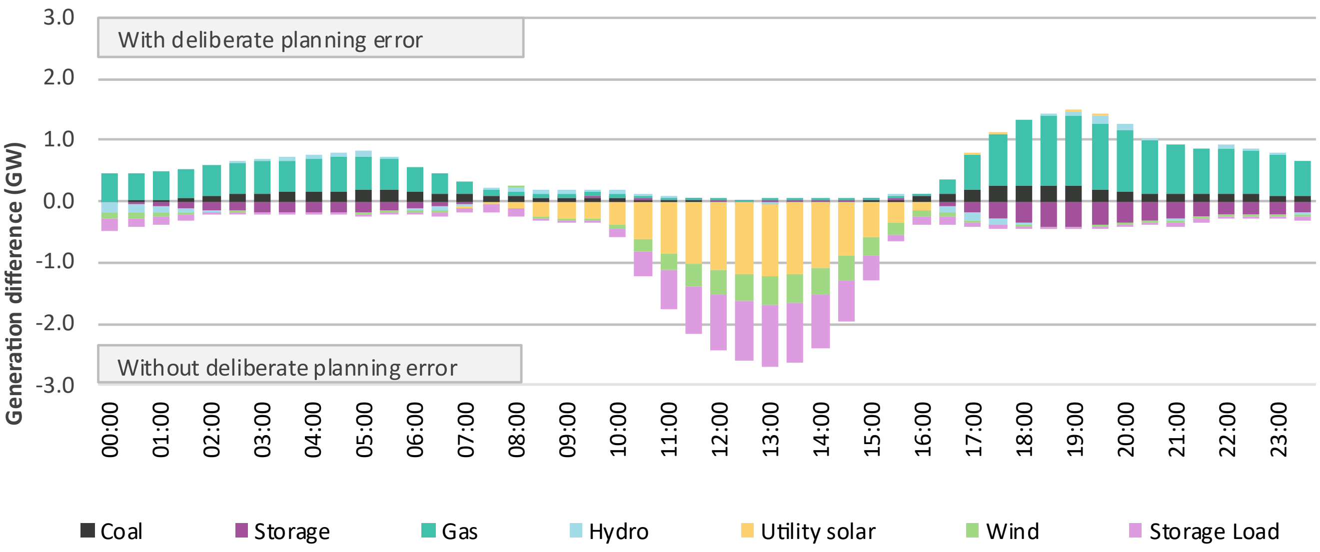


Figure 15 shows the impact of the suboptimal storage management on the projected NEM generation mix during a day in 2039-40. As the figure shows, less energy from storage is dispatched during the day, while additional flexible and mid-merit gas generation fills the gap during the morning, evenings and overnight. This shift occurs because the energy targets applied in the deliberate planning error approach limit the ability of the storage to charge from VRE generation in the middle of the day, reducing its capacity to operate fully during the evening peak. The lower energy levels reflect that storage devices may be unable to provide perfect and complete operational precision under varying power system conditions.

When the deliberate planning error approach has been applied, shallow and medium storage units tend to reach the modelled dispatch limits more frequently when compared to the base operability approach. These breaches occur only during a small fraction of the total operating intervals in a year, indicating that while imperfect planning foresight increases operational challenges, the overall isolated impact of this risk on system reliability is projected to be limited.

The lower solar and wind dispatch in the chart also indicates that, without storage capacity to capture this energy, greater economic offloading would occur as energy is over-abundant in the middle of the day, highlighting the crucial role of storage in balancing VRE throughout the day.

Figure 15 Difference in the projected time-of-day generation mix, with and without deliberate planning error approach, *Step Change*, 2039-40 (GW)



Note: in this chart, a positive value indicates the higher generation in deliberate planning error case, relative to the base case. A negative value indicates higher generation in the base case.

A4.6 Operating the power system during long, dark and still conditions

The NEM must be resilient in its capability to provide energy in all conditions, including when there is minimal or no sunshine or wind for prolonged periods. The ODP will provide resilience during long, dark and still periods through a geographically and technologically diverse mix of VRE generation, supported by hydro and flexible gas generation, demand side response and storages of various depths. Transmission augmentations enable the transport of electricity from regions with excess generation to regions experiencing tighter VRE supply conditions.

VRE lulls are defined in this analysis as multi-day events where availability from wind and solar generation across the NEM is sustained below the fifth percentile of recently observed weather history[13].

The timing, severity and duration of prolonged dark and still weather conditions over a wide area are difficult to predict. AEMO applies historical 'reference years' in the ISP modelling to capture the impact of weather conditions that impact the power system, in different locations and across all times of the day and year. AEMO's modelling leverages 15 years of observed weather patterns, providing a diverse mix of weather conditions, but future conditions may provide more extreme conditions than have been observed in this period. Climate analysis undertaken by Risk Frontiers[14] projects that to 2090 the average duration and frequency of solar lulls across the NEM is expected to decrease, whilst the frequency and average duration of wind lulls is projected to remain relatively consistent with observed history.

Definitions relevant to VRE lulls used in this appendix

- **Available capacity factor** – the percentage of a given generator or group of generators available to generate for a given period, relative to its maximum generation capacity. For example, a wind farm with a maximum capacity of 100 megawatts (MW) that is currently is available to generate 50 MW has a capacity factor of 50%. If the same wind farm generated 1,000 megawatt hours (MWh) in a day, its daily available capacity factor would be 41.66%, given it could produce 100 MW for 24 hrs, or 2,400 MWh if at full output for the day.
- **VRE lull** – where the daily available capacity factor of all relevant VRE does not exceed the fifth percentile for at least three consecutive days. For example, if the fifth percentile for VRE was at 20%, any three consecutive days with a daily capacity factor lower than this is considered a VRE lull. A VRE lull can be defined for a specific sub-region, a region, or the entire NEM. In this analysis, a VRE lull is defined across the NEM, or for southern mainland regions when specified.

Diversity of the renewable generation mix provides resilience for the NEM

Long, dark and still conditions typically can last for hours or a whole day and are problematic for system operability when they persist for multiple days. These weather conditions are most likely to occur during winter and cause longer VRE lulls when lower solar generation coincides with still wind conditions.

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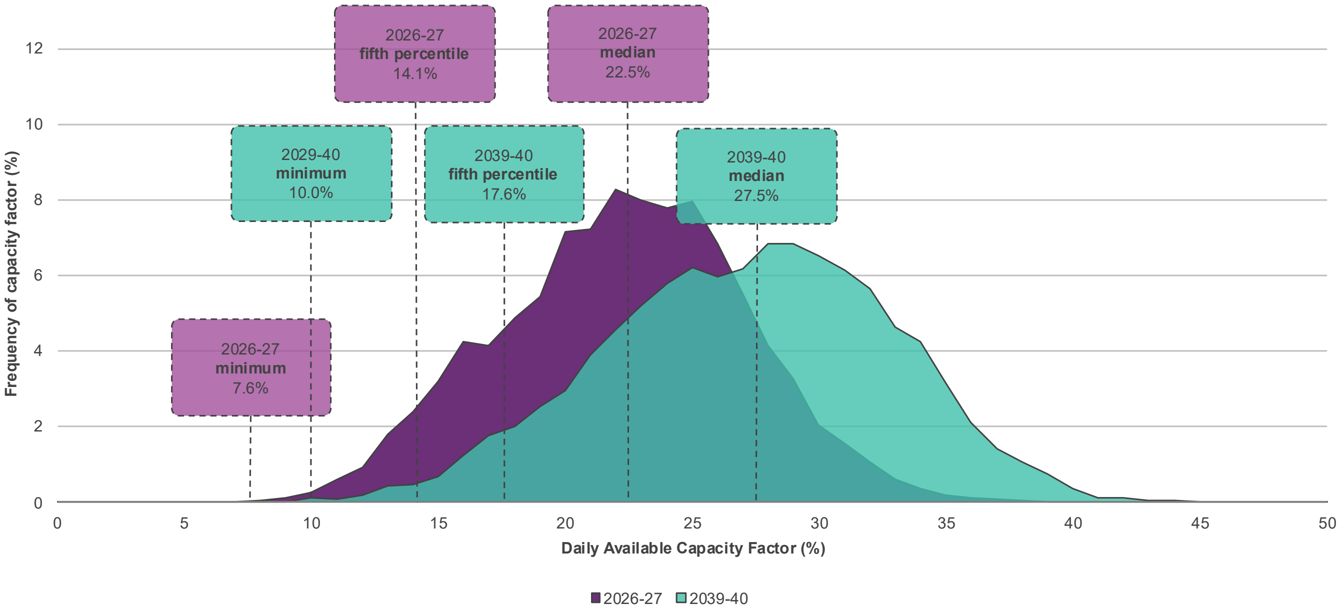
[13] This definition is aligned with the VRE lulls definition from analysis undertaken by Risk Frontiers for ASL to use in the 2025 Infrastructure Investment Objectives report. Refer to *Impact of climate change on VRE lulls*, at https://asl.org.au/-/media/services/files/publications/iio-report/2025/250813-impact-of-climate-change-on-vre-lulls-report-by-risk-frontiers.pdf?rev=c62f4f6a7912476593a834d01e71fab3&sc_lang=en.

[14] Undertaken by Risk Frontiers for ASL to use in the 2025 Infrastructure Investment Objectives report.

In a system with a high proportion of VRE, the resulting energy shortage may cause reliability risks if sufficient firming resources are not available for dispatch, or if fuel supplies (such as gas or diesel) are not adequately available to enable flexible gas operation for sustained duration. Delivering geographical diversity of generation and firming resources is a strong benefit of the network developments in the ODP to improve the power system's resilience to weather variability.

Figure 16 shows the spread of daily available capacity factors that are forecast for VRE across the NEM in 2026-27 and 2039-40, indicating that the capacity factors for VRE will increase in the future as more geographical diversity is introduced, and new VRE developments connect at locations of high resource. Furthermore, wind turbines are expected to develop with longer blades, higher hub heights, and generally assumed to be increasingly efficient and effective over more diverse wind speeds than older wind turbines.

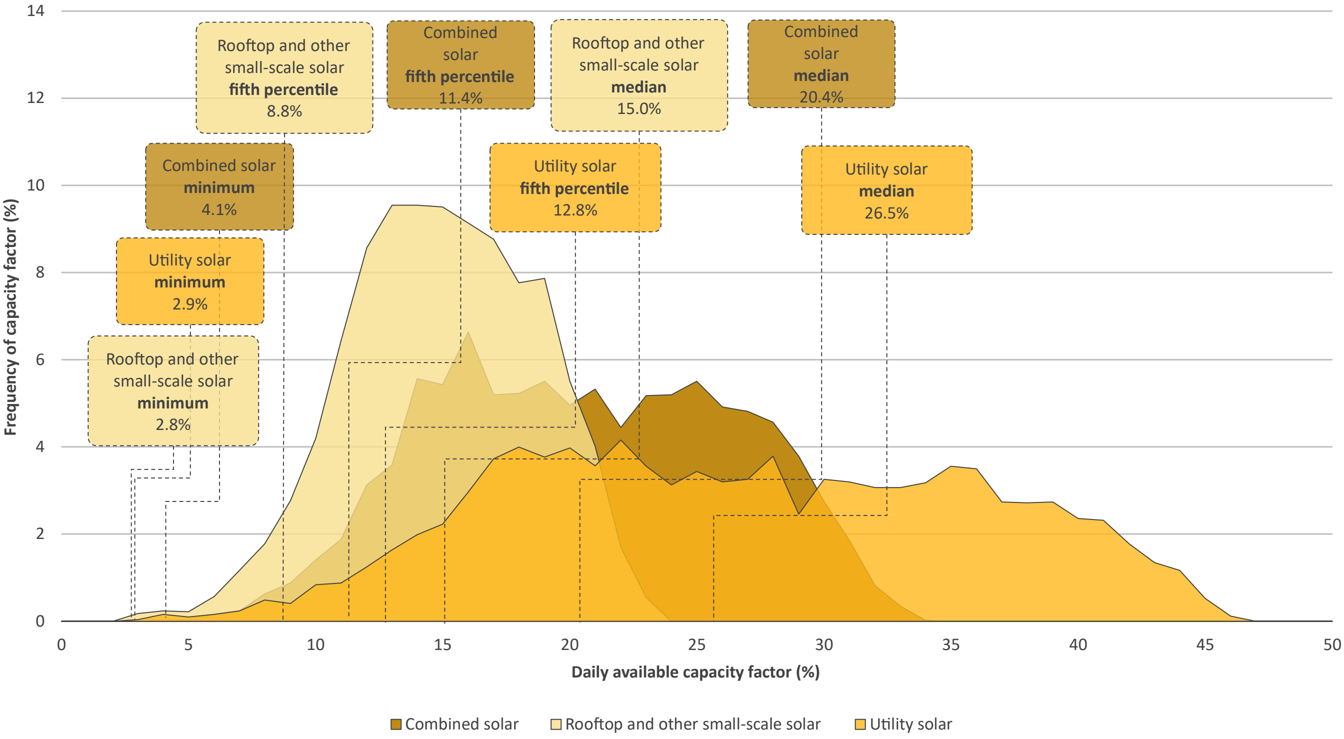
Figure 16 Forecast frequency of VRE daily available capacity factors across the NEM with minimum, fifth percentile and median capacity factor, across all reference years, 2026-27 and 2039-40



For solar generators, utility-scale developments will have materially higher capacity factors, as they are designed and developed to harness more solar energy, using technologies such as single-axis tracking to follow the sun's direction, improving panel efficiency, and are less impacted by shading from trees and surrounding buildings.

Figure 17 shows how utility solar typically has a higher capacity factor than rooftop and other small-scale solar. The generation mix for utility scale devices also tends to be more geographically diverse than rooftop and other small-scale solar, which is an important driver of weather resilience. Solar developments at lower latitudes (closer to the equator) also receive more consistent sunlight across the year, meaning that NEM-wide solar aggregate capacity factors will be influenced by the geographical location of new developments.

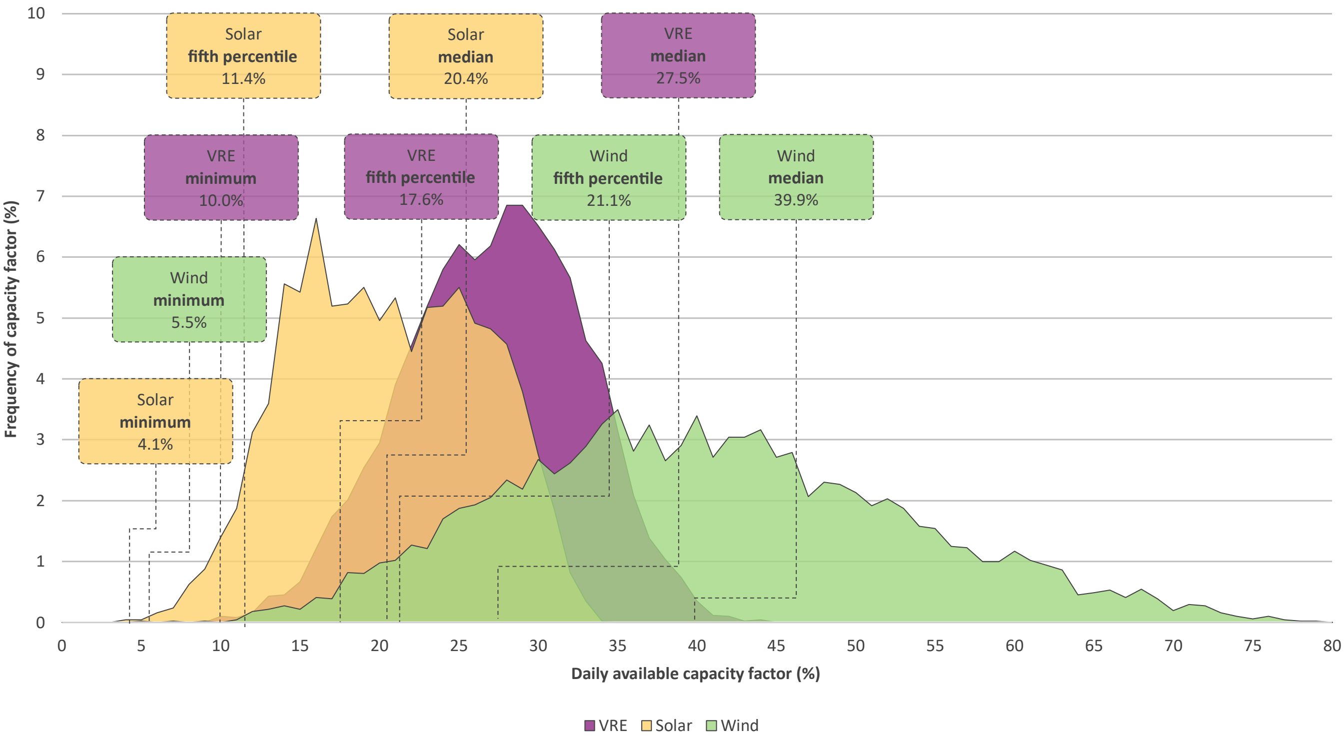
Figure 17 **Forecast frequency of total solar, rooftop and other small-scale solar, and utility solar daily available capacity factors across the NEM with minimum, fifth percentile and median capacity factor, across all reference years, 2039-40**



Note: the analysis applies the projected geographical distribution of these technologies, across regions and REZs in the proposed ODP, and therefore is not a generic estimate of any solar farm at any location.

Diversity of renewable energy technologies provides resilience through different weather conditions. **Figure 18** demonstrates the aggregate minimum daily output from wind and solar generators combined is roughly twice as high than if the system relied on either wind or solar alone.

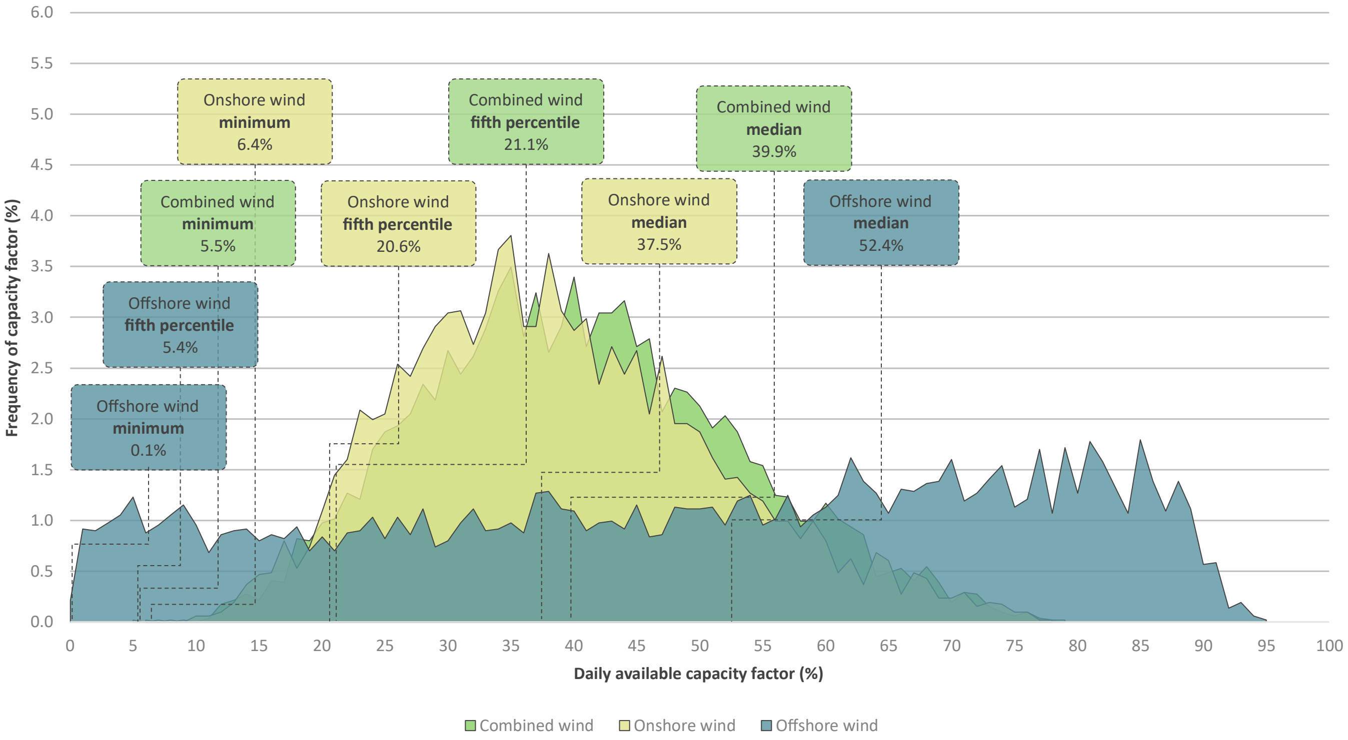
Figure 18 **Forecast frequency of VRE, solar and wind daily available capacity factors across the NEM with minimum, fifth percentile and median capacity factor, across all reference years, 2039-40**



Note: total VRE in this figure is reported as the total availability of both wind and solar technologies relative to installed capacity, it is not the simple addition of the individual minimum capacity factors for solar and wind. The analysis applies the projected geographical distribution of these technologies, across regions and REZs in the proposed ODP, and therefore is not a generic estimate of any wind farm or solar farm at any location.

Similar to a mix of wind and solar, a mix of onshore and offshore wind provides additional resilience by taking advantage of diverse wind resources. **Figure 19** shows how forecast daily capacity factors for offshore wind are relatively evenly distributed, while daily available capacity factors for onshore wind are more normally distributed around its median annual capacity factor. This technological diversity improves overall wind availability during periods of low onshore wind resource availability.

Figure 19 **Forecast frequency of total wind, onshore wind and offshore wind daily available capacity factors across the NEM with minimum, fifth percentile and median capacity factor, across all reference years, 2039-40**



Note: the analysis applies the projected geographical distribution of these technologies, across regions and REZs in the proposed ODP, and therefore is not a generic estimate of any wind farm at any location

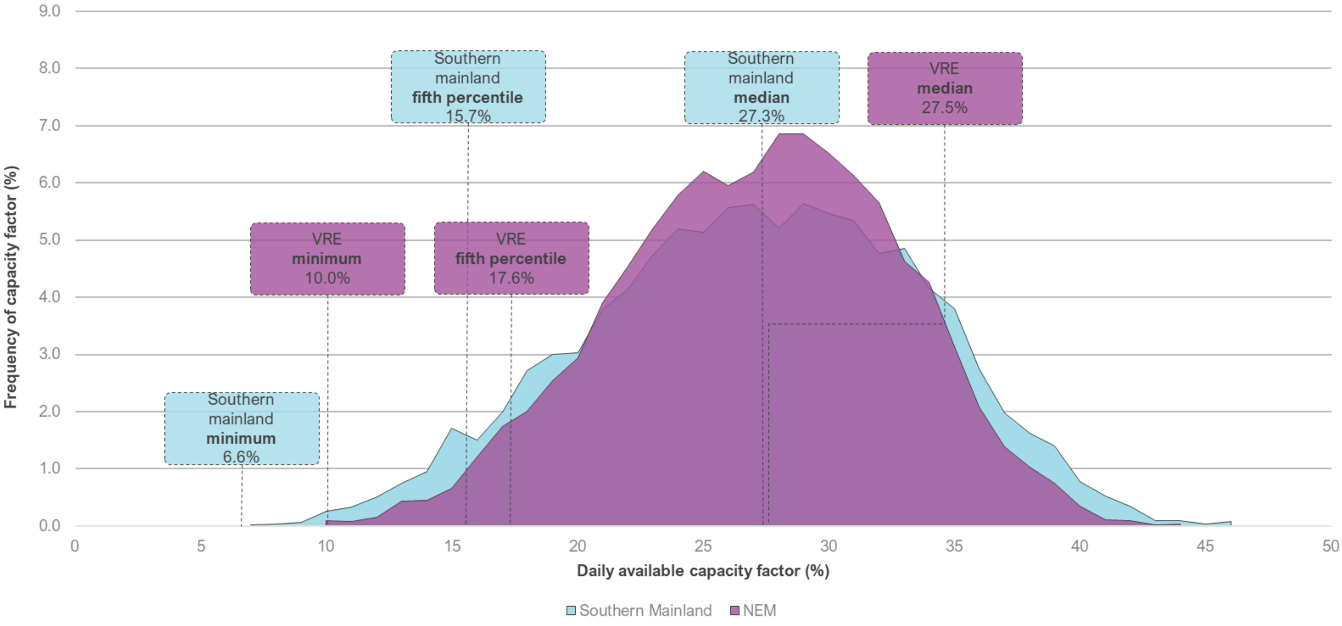
The future NEM is capable of meeting demand during periods of very low VRE

The geographic diversity of VRE generation and investment in network developments will help reduce reliability risks in periods of low renewable resources in any single NEM region by enabling the sharing of excess generation from one region to another experiencing lower renewable resource availability. This will also reduce the reliance on storage and flexible gas generation.

Winter months have lower solar availability with shorter days, which is more pronounced at higher latitudes in southern Australia, coinciding with colder conditions that increase heating loads (particularly as consumers electrify their traditional gas heating appliances). Victoria, South Australia and New South Wales are most exposed to the risk of these conditions while also providing limited geographical diversity, as weather conditions affecting one region tends to influence the weather of neighbouring regions.

As shown in **Figure 21**, the minimum, fifth percentile and median capacity factor of the southern mainland NEM is lower than that of the NEM as a whole.

Figure 20 Forecast frequency of VRE daily available capacity factors for the NEM and southern mainland regions with minimum, fifth percentile and median capacity factor, across all reference years, 2039-40



While Tasmania also experiences fewer daytime hours in winter, it also has significant amounts of hydro capacity that provide resilience to low VRE days. When the southern mainland is experiencing periods of low coincident VRE generation, Queensland and Tasmania can share excess generation through the transmission system.

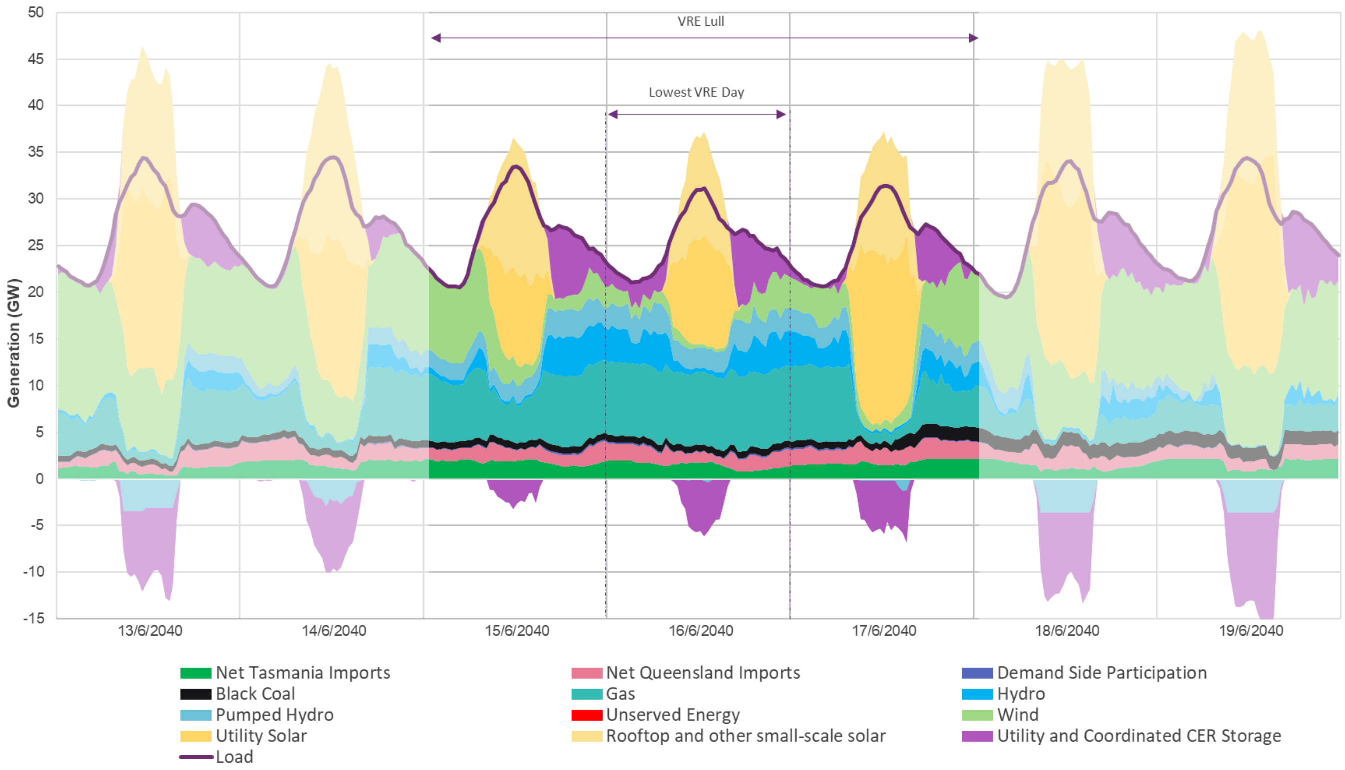
Figure 21 shows the estimated dispatch mix in June 2040 in the lead up to and during the most severe VRE lull event assumed for the southern mainland regions in the Draft 2026 ISP datasets. This week-long period includes the date of the mainland's minimum available capacity factor for all VRE, assumed to occur on 16 June with the mainland regions experiencing low wind generation and reduced solar generation. The ability for Queensland and Tasmania to export surplus generation during this period is limited by the capacity of the transmission system.

During this lowest available capacity factor day in the southern mainland in the modelled reference years:

- Southern mainland regions experience high heating loads and relatively low VRE availability due to still, cloudy, and cool weather conditions.
- The low VRE conditions are the most extreme on 16 June but start from the afternoon of the day before, with low solar production and relatively low wind output and continue into the next day.
- On these days, gas generation is required to run continuously at peak output to cover the VRE shortfalls, while hydro and storages also have critical contributions. This modelling applies the daily gas fuel limits described in Appendix A10 for gas development projection Option 3 to ensure that gas availability is appropriately considered through extended periods of low VRE availability.
- Storages play a critical role in firming intermittent generation during the VRE lull. Storages are able to charge for short periods during the middle of the day when solar is more abundant and shift that energy to support the evening peaks. If solar is less available on these low VRE periods, more flexible demand responses, discharge from deeper storages and greater utilisation of flexible gas may all be needed.

- As discussed in Section A4.5, storage operators are modelled to prepare for the upcoming low VRE periods by charging during daytime periods and preserving some of their stored energy for periods of VRE scarcity, assuming these conditions are forecast ahead of time. Imports from neighbouring regions, gas and hydro provide firming during the evening peaks, complementing utility storages.
- Sustained support is provided from hydro resources in New South Wales and Victoria, made more accessible throughout the southern mainland by transmission augmentations in the proposed ODP.

Figure 21 Forecast operability across the southern mainland NEM regions (excluding Queensland and Tasmania) for the VRE lull with the lowest single day VRE period in 2039-40, *Step Change* (GW)



Note: gas includes flexible gas, mid-merit gas, biomass and diesel generators.

Figure 22 and **Figure 23** show the forecast available energy for storages of different depths during the same VRE lull period, demonstrating the critical role that storages are forecast to play in firming energy and meeting demand when VRE generation is less available.

All depths of storage are heavily relied on during this period of VRE lull:

- All storages facilitate the firming of energy from previous higher VRE periods when excess energy is stored for use in later, lower VRE periods. Storages start discharging from the evening of 15 June when VRE generation decreases.
- Shallow and medium storages charge where possible on the 16 June but the dispatch of storage on 15 June means they start at a lower stored energy availability leading into the evening of 16 June when VRE generation is the lowest.

Figure 22 **Forecast available energy for different storage depths in southern mainland NEM regions and Snowy 2.0 water level for a VRE lull with the lowest VRE day, *Step Change*, 2040 (MWh)**

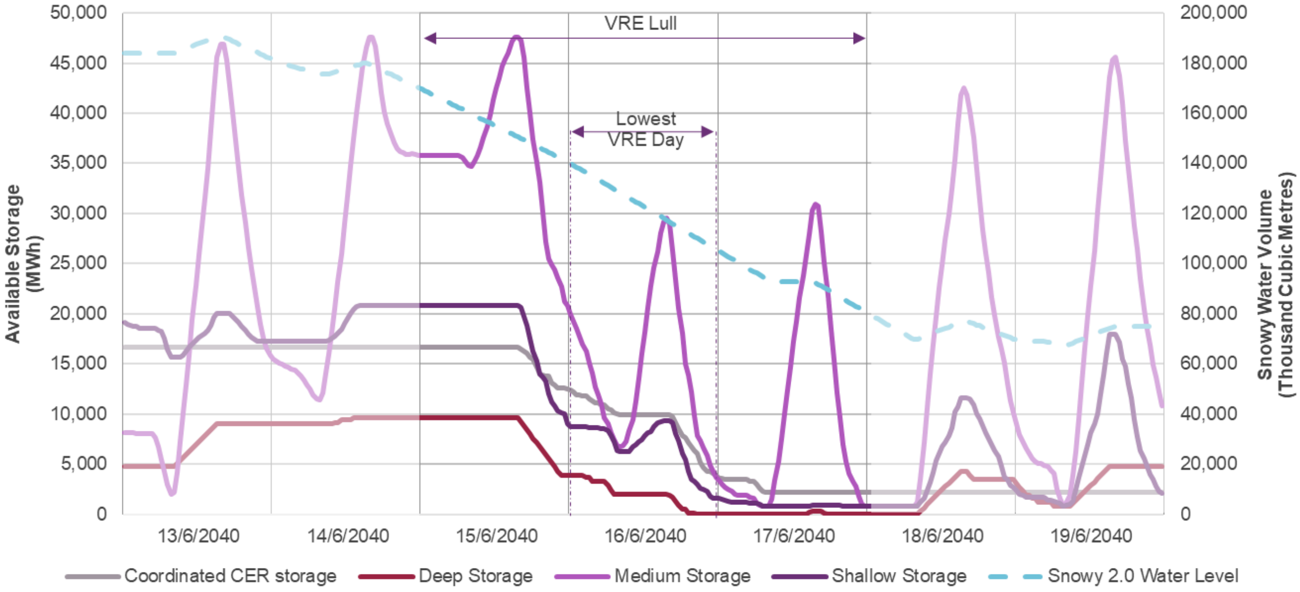
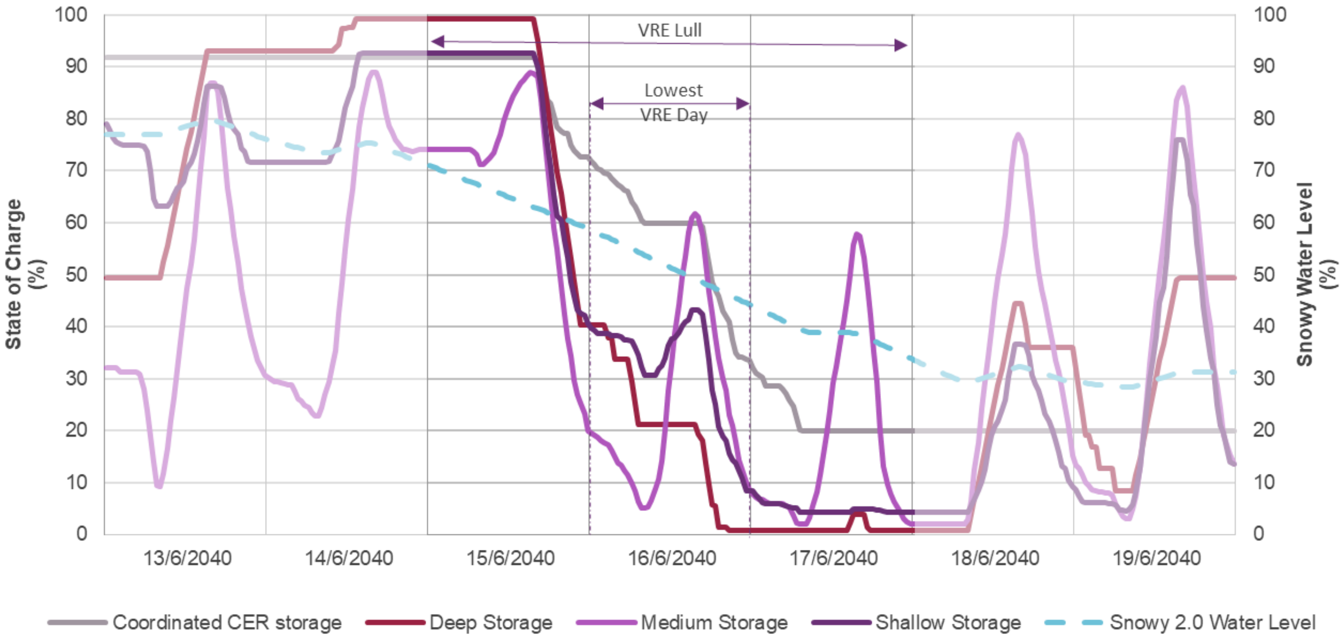


Figure 23 **Forecast state of charge for different storage depths in southern mainland NEM regions and Snowy 2.0 water level for a VRE lull with the lowest VRE day, *Step Change*, 2040 (%)**



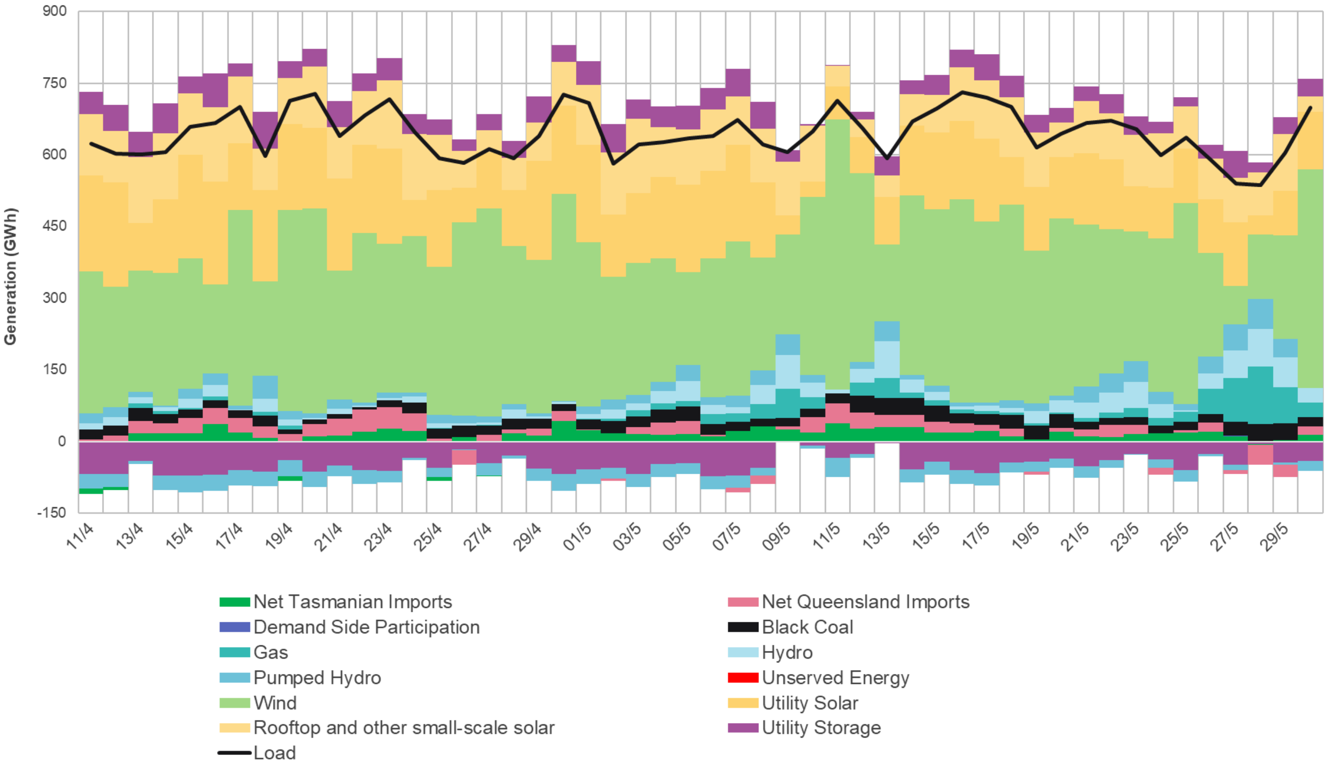
NEM resilience through prolonged low VRE periods

Figure 24 shows the forecast generation mix for the southern mainland NEM regions during the longest period assumed in 2040 where daily VRE availability is below the median daily available capacity factor, between 11 April 2040 and 30 May 2040. This simulation reflects weather conditions observed in 2017.

During this time, even with levels of VRE below median levels across the period, wind and solar generation still make up most of the generation mix. Reliance on other generation technologies such as gas and hydro increases from early May, and storages of all depths are critical in firming energy to meet peak demands. While there are aggregate imports from Queensland and Tasmania, some periods exhibit excess VRE in southern mainland to support exports to the other regions.

This analysis provides a sample demonstration that with appropriate energy and fuel management, the NEM is capable to withstand lower levels of VRE availability under the proposed ODP, even for extended durations.

Figure 24 Forecast daily generation mix during sustained VRE conditions in southern mainland below median capacity factor, *Step Change*, May-June 2040 (GWh)



A4.7 Maintaining reliability during the transition

AEMO has undertaken a preliminary reliability analysis for the Draft 2026 ISP ODP, accounting for weather variability and generator outages[15]. AEMO is continuing to assess any potential risk factors and will examine whether additional firming solutions would be needed in addition to the generation, storage and network investments in the proposed ODP to support the reliability of the power system. This extended analysis will be provided in the final 2026 ISP.

The preliminary reliability assessment has identified summary insights consistent with previous ESOO and ISP reliability analyses, primarily that:

- Reliability risks in the NEM vary with different weather conditions and over time, as coal capacity retires from the power system. The Draft 2026 ISP reaffirms that renewable energy, connected by transmission and distribution, firmed with storage and backed up by gas, presents the least-cost way to supply secure and reliable electricity to consumers as coal plants retire, while meeting government policies through to 2050.
- Reliability risks shift from summer to winter, as the NEM evolves from a capacity-constrained power system to one with greater energy adequacy challenges.

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[15] To manage simulation complexity, this reliability analysis has simulated fewer random generator outage patterns and reference years than is applied to do a formal reliability assessment in the ESOO.

Glossary

This glossary has been prepared as a quick guide to help readers understand some of the terms used in the ISP. Words and phrases defined in the National Electricity Rules (NER) have the meaning given to them in the NER. This glossary is not a substitute for consulting the NER, the Australian Energy Regulator's (AER's) Cost Benefit Analysis Guidelines, or AEMO's *ISP Methodology*.

Term	Acronym	Explanation
Actionable ISP project	-	Actionable ISP projects optimise benefits for consumers if progressed before the next ISP. A transmission project (or non-network option) identified as part of the ODP and having a delivery date within an actionable window. For newly actionable ISP projects, the actionable window is two years, meaning it is within the window if the project is needed within two years of its earliest in-service date. The window is longer for projects that have previously been actionable. Project proponents are required to begin newly actionable ISP projects with the release of a final ISP, including commencing a RIT-T.
Actionable project progressing under a jurisdictional framework	-	A transmission project (or non-network option), other than an actionable ISP project, which optimises benefits for consumers if progressed before the next ISP, is identified as part of the ODP, and which will progress under a jurisdictional policy that AEMO considers under NER 5.22.3 (b) and includes in the ISP.
Actionable New South Wales project and actionable Queensland project	-	A transmission project (or non-network option) that optimises benefits for consumers if progressed before the next ISP, is identified as part of the ODP, and is supported by or committed to in New South Wales Government or Queensland Government policy and/or prospective or current legislation.
Anticipated project	-	A generation, storage or transmission project that is in the process of meeting at least three of the five commitment criteria (planning, construction, land, contracts, finance), in accordance with the AER's Cost Benefit Analysis Guidelines. Anticipated projects are included in all ISP scenarios.
Candidate development path	CDP	A collection of development paths which share a set of potential actionable projects. Within the collection, potential future ISP projects are allowed to vary across scenarios between the development paths. Candidate development paths have been shortlisted for selection as the ODP and are evaluated in detail to determine the ODP, in accordance with the ISP Methodology.
Capacity	-	The maximum rating of a generating or storage unit (or set of generating units), or transmission line, typically expressed in megawatts (MW). For example, a solar farm may have a nominal capacity of 400 MW.
Committed project	-	A generation, storage or transmission project that has fully met all five commitment criteria (planning, construction, land, contracts, finance), in accordance with the AER's Cost Benefit Analysis Guidelines. Committed projects are included in all ISP scenarios.
Consumer energy resources	CER	Generation or storage assets owned by consumers and installed behind-the-meter. These can include rooftop solar, batteries and electric vehicles (EVs). CER may include demand flexibility.
Consumption	-	The electrical energy used over a period of time (for example a day or year). This quantity is typically expressed in megawatt hours (MWh) or its multiples. Various definitions for consumption apply, depending on where it is measured. For example, underlying consumption means consumption being supplied by both CER and the electricity grid.
Cost-benefit analysis	CBA	A comparison of the quantified costs and benefits of a particular project (or suite of projects) in monetary terms. For the ISP, a cost-benefit analysis is conducted in accordance with the AER's Cost Benefit Analysis Guidelines.
Counterfactual development path	-	The counterfactual development path represents a future without major transmission augmentation. AEMO compares candidate development paths against the counterfactual to calculate the economic benefits of transmission.
Demand	-	The amount of electrical power consumed at a point in time. This quantity is typically expressed in megawatts (MW) or its multiples. Various definitions for demand, depending on where it is measured. For example, underlying demand means demand supplied by both CER and the electricity grid.

Term	Acronym	Explanation
Demand-side participation	DSP	The capability of consumers to reduce their demand during periods of high wholesale electricity prices or when reliability issues emerge. This can occur through voluntarily reducing demand, or generating electricity.
Development path	DP	A set of projects (actionable projects, future projects and ISP development opportunities) in an ISP that together address power system needs.
Dispatchable capacity	-	The total amount of generation that can be turned on or off, without being dependent on the weather. Dispatchable capacity is required to provide firming during periods of low variable renewable energy output in the NEM.
Distribution network service provider	DNSP	A business which owns, controls or operates a distribution system (including a distribution network).
Economic offloading	-	Refers to a generator being dispatched below its maximum availability, because some or all of its output was bid into price bands greater than the regional reference price. This may also be referred to as economic 'spill' or 'spilled energy' as generators reduce output due to low market prices or lack of available demand.
Firming	-	Grid-connected assets that can provide dispatchable capacity when variable renewable energy generation is limited by weather, for example storage (pumped-hydro and batteries) and gas-powered generation.
Future distribution project	-	A distribution project that is part of the ODP and forecast to be needed in the future. The project is an ISP development opportunity and does not address an identified need specified in the ISP. The ISP cannot make a distribution project 'actionable' or require commencement of the Regulatory Investment Test for Distribution (RIT-D).
Future ISP project	-	A transmission project (or non-network option) that addresses an identified need in the ISP, that is part of the ODP, and is forecast to be actionable in the future.
Identified need	-	The objective a TNSP seeks to achieve by investing in the network in accordance with the NER or an ISP. In the context of the ISP, the identified need is the reason an investment in the network is required, and may be met by either a network or a non-network option.
ISP development opportunity	-	A development identified in the ISP that does not relate to a transmission project (or non-network option) and may include generation, storage, demand-side participation, or other developments such as distribution network projects.
National Electricity Rules	NER	The Rules are legally binding rules made under the National Electricity Law, which govern the operation of the National Electricity Market and the ways in which AEMO manages power system security. The Rules also provide the regulatory framework for network connections and access, national transmission planning and pricing for network services. The Rules are mainly made by the AEMC having regard to the National Electricity Objective.
Net market benefits	-	The present value of total market benefits associated with a project (or a group of projects), less its total cost, calculated in accordance with the AER's Cost Benefit Analysis Guidelines.
Non-network option	-	A means by which an identified need can be fully or partly addressed, that is not a network option. A network option means a solution such as transmission lines or substations which are undertaken by a Network Service Provider using regulated expenditure.
Optimal development path	ODP	The development path identified in the ISP as optimal and robust to future states of the world. The ODP contains actionable projects, future ISP projects and ISP development opportunities, and optimises costs and benefits of various options across a range of future ISP scenarios.
Regulatory Investment Test for Transmission	RIT-T	The RIT-T is a cost benefit analysis test that TNSPs must apply to prescribed regulated investments in their network. The purpose of the RIT-T is to identify the credible network or non-network options to address the identified network need that maximise net market benefits to the NEM. RIT-Ts are required for some but not all transmission investments.
Reliable (power system)	-	The ability of the power system to supply adequate power to satisfy consumer demand, allowing for credible generation and transmission network contingencies.
Renewable energy	-	For the purposes of the ISP, the following technologies are referred to under the grouping of renewable energy: "solar, wind, biomass, hydro, and hydrogen turbines". Variable renewable energy is a subset of this group, explained below.
Renewable energy zone	REZ	An area identified in the ISP as high-quality resource areas where clusters of large-scale renewable energy projects can be developed using economies of scale.

Term	Acronym	Explanation
Renewable lull	-	A prolonged period of very low levels of variable renewable output, typically associated with dark and still conditions that limit production from both solar and wind generators.
Rooftop and other small-scale solar	-	Solar photovoltaic (PV) generation assets that are not centrally controlled by AEMO dispatch. Examples include residential and business rooftop PV as well as larger commercial or industrial “non-scheduled” PV systems.
Scenario	-	A possible future of how the NEM may develop to meet a set of conditions that influence consumer demand, economic activity, decarbonisation, and other parameters. For the Draft 2026 ISP, AEMO has considered three scenarios: *Slower Growth*, *Step Change* and *Accelerated Transition*.
Secure (power system)	-	The system is secure if it is operating within defined technical limits and is able to be returned to within those limits after a major power system element is disconnected (such as a generator or a major transmission network element).
Sensitivity analysis	-	Analysis undertaken to determine how modelling outcomes change if an input assumption (or a collection of related input assumptions) is changed.
Spilled energy	-	Energy from variable renewable energy resources that could be generated but is unable to be delivered. Transmission curtailment results in spilled energy when generation is constrained due to operational limits, and economic spill occurs when generation reduces output due to market price. This can also be referred to as ’economic offloading’.
Transmission network service provider	TNSP	A business that owns, controls or operates a transmission network.
Utility-scale or utility		For the purposes of the ISP, ‘utility-scale’ and ‘utility’ refers to technologies connected to the high-voltage power system rather than behind the meter at a business or residence.
Value of greenhouse gas emissions reduction	VER	The VER estimates the value (dollar per tonne) of avoided greenhouse gas emissions. The VER is calculated consistent with the method agreed to by Australia’s Energy Ministers in February 2024.
Virtual power plant	VPP	An aggregation of resources coordinated to deliver services for power system operations and electricity markets. For the ISP, VPPs enable coordinated control of consumer-scale batteries.
Variable renewable energy	VRE	Renewable resources whose generation output can vary greatly in short time periods due to changing weather conditions, such as solar and wind.