AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Engineering Roadmap

FY2025 Priority Actions Report

A report for the National Electricity Market, the interconnected power system in Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia, and Tasmania.

Important notice

Purpose

This report outlines activities the Australian Energy Market Operator (AEMO) plans to undertake in the 2024-25 financial year (FY2025) to advance operational capability for times of high renewables, keeping the National Electricity Market (NEM) ahead of engineering challenges of the energy transition before they emerge operationally. The report continues the Engineering Roadmap to 100% Renewables work by reviewing actions undertaken in the 2023-2024 financial year, and by providing transparency on the specific engineering and operational readiness activities that AEMO intends to progress in FY2025. It also introduces the annual Transition Plan for System Security that AEMO is required to publish annually by 1 December following the AEMC's Improving Security Frameworks rule change.

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Version control

Version	Release date	Changes
#1	15/08/2024	Initial publication

AEMO acknowledges the Traditional Owners of country throughout Australia and recognises their continuing connection to land, waters and culture. We pay respect to Elders past and present.

Executive summary

Australia's transition to renewables continues at pace. The past year has seen continued progress in the transition:

- Records continue to be broken for instantaneous renewable penetration and potential, with recent records of 72.1% renewable penetration and 99.7% renewable potential in the National Electricity Market (NEM).
- Distributed photovoltaics (DPV) provided a record 101.7% of South Australia's underlying demand over a 30-minute interval on 31 December 2023.

Growth in renewable energy needs to continue to accelerate to enable the futures envisioned in the 2024 Integrated System Plan (ISP)[1]. These futures will require the power system to be capable of operating at times with up to 100% generation from renewables. The Engineering Roadmap aims to advance operational capability for times of high renewables, keeping ahead of engineering challenges of the energy transition before they emerge operationally, supporting the continuing market growth in renewables as the power system portfolio evolves.

Continued delivery of priority activities within the NEM Engineering Roadmap during financial year (FY) 2024 has helped enable this progress, with 17 of the 18 committed actions[2] complete and the remaining action in progress. Key outputs include technical publications on inertia, a 100% inverter-based generation study in Tasmania, specifications for grid-forming inverters and electric vehicle standards for grid operation. For consumer energy resources (CER), outputs include significant improvements in compliance, development of emergency backstop requirements and coordinated engagement on changes to the National Electricity Rules (NER). Together, these actions supported the continued increase in renewable penetration records and helped to avoid further curtailment of renewables and costly market interventions.

This progress was only made possible through detailed collaboration on a number of work programs with stakeholders across the energy sector including network service providers (NSPs), market bodies, governments, original equipment manufacturers (OEMs), researchers, and consumers themselves. But a scale up in effort is required to enable Australia to keep breaking new ground and accelerate the energy transition towards 100% renewables. To progress through upcoming transition milestones, the resourcing and effort required from distribution network service providers, transmission network service providers, and other key stakeholders across the energy sector is new, different, and in addition to current activities.

With the help of a grant from the Australian Renewable Energy Agency (ARENA) of up to $15m over 18 months, AEMO is scaling up its Engineering Roadmap efforts for FY2025 and beyond. The 37 FY2025 Priority Actions identified in this report enable progress across three focus areas:

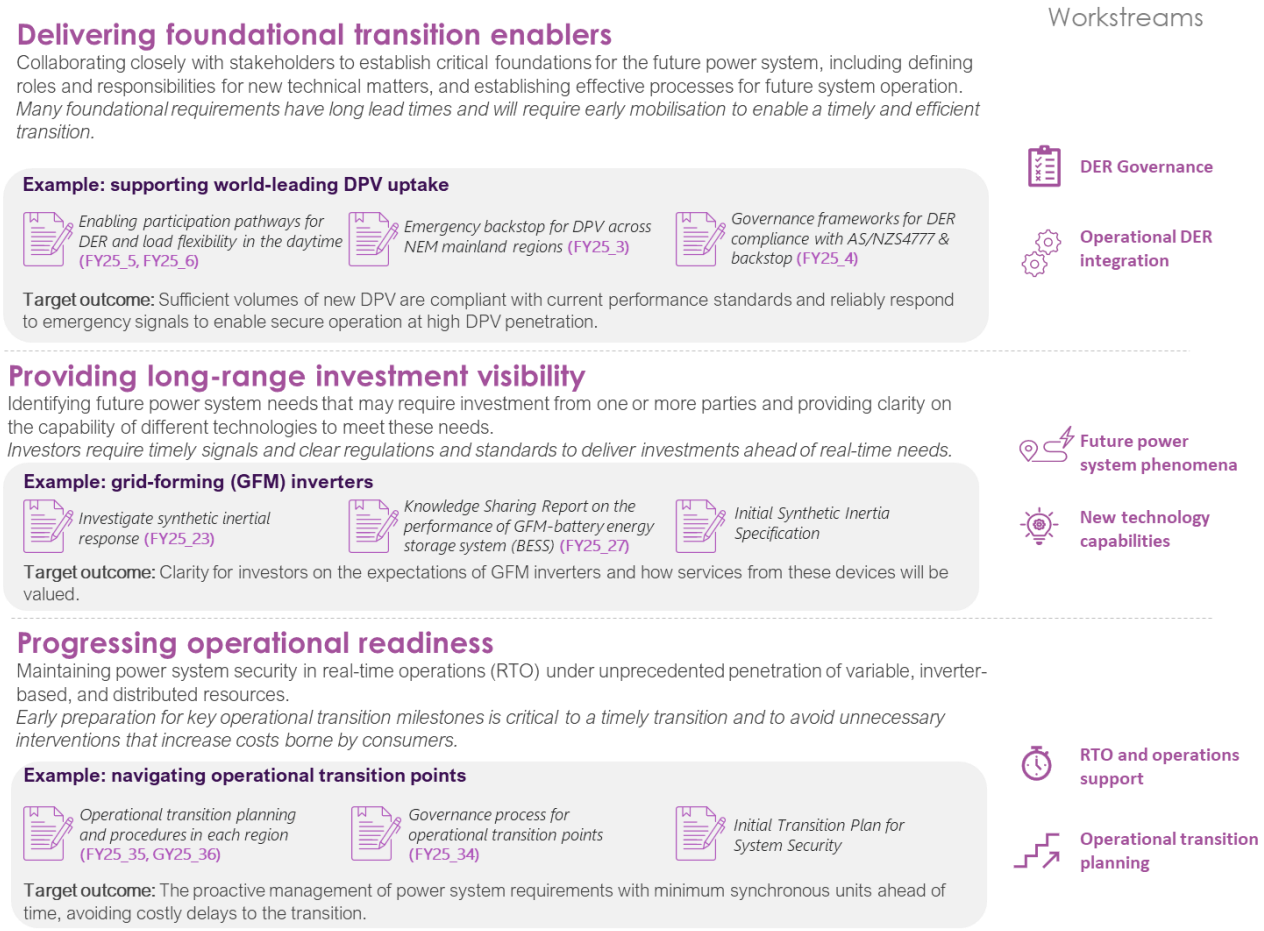
- Delivering foundational enablers
- Providing long-range investment visibility
- Progressing operational readiness

Further detail on these focus areas, with example actions, is outlined in Figure 1.

[1] https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp

[2] https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/nem-engineering-roadmap-fy2024--priority-actions.pdf

Figure 1 Overview of AEMO's priority actions for FY2025



In addition to the Engineering Roadmap, the Australian Energy Market Commission (AEMC) made a final determination on the Improving Security Frameworks (ISF) rule change[3]. The rule change provides AEMO with new tools to manage system security and provide better incentives for participants to invest in providing system security in the longer-term. As part of the regulated changes, NER 5.20.8 requires AEMO to publish an annual Transition Plan for System Security to convey its understanding of the security needs of the system, and how these may evolve.

AEMO intends to leverage progress made in the Engineering Roadmap on building operational readiness to shape the approach to this new publication, and requests feedback from stakeholders in Section 3.

There is a significant and expanding body of critical work to continue with and we look forward to continuing this collaboration with stakeholders for FY2025 and beyond.

[3] See https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition.

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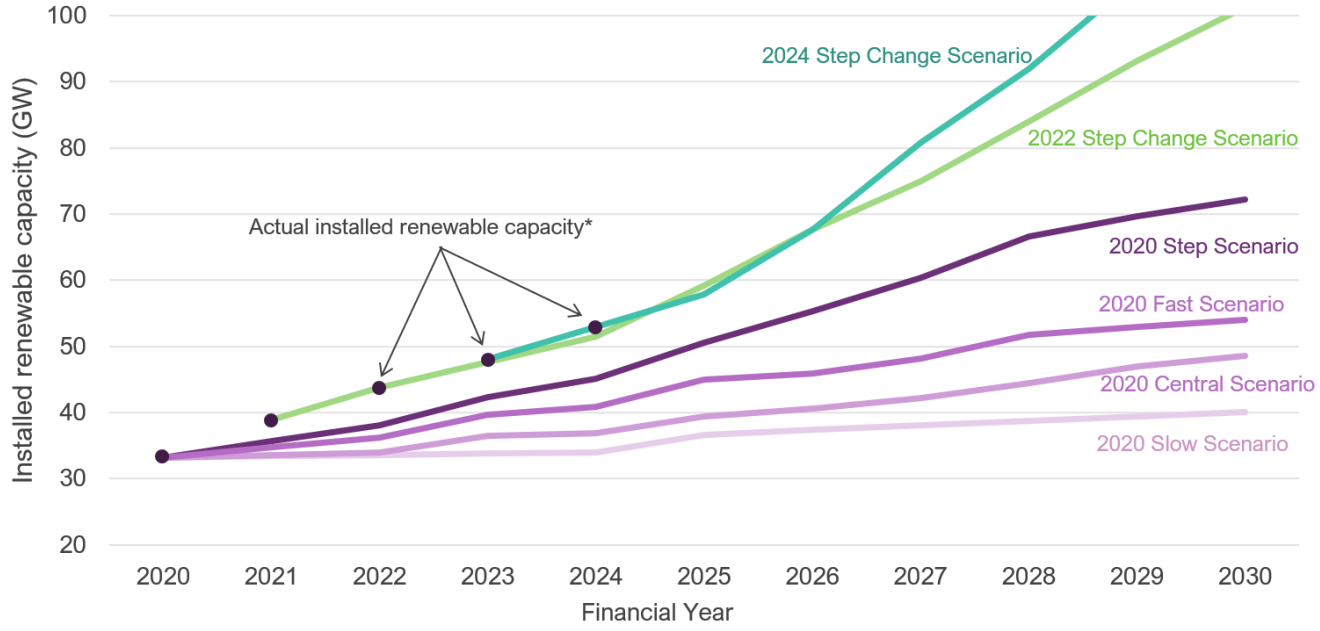
1 The transition to renewables

1.1 State of the transition

Australia is undergoing a renewables step change

The National Electricity Market's (NEM's) transition to higher renewables continues to occur at pace. Actual installed renewable capacity is tracking above the fastest *Step Change* scenario originally envisioned in the 2020 *Integrated System Plan* (ISP). The recently published 2024 ISP incorporates this progress in the latest *Step Change* Scenario (Figure 2).

Figure 2 Actual installed renewable capacity and ISP *Step Change* scenario forecast, financial year (FY) 2020 to 2030 (gigawatts (GW))



*Renewable capacity includes the following technology types: hydro, utility storage, coordinated consumer energy resources (CER) storage, passive CER storage, offshore wind, onshore wind, utility solar, rooftop solar and other distributed solar.

The growth in new renewable capacity has facilitated accelerating instantaneous penetrations of renewables in the NEM, with a new record of 72.1% reached in October 2023 (Figure 3).

In the same month, a record instantaneous renewable potential of almost 100% (99.7%) was achieved. That is, had all available renewable resources in that 30-minute interval bid into the market and been dispatched, then 99.7% of demand could have potentially been met by renewable resources.

Additionally, on 31 December 2023, distributed photovoltaics (DPV) was generating electricity at a level sufficient to provide 100% of South Australia's underlying demand over a 30-minute interval, and in fact exceeded this by an additional 1.7%. At the time, synchronous generators were also online to maintain system security with all excess generation exported to other regions. This rapid progress in renewables penetration while maintaining system security is a testament to the collaborative efforts of the entire energy sector over the past five years, including

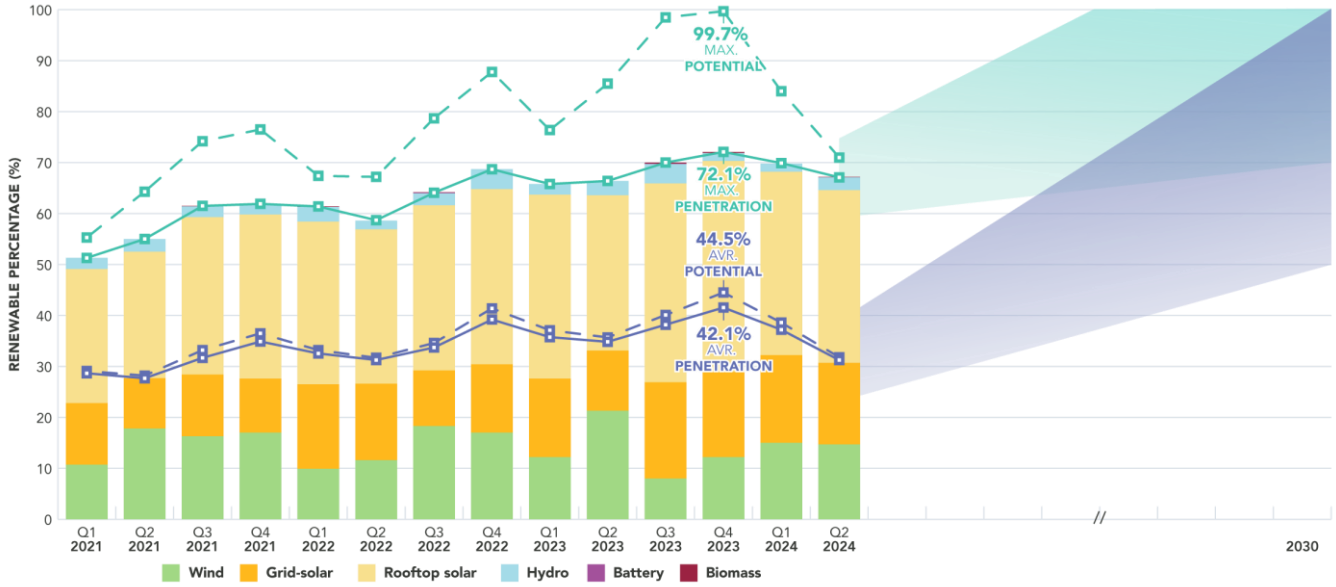
governments, network service providers (NSPs), market participants, industry, and consumers themselves through their own CER.

Renewable potential and penetration

Renewable potential in the chart below refers to the total available energy from renewable generators over a 30-minute interval given the weather conditions at that time, regardless of whether those generators ultimately provide all that electricity into the NEM.

Renewable penetration in the chart below refers to the proportion of NEM generation sourced from renewables over a 30-minute interval. This can be less than the corresponding renewable potential at that time.

Figure 3 NEM actual and projected instantaneous renewable penetration and resource potential to 2030



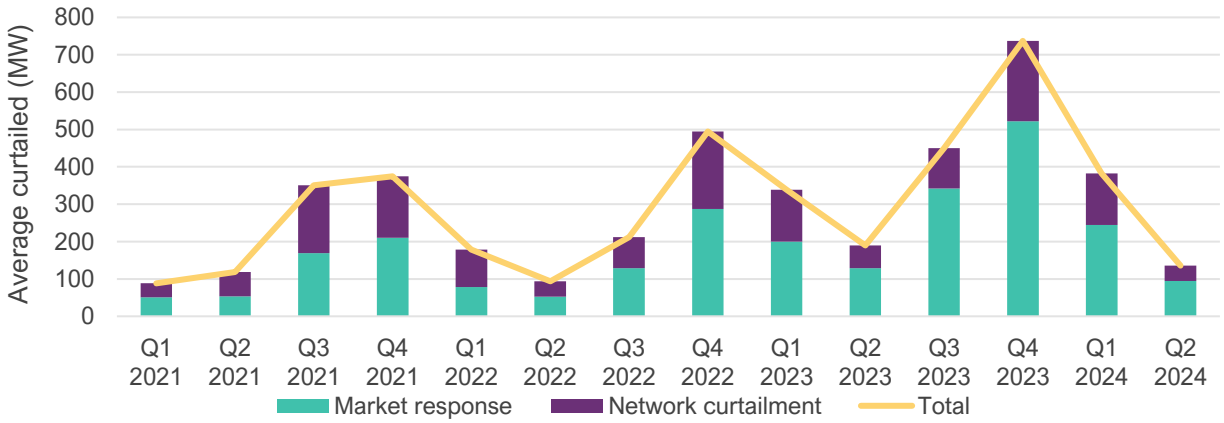
The gap between the achieved renewable penetration and the potential is a result of both market responses and power system security requirements. When the market spot price is lower than the bid of a scheduled renewable generator, it is dispatched below its instantaneous potential, a market response known as “economic offloading”. Low and negative spot prices often occur during the middle of the day, when there is abundant solar generation, by large-scale solar generation bidding into the market and by DPV reducing demand from the grid.

To date, economic offloading has tended to occur in most instances prior to system security limits binding. Over 2023, an average 68% of large-scale wind and solar curtailment was due to market responses, with the remainder primarily attributed to network curtailment, as shown in Figure 4. This situation may change as wind and solar capacity increases, and why it is critical that AEMO, where efficient to do so, pre-emptively resolves operational or system security constraints.

The Engineering Roadmap seeks to remove the technical and engineering barriers to high renewable penetration ahead of time, such that these do not become a barrier to the market operating with higher proportions of

instantaneous renewables. This is a critical step towards enabling a higher average contribution from renewables, and thereby enabling the decarbonisation of Australia's electricity supply in line with government targets.

Figure 4 Wind and solar curtailment drivers, 2021 to 2024 (megawatts (MW))



Preparing for new operational transition points

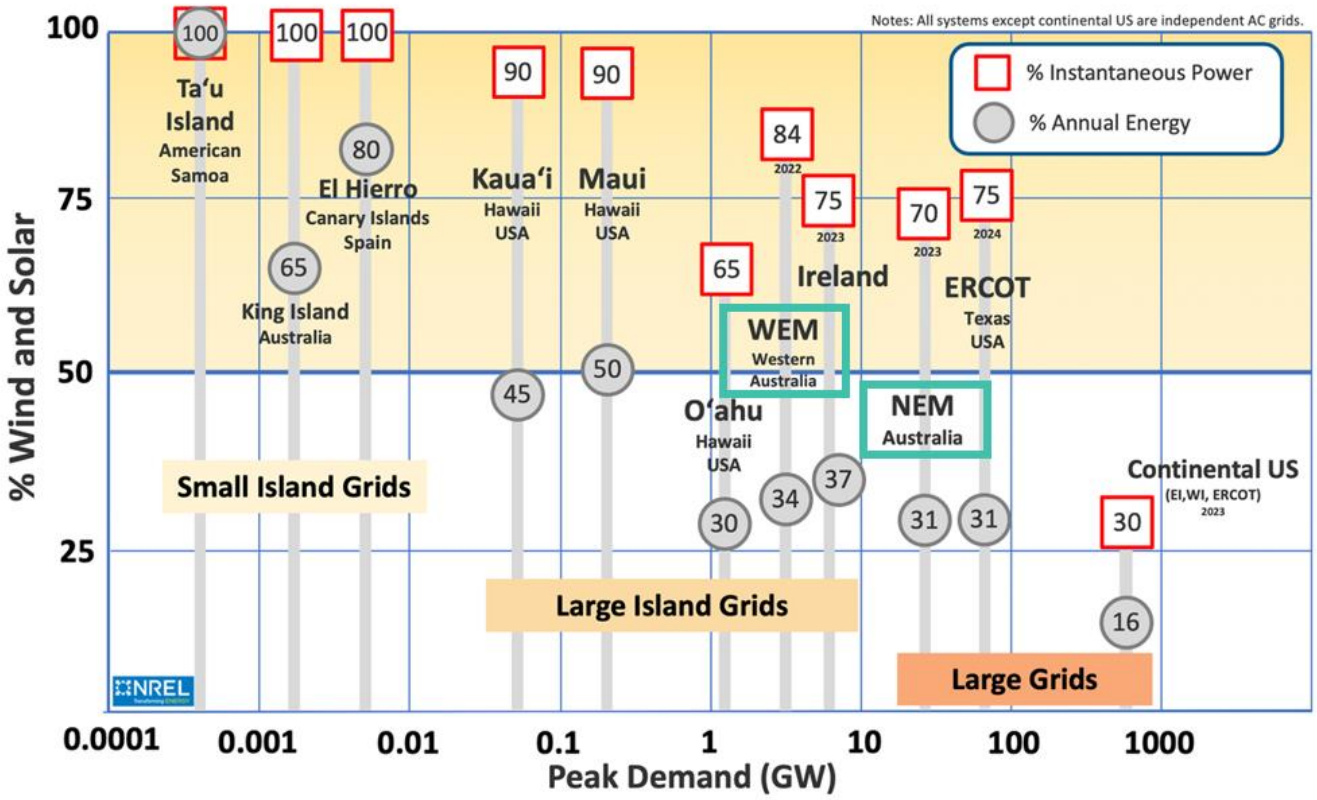
The focus of the Engineering Roadmap is to advance the operational capability for times of high renewables, aiming to keep the NEM ahead of the engineering challenges of the energy transition before they emerge operationally. Historical key events and milestones have already necessitated changes in the way AEMO manages the NEM technical operating envelope. These include the closure of large coal generators such as Hazelwood and Northern, and in South Australia the ongoing reduction in the minimum number of synchronous generators online, and DPV providing at times more than 100% of underlying demand.

Progressing through these milestones has required concerted efforts across the sector. Going forward, AEMO is enhancing processes and governance to support advance preparation for these, referred to as “Operational Transition Points”, with the aim to enable the system to manage new operational conditions securely and reliably as they arise in real-time. Upcoming operational transition points include the reduction of minimum synchronous generators online, the continued secure operation of the NEM as coal generators transition to retirement, and enabling secure operation in all NEM regions with increasing levels of consumer generation behind the meter.

Maintaining system security through these transition points is a challenge for the entire energy sector, indicated by declared security needs for the system increasing over the past five years, alongside rates of renewable curtailment. Developing power system capability to progress through these emerging operational transition points requires novel solutions developed through the detailed technical engineering work and coordinated action outlined in the Engineering Roadmap. The resourcing and effort required from AEMO, NSPs and the broader energy industry to progress through these operational transition points is new, different, and over and above existing activities.

Australia finds itself at the edge of current global capability of power system management in several aspects, including DPV penetration and the maximum instantaneous contribution of variable renewables in large, GW scale power systems (Figure 5).

Figure 5 International comparison of wind and solar penetration for different sized power systems



Source data provided by the National Renewable Energy Laboratory (NREL)[4].

But while much is being achieved, there is more to do to enable net zero for Australia. AEMO's optimal development path of the 2024 ISP outlines the lowest-cost pathway of essential generation, storage and transmission infrastructure to meet consumers' energy needs for secure, reliable and affordable energy, and to achieve net zero. This includes a requirement for continued deployment of large volumes of new generation across the NEM.

State of new generation connections

The amount of renewable generation being connected into the network is rapidly growing. Over the past 3 years, the number of connection applications received by AEMO has more than doubled from 6.5GW across 45 sites in FY2022, to 19GW across 81 sites in FY2024.

The connection assessment process is a collaborative effort between AEMO, NSPs, developers and original equipment manufacturers (OEM) to facilitate the approval of generation and storage connection applications. AEMO and the Clean Energy Council (CEC) established the Connections Reform Initiative (CRI) in 2022 to codesign improvements to this process. The ideas generated through the CRI are being implemented in real time, on real projects, and in some cases in collaboration with state and federal governments. Whilst work is ongoing to consistently embed these improvements across all connection processes, the benefits of the CRI are already being demonstrated through the step up in connections approvals from 6.9GW in FY2023 to 12GW in FY2024,

[4] https://www.nrel.gov/

and the time taken to reach full output across 75% of projects reducing from 11.2 months in FY2023 to 6.9 months or less in FY2024[5].

Whilst AEMO approved 12GW of connection applications in FY2024, the time taken for developers, construction providers and OEMs to physically deliver these projects has increased substantially (with 75% of projects taking up to 21 months to be constructed and ready for market registration). Key challenges include project financing, the volume and complexity of contractual arrangements, workforce resourcing, and supply chain constraints. This led to only 2.4GW of projects achieving market registration and 2.2GW achieving full output in FY2024. These are challenges that fall outside of AEMO's direct remit and instead require broad whole-of-sector efforts to address, without which there will be difficulties in realising the 2024 ISP Optimal Development Path.

1.2 The Engineering Roadmap

The Engineering Roadmap advances operational capability for times of high renewables, aiming to keep the NEM ahead of the engineering challenges of the energy transition before they emerge operationally. It identifies the critical engineering actions required to progress through key milestones in the energy transition and provides a technical base to inform industry prioritisation of efforts. This includes ongoing actions required for renewable penetration to continue to grow towards its potential.

Figure 6 below summarises the journey to date from the Engineering Framework to this current report on FY2025 priority actions. The Engineering Framework reviewed present day activities and capabilities against a set of future conditions to identify potential gaps requiring further consideration, as detailed in the NEM Engineering Framework Initial Roadmap[6]. This gap analysis informed the *Engineering Roadmap to 100% Renewables*[7], in which 174 actions were identified to prepare the NEM for upcoming operational conditions, including operation at up to 100% instantaneous renewables. AEMO is concurrently publishing an equivalent roadmap report providing this view for Western Australia's South West Interconnected System (SWIS)[8]. Actions identified in the SWIS report will continue to be coordinated and delivered alongside actions identified in this NEM report, ensuring leveraging of shared experiences between the two systems.

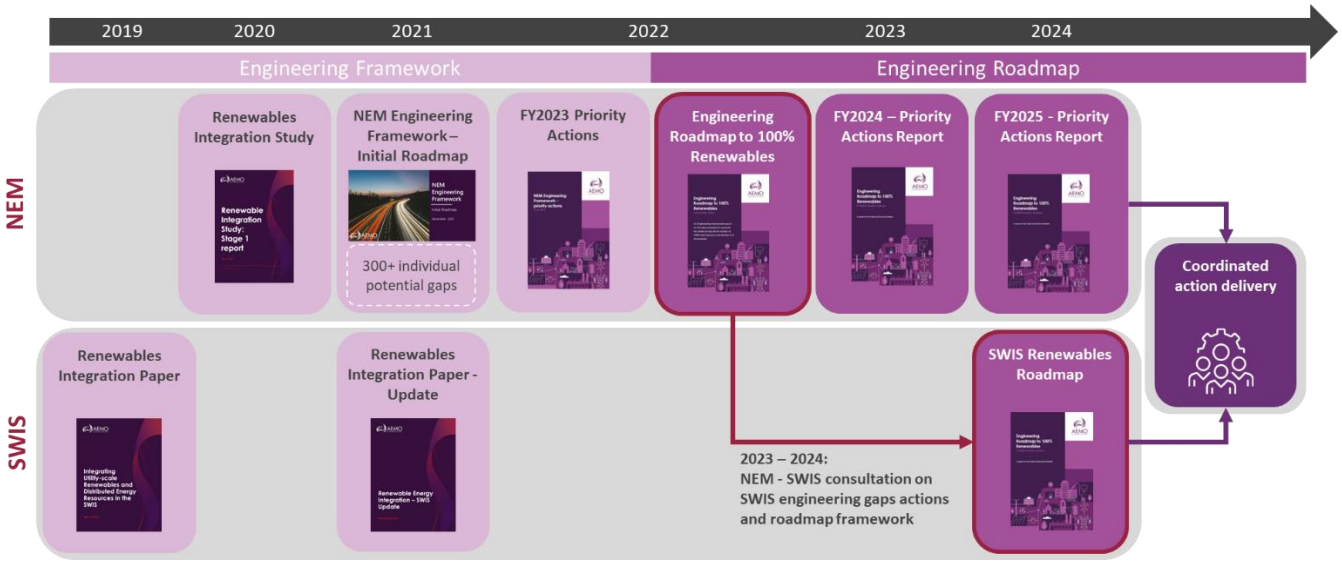
[5] See https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/participate-in-the-market/network-connections/connections-scorecard.

[6] At https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-initial-roadmap.pdf

[7] At https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/engineering-roadmap-to-100-per-cent-renewables.pdf.

[8] At https://aemo.com.au/en/initiatives/major-programs/engineering-roadmap.

Figure 6 Progress of Engineering Roadmap



The most recent NEM Engineering Roadmap report, the *FY2024 Priority Action Report*[9] published in July 2023, identified 18 NEM committed priority actions for the 2023-24 financial year (FY2024). Detail on the progress made across these FY2024 actions is provided in Section 1.4 and Appendix A1 of this report.

1.3 Capability uplift and ARENA funding

While power systems worldwide are facing similar energy transitions, Australia finds itself needing to engineer solutions sooner than other countries due to our aging coal generation fleet and world-leading rate of DPV uptake by consumers. This means Australia is facing a compressed period of change where we need to re-engineer our power systems to cope with a diverse and flexible energy mix that is different to what our power systems were originally designed for over a hundred years ago.

The resourcing and effort required from key stakeholders to progress through upcoming transition milestones is new, different, and in addition to current activities, and requires close collaboration between AEMO, NSPs, and the wider energy industry. As a first step towards enabling this uplift, and working within the financial constraints laid out in AEMO's FY24 Budget and Fees[10], AEMO approached the Australian Renewable Energy Agency (ARENA) seeking a grant to accelerate a step-change in AEMO's implementation of the NEM Engineering Roadmap.

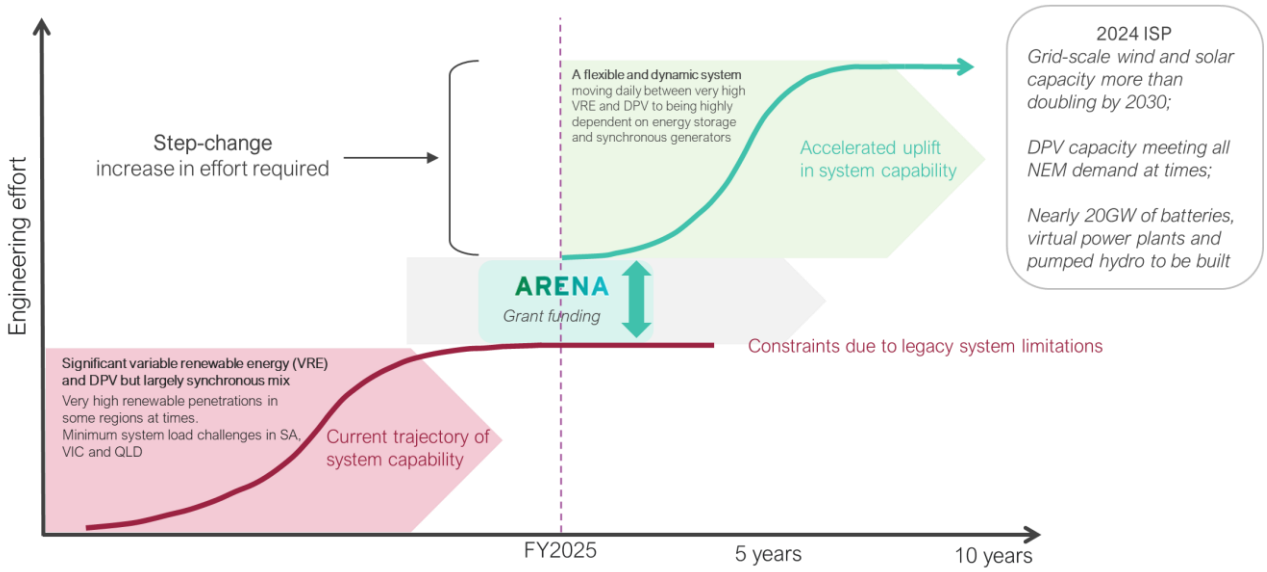
AEMO received a commitment of up to $15 million in grant funding from ARENA to enable this acceleration over an 18-month period commencing 1 January 2024. The grant has enabled AEMO to bring forward activities by one to two years, allowing more activities to be undertaken in FY2025 through a step-change in new resources allocated to Engineering Roadmap efforts, thereby helping accelerate the NEM's readiness for high renewable operation. This will, in turn, help reduce future curtailment of renewables, alleviate future system security management challenges, and reduce future reliance on coal generation that is scheduled to close. The ARENA

[9] At https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/nem-engineering-roadmap-fy2024--priority-actions.pdf.
[10] See aemo-fy24-budget-and-fees.pdf.

funding comes at a pivotal time for Australia's transition to a renewables-dominated power system, and this funding commitment and acceleration of activity is reflected in the increased volume of AEMO's FY2025 Priority Actions outlined in this report.

The Initial Roadmap included a stylised visual showing the uplift in power system capability required to meet the pace of the energy transition, and an updated version of this is included below in Figure 7, including the acceleration that the ARENA funding provides to enable the transition to a net zero power system.

Figure 7 Uplift in engineering effort required from FY2025 onwards



While ARENA's funding is helping achieve the resourcing levels required to support AEMO's Engineering Roadmap implementation efforts, a similar uplift in effort will be required by transmission and distribution NSPs to manage the increasing engineering efforts needed from their businesses. Through this report and the upcoming Transition Plan for System Security, AEMO identifies several areas requiring concerted NSP uplift, and that the resourcing and efforts required for key stakeholders to progress through upcoming transition milestones is new, different, and in addition to current activities.

1.4 Engineering Roadmap progress in FY2024

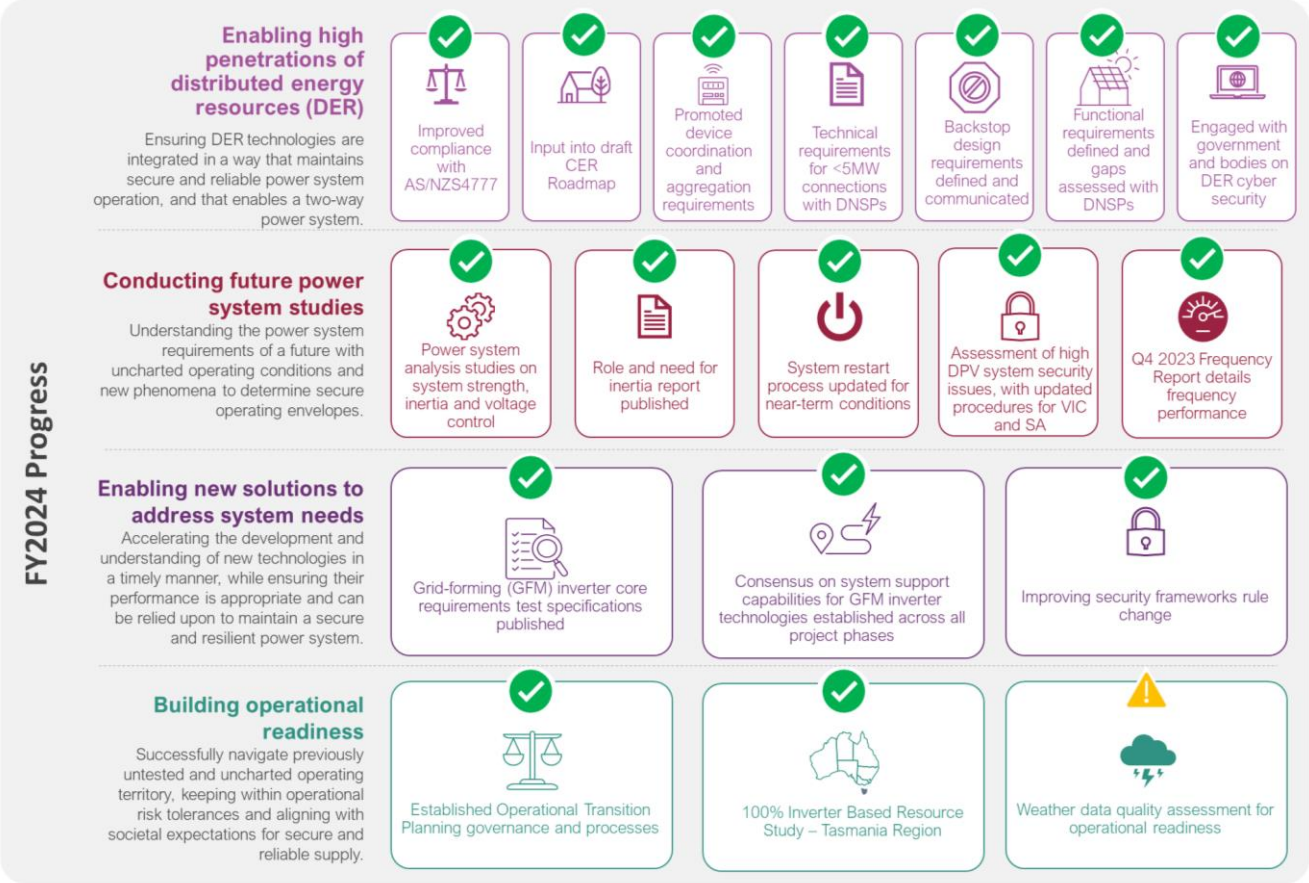
Through the collaborative efforts of the energy sector, the continued delivery of priority activities within the Engineering Roadmap has helped contribute to the ongoing series of renewable penetration records in FY2024 (Section 1.1).

The progress made has only been possible through detailed collaboration with stakeholders across the energy sector including both distribution network service providers (DNSPs) and transmission network service providers (TNSPs), market bodies, governments, OEMs, researchers, and consumers themselves. And the collaboration has occurred across a number of work programs, including changes to the National Electricity Rules (NER), standards committees, executive forums, industry consultation, and integration with government strategic initiatives.

Of the 18 actions FY2024 Engineering Roadmap Priority Actions[11], 17 have been completed, with the remaining action, weather data quality assessments for operational readiness, nearing completion (see Figure 8).

The FY2024 report identified four key themes for the financial year, with a summary of the progress made in each area provided below. Further detail on published reports and all 18 actions is in the Appendix A1.

Figure 8 AEMO FY2024 Actions



Enabling high penetrations of DER

The seven actions in this area considered Australia's high penetrations of DER. This term is used within this technical engineering report to incorporate both small-CER, such as DPV and electric vehicles, and also larger resources embedded within the distribution network, such as community batteries. These larger resources are not strictly "consumer owned" but are still geographically dispersed, connected to the distribution network, and interact differently with the power system than large-scale generation and load. Significant policy efforts across the sector concentrate on CER, which is vitally important for the transition; in this report we include CER within the broader category of DER to reflect the nature of grid interaction and to align with international convention.

This workstream focused on capabilities to assist in maintaining system security during times when DPV becomes the dominant source of generation in the NEM. These periods of time will continue to grow as the DPV resources continue to be installed by consumers. Correspondingly system security capabilities will need to continue to

[11] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2023/nem-engineering-roadmap-fy2024--priority-actions.pdf.

evolve. Initial capabilities included technical standards for improved predictability of response, with particular focus during FY2024 on improvement in compliance with those technical standards. This has only been made possible with significant stakeholder collaboration across the sector. Similarly, power system security can be maintained with higher levels of DPV through the continued rollout of last resort DPV curtailment mechanisms across the NEM which can be used in emergency and unusual conditions.

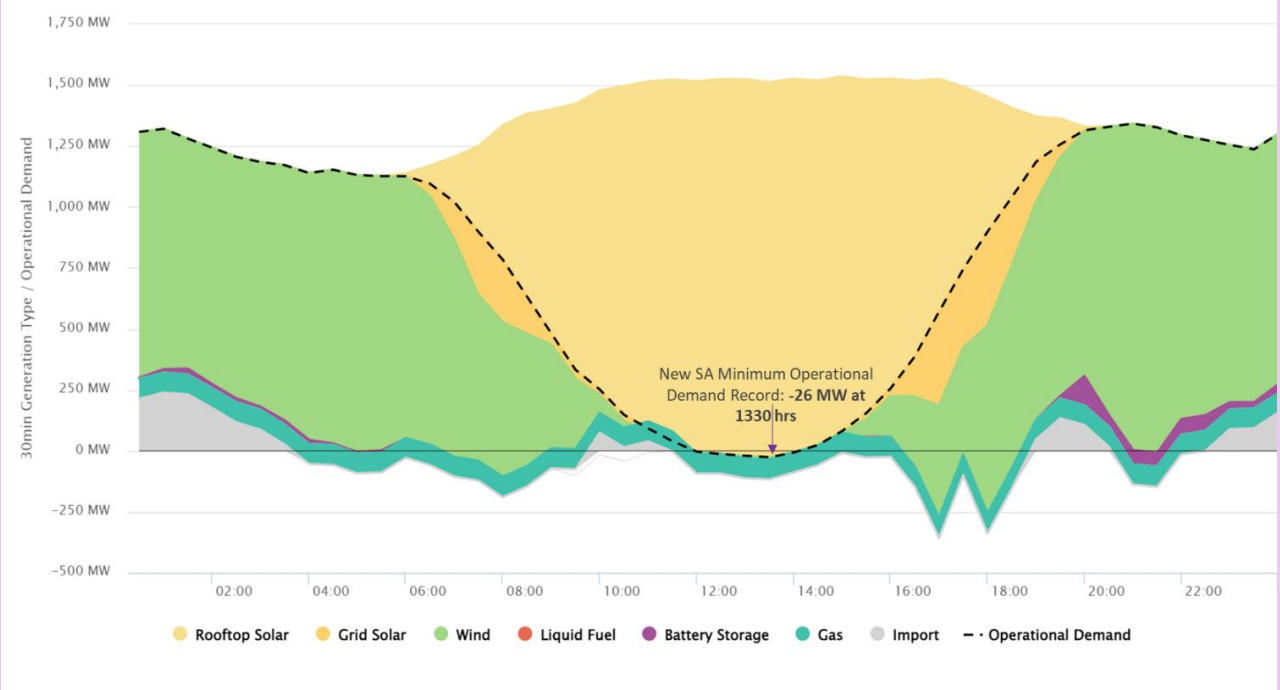
The importance of successful DER operation in the power system has led to a significant uplift in engagement on technical aspects which has included the establishment of the AEMO-DNSP Executive Forum, detailed collaboration for the National CER Roadmap, engagement with market development and rule change initiatives, participation in Australian Standards committees, and partnerships with research projects and trials. More work is still to be done in this space, as outlined in Section 2.1.

Other efforts to harness the future potential of DER have included:

- Increasing opportunities for mid-scale DER have highlighted a gap in performance standards for this range. Following close collaboration with industry and DNSPs, requirements have been drafted and are in preparation for formal consultation. These will ensure that all new DER devices perform in a way that supports the stability of the power system, just like existing standards for generators greater than 5 MW and smaller than 200 kilowatts (kW).
- The *EV Technical Standards for Grid Operation – Insights for the National Electricity Market*[12]*,* published in December 2023, provided an initial exploration of the emerging and potential transmission-scale power system opportunities and risks associated with growing electric vehicle (EV) charging loads. This work will help inform future regulatory design and technical standards for EV charging equipment to ensure that consumers can maximise the value of their investments, and that these devices can assist with supporting a more stable power system.
- Requirements for interoperability have been progressed through collaboration to propose updates to AS/NZS4777 and Common Smart Inverter Profile – Australia (CSIP-Aus). These requirements will assist with promoting minimum DER device capability for coordination and aggregation, such as physical device capability and communication protocols, to enable more active DER participation. More active DER participation will facilitate more DER operation on the power system by reducing the need for active DPV management and intervention such as last resort DPV curtailment.

[12] At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/enx---ev-technical-standards-for-grid-operation---insights-for-the-nem.pdf.

Record rooftop solar DPV generation provided more than 100% of underlying demand in South Australia



On New Years Eve 2023, DPV provided more than 100% (101.7%) of underlying demand in South Australia – a world-record for a grid of this size. At the time (and as a result) the region achieved a record minimum operational demand of -26 MW at 1330 hrs, requiring export of excess DPV and other generation to connected electricity market regions. As shown in the figure above this only occurred for a short period of time. This opportunity will occur more frequently and in more locations as more DPV in installed by consumers and power system security arrangements will need to keep pace.

This operational milestone was only possible through deep collaborative efforts of the South Australian energy sector over a number of years. This includes the concerted engineering uplift to maintain power system security under these conditions. The particular activities undertaken in SA include establishing effective last resort DPV curtailment mechanisms, improvement in rooftop solar compliance with technical standards, closer coordination between SA Power Networks, AEMO and original equipment manufacturers, and the detailed power system studies and operational readiness that has supported the ongoing reduction in the minimum number of synchronous generators online.

The FY2025 Priority Actions and upcoming Transition Plan for System Security seek to enable similar milestones for the whole of the NEM, noting similar deep collaborative effort across stakeholders will be required to achieve this milestone in other NEM regions along the transition to enable net zero.

Conducting future power system studies

The five actions identified under this objective included publication of key engineering studies aimed at assessing the secure technical envelope of the power system with reducing, and at times no, synchronous generation online have included:

- The *Role and Need for Inertia in a NEM-Like System*[13] report published in May 2024, summarising an independent high level simulation-based analysis on frequency and angle stability under low levels of synchronous inertia conducted by Vysus Group.
- The *100% Inverter Based Resource Generation Study – Tasmania Region*[14] published in March 2024, which summarised a scoping study conducted in collaboration with TasNetworks to identify the most significant system security considerations regarding operation of the Tasmanian network without any synchronous generation. The report concluded that operation at 100% inverter-based resources (IBR) penetration is not possible with the current resource mix, and that additional assets would be required to make this operating condition feasible. AEMO is continuing to explore options for enabling this trial in the future.

Enabling new solutions to address system needs

The three actions in this area contributed significant progress towards knowledge and consensus on system support capabilities for GFM inverter technologies across all project phases, following on from the 2023 publication of the *Voluntary Specification for Grid-forming Inverters*[15] (Voluntary Specification) and the accompanying *Core Requirements Test Framework*[16] (Test Framework) in January 2024. This document provides a framework for testing equipment and control modes in simulation to core capabilities listed in the Voluntary Specification.

More detail on the progress and ongoing work required to best enable GFM inverter technologies is included in Section 2.2.

Building operational readiness

Of the three actions in this area, two are complete. The remaining action, weather data quality assessment for operational readiness in collaboration with the Bureau of Meteorology, is in progress. Actions have focused on the uplift required in AEMO and NSP capability to navigate new operational conditions on the way to the first periods of 100% renewable penetration, while keeping within operational risk tolerances and maintaining a secure and reliable system.

AEMO and NSPs have worked closely through the National Electricity Market Operations Committee (NEMOC) and joint planning committees to establish governance and processes to support the identification and navigation of forthcoming operational transition points. This framework will be used to facilitate transition planning across all time horizons, from multi-year forward planning through to the real-time secure management of the NEM's technical operating envelope. This transition planning approach will inform the structure and content of the

[13] At https://aemo.com.au/-/media/files/initiatives/engineering-framework/2024/ao_geas-role-of-inertia-in-a-nem-like-system.pdf.
[14] At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/tasmania-100-percent-ibr-generation-study.pdf.
[15] At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf.
[16] At https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf.

Transition Plan for System Security (described in Section 3), which will highlight the scope and scale of engineering effort required to transition to a low- and zero-emissions power system.

The progress made in FY2024 was only possible through detailed collaboration with stakeholders across the energy sector including NSPs, market bodies, governments, OEMs, researchers, and customers themselves. Together these actions support the continued increase in renewable penetration, and support efforts to enable net zero.

There is a significant and expanding body of critical work to continue with and we look forward to continuing this collaboration with stakeholders for FY2025 Actions and beyond.

2 Priorities for FY2025

The Engineering Roadmap aims to advance operational capability for 100% renewables, keeping the NEM ahead of the engineering challenges of the energy transition before they emerge operationally. There is a wide range of critical actions that will be progressed in FY2025 to help prepare for a high renewable power system.

These actions are a result of continual prioritisation of effort towards the areas that will deliver the highest value for consumers, based on stakeholder feedback and principles prepared during the development of the Initial Roadmap[17], shown in Figure 9.

Figure 9 Prioritisation principles

FY2025 Priority Actions fall broadly in the three focus areas shown in Figure 10, and build on previous actions from FY2024, incorporating past progress, updated understanding of power system phenomena, and recognition of the growing body of effort required to accelerate system capability.

[17] See https://aemo.com.au/-/media/files/initiatives/engineering-framework/2022/initial-roadmap-information-session-pack.pdf.

Priorities for FY2025

These three focus areas are further organised into six workstreams, with more detail on the proposed actions under each workstream included in Appendix A2. These priority actions will be reviewed periodically, under a formal governance process, to identify industry challenges and opportunities, and be re-prioritised as necessary. An established change process is in place to effectively navigate this evolving landscape.

Figure 10 Priority focus areas and workstreams

2.1 Delivering foundational transition enablers

This focus area recognises that many of the actions needed to enable the transition have long lead times and require concerted collaborative effort across the energy sector to progress. As a result, immediate progress is required now to ensure timely delivery of outcomes that will support the continued acceleration towards net zero. A number of these initiatives relate to those that will build a foundation for the system to operate effectively and efficiently with very high levels of DER.

With continuing DER growth, industry focus is evolving from understanding and accommodating DER within the existing system to placing DER as a central pillar within a redesigned system, recognising the vital contributions of customers, distribution networks and the DER industry to a net zero future.

In July 2024, the Energy and Climate Change Ministerial Council endorsed the National Consumer Energy Resources Roadmap. The roadmap sets out an overarching vision and implementation plan for national reform priorities to build national consistency and support a harmonised approach to harnessing the full potential of these resources. The implementation plan identifies priority reforms across four work streams: consumers, technology, markets and power system operations[18].

AEMO priority workstreams under this focus area complement the National CER Roadmap and include:

- **DER governance** – Ensuring appropriate enduring accountability across industry to meet ongoing technical requirements as DER capacity growth continues rapidly with increasing penetration of DPV, small-scale batteries, and EVs.
- **Operational DER integration** – Actively managing and monitoring issues emerging in operational timeframes (now – 2 years ahead) as the NEM experiences world leading levels of DER.

Specific detail of actions within these workstreams is in Appendix A2, with a case study and example actions included below (Figure 11).

[18] https://www.energy.gov.au/energy-and-climate-change-ministerial-council/working-groups/consumer-energy-resources-working-group/national-cer-roadmap

Figure 11 Case Study 1

Case Study 1 Supporting world-leading DPV uptake

To accommodate increasing volumes of DPV, mechanisms must be in place to maintain system security. This includes having sufficient visibility, predictability, and controllability of the power system, achieved by:

- Increasing uptake of DPV systems and active CER responding to market, network, or tariff signals.
- Majority DPV compliance with performance standards to help maintain system stability.
- The ability to reduce aggregate DPV generation if required as a last resort to maintain system security.

Aims

- Foundational capabilities to maintain system security and support continued consumer uptake of DPV
- Participation pathways and incentives for active CER participation, managing and making use of abundant DPV generation in the daytime.

Past priority actions

Key outcomes

- Introduced DPV backstop requirements and procedures in jurisdictions where needed first.
- Preparation for urgent rollout across mainland NEM in collaboration with DNSPs and jurisdictional governments.
- Successfully managed SA islanding event in November 2022 through backstop activation.

Actions

2020

First DPV backstop requirements introduced in SA

2023

Update to the Compliance of Distributed Energy Resources with Technical Settings

2023-24

Initial backstop requirements introduced in QLD (>10kW) and VIC (new or replaced)

2024

Functional requirements and operational procedures defined with DNSPs

FY 2025

- Implement DPV emergency backstop capability.
- Redefining market and power system operation roles and responsibilities for a high CER future.
- Uplift compliance with ride-through. requirements to limit the growth in contingency sizes and therefore limit use of backstop.
- Frameworks and incentives for active CER participation, and integration within power system and market operation.

Enabling participation pathways for DER and load flexibility in the daytime **(FY25_5, FY25_6)**

Emergency backstop for DPV across NEM mainland regions **(FY25_3)**

Governance frameworks for DER compliance with AS/NZS4777 & backstop **(FY25_4)**

Operational roles and responsibilities for a high CER future **(FY25_1)**

Future State

- Power system security is maintained with increasing DPV generation and low levels of intervention.
- Growth in active CER participation allows DPV generation to be managed and better utilised.

Processes for managing system restart and cyber security compromise of DER devices.

DNSP -implementation of flexible export options for DPV customers

Operational integration of increasing active CER participation (e.g. virtual power plants (VPPs), community batteries and EV charging).

2.2 Providing long-range investment visibility

Timely investment in assets to support the secure operation of the power system is critical to enable the transition to net zero. This investment will necessarily include technologies that may have a long lead time to market and resources that may have supply-chain limitations. This focus area seeks to identify emerging gaps that require investment, enabling solutions to be deployed in advance of their real-time need. This includes giving clarity to investors on the potential services that emerging technologies can provide.

Early understanding of the emerging needs of the power system, coupled with appropriate signalling for the services required to meet those needs, can enable investors to deploy innovative and timely solutions to support the future power system.

To enable efficient investment in service delivery, technical and commercial specifications are needed to guide developers' scoping and configuration decisions. For example, by specifying the performance requirements and procurement processes for synthetic inertia, grid-forming batteries can be configured with this capability from the beginning of the design lifecycle.

Additionally, building modelling capability, for example the use of impedance-based frequency scans of IBRs and the network to identify the root causes of oscillations in the grid, can provide insights into identifying long-term solutions to operational phenomena.

Workstreams under this focus area include:

- **Future power system phenomena** – exploring new behaviours and system phenomena as the configuration of the power system changes, with inverter-based resources as an increasingly prevalent portion of the generation mix.
- **New technology capabilities** – enabling new technologies to be integrated into the power system, by completing required desktop investigations and real-world demonstrations.

Specific detail of actions within these workstreams is in Appendix A2, with a case study and example actions included overleaf (Figure 12).

Figure 12 **Case Study 2**

Case Study 2 Grid-Forming Inverters

AEMO continues to progress activities to better understand GFM inverter capability and how they can provide necessary power system needs, including for:

- System strength
- Synthetic inertia
- System restoration
- Power system damping

Aims

- Guide GFM inverter developers in specifying requirements for OEMs
- Technical studies to understand GFM inverter benefits and limitations.
- Regulatory and process change to facilitate delivery of services and capabilities.

Past priority actions	FY 2025	Future State
Key outcomes • GFM inverter capabilities defined for power system support. • Simulation test methods developed to determine whether GFM inverters will provide expected benefits. • Developed understanding of synthetic vs. synchronous inertia in the NEM to guide regulatory change.	• Understand constraints of GFM inverter capability in providing system security services. • Clarify how system security service provision from GFM inverters may be valued to inform investment decisions.	• Regulatory change facilitates the delivery of GFM inverter services and capabilities. • System security procurement processes are established to incorporate GFM inverters.
Actions 2021  *Application of Advanced Grid-scale Inverters in the NEM* 2023  *Voluntary Specification for Grid-Forming Inverters* 2024  *Testing Framework for Grid-Forming Inverters* 2024  *The Role and Need for Inertia in a NEM-Like System*	*Investigate synthetic inertial response* **(FY25_23)** *Knowledge Sharing Report on the performance of GFM-battery energy storage system (BESS)* **(FY25_27)** *Initial Synthetic Inertia Specification** *Proposed Access Standard Review, GFM inverter Technology Workstream**	*Service procurement appropriately considers GFM inverters* *Regulatory framework supports GFM inverter capabilities during connection & commissioning*

*Regulatory change activity related to the Engineering Roadmap

2.3 Progressing operational readiness

This focus area further builds AEMO's operational readiness to navigate new conditions with high penetrations of inverter-based renewables and distributed resources by establishing a dedicated framework for transition planning through the definition, preparation, and secure management of operational transition points.

Early preparation for operational transition points is critical to ensure a timely and efficient transition, mitigating the risk of delays in navigating these points which may otherwise result in costly interventions. Examples of these delays include directing plant or extending the operating life of a generator scheduled for forthcoming closure to support the system while new assets (such as synchronous condensers or grid-forming batteries) are procured and commissioned.

With sufficient forward understanding of the capabilities needed to securely operate the system through upcoming transition points, it is possible to avoid the need for fast-tracked solutions that may not be as efficient as a well-planned, proactive response.

Actions in this area seek to accelerate readiness for upcoming operational transition points and establish a common understanding of forthcoming transition points in a timely manner to enable efficient investment in any new assets or services required to navigate them.

The workstreams under this focus area are:

- **RTO and operations support** – uplifting the capability of AEMO's RTO and supporting functions to adapt to the needs of a high renewables power system.
- **Operational Transition Planning** – delivering proactive study, sequencing, and governance to critical system configurations known as 'operational transition points' to ensure secure system operation can be maintained in the long-term interest of consumers.

Specific detail of actions are included in Appendix A2, with a case study and example actions included overleaf (Figure 13).

Figure 13 Case Study 3

Case Study 3 Navigating operational transition points

The NEM is progressing toward operational transition points at speed, including reductions in the minimum number of synchronous generators online and the transition of coal generators to retirement, which have traditionally helped maintain system security through the provision of voltage control and inertia.

A rigorous approach is needed to prepare for these key changes to power system operations ahead of time by removing technical and process barriers and enabling new system configurations in a safe and secure manner.

Aims

- Proactively manage power system requirements for each transition point.
- Avoid the need for reactive measures or delays to the transition.

Past priority actions	FY 2025	Future State
Key outcomes • Highlighted need for formal operational transition planning. • Processes established to support the navigation of initial operational transition points.	• Successfully implement the next major system transition point. • Progress operational preparedness for upcoming transition points, including new minimum operational demand conditions and potential coal unit decommitments.	• Ongoing identification and navigation of operational transition point as they arise. • Clear visibility of system requirements for emerging operational transition points via the Transition Plan for System Security.
Actions 2022 – *Plan for operation of SA from four to two synchronous generator minimum* 2023 – *Minimum generation levels defined for each NEM region* 2023-24 –  *Tasmania 100% IBR study* 2024 – *Plan for initial operation of SA with fewer synchronous generators online*	*Operational transition planning and procedures in each region* **(FY25_35, FY25_36)** *Identification and analysis of forthcoming operational transition points* **(FY25_33, FY25_37)** *Governance process for operational transition points* **(FY25_34)** *Initial Transition Plan for System Security* *Transitional Services Guideline**	*Ongoing annual Transition Plan for System Security* *Transitional services to enable secure operation, undertake trials and demonstrate new technology capabilities*

*Regulatory change activity related to the Engineering Roadmap

2.4 Research engagement

The significant investment landscape for energy research in Australia and globally has the potential to assist Australia's energy transition and AEMO's role within it. AEMO's research interests span a wide range of areas related to the operation of power systems and markets, from immediate practical challenges of secure system operation with high penetration of renewables to fundamental research questions for longer-term challenges in enabling a net zero power system.

In addition to seeking to engage across the Australian energy sector, AEMO continues to engage with international colleagues in researching and developing best practice for operating a high-renewables system. In the past year AEMO has developed deeper collaboration through the Global Power Systems Transformation (G-PST) Consortium, of which AEMO is a founding member, which aims to accelerate power system transitions to low emission and low-cost systems while maintaining security and reliability. AEMO's research engagements align with and contribute to the broader G-PST Research Agenda[19]. Australia is also learning from similar transition efforts around the world, including the UK National Energy System Operator, Eirgrid's Shaping Our Electricity Future Roadmap 2030, and several others, and continues to share findings from the Australian energy transition with the international research community, in particular through Conseil International des Grands Réseaux Electriques (CIGRE, the International Council on Large Electric Systems), the Energy Systems Integration Group (ESIG), and the Institute of Electrical and Electronics Engineers (IEEE).

AEMO is currently developing a research engagement strategy that will include periodic publication of strategic research priorities, maintaining a living view of AEMO's research interests and supporting engagement with research organisations.

AEMO is open to considering topics that the research sector considers of interest in supporting AEMO's objectives in enabling a net zero power system for Australia. Interested parties should email research@aemo.com.au for further information.

[19] See https://globalpst.org/wp-content/uploads/042921G-PST-Research-Agenda-Master-Document-FINAL_updated.pdf.

3 The *Transition Plan for System Security*

In early 2024, the Australian Energy Market Commission (AEMC) made a final determination on the Improving Security Frameworks (ISF) rule change which outlined several measures to address system security issues efficiently and proactively through the transition[20]. One of these measures requires AEMO to publish an annual *Transition Plan for System Security* by 1 December to convey its understanding of the security needs of the system and how these needs may evolve.

NER 5.20.8 Publication of the Transition Plan for System Security

(a) AEMO must publish annually by 1 December the Transition Plan for System Security on its website.

(b) The purpose of the Transition Plan for System Security is to make available to Market Participants and other interested persons an analysis of:

(1) how AEMO is planning to maintain power system security through the transition to a low- or zero-emissions power system; and

(2) AEMO's current technical understanding of what is needed to achieve power system security in a low- or zero-emissions power system and the work AEMO is undertaking to improve this understanding and to specify the range of services that will be required in a low- or zero-emissions power system.

3.1 Proposed approach

In accordance with the AEMC rule, the *Transition Plan for System Security* report will provide a clear vision of how AEMO is proactively planning to maintain power system security to enable net zero. These plans will be communicated through the lens of accelerating readiness for upcoming operational transition points (see Section 1.1), which provide a means of linking actions to critical milestones in advance of outcomes being needed. The report will focus on three separate horizons shown below in Figure 14. These horizons are identified by outcome, not action – that is, critical actions are required to commenced in the immediate term to facilitate outcomes in both Horizon 2 and 3.

[20] See https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition

The Transition Plan for System Security

Operational transition points are a means to enable management of the technical operating envelope of the NEM in real-time operations while meeting power system security obligations and reliability requirements. Preparing for and implementing these transition points occurs primarily in the operational time horizon (Horizon 1 in Figure 14). Identification of upcoming transition points across Horizon 2 is required to ensure sufficient time is available for investment and other preparatory activities to be completed. By successively commissioning the system at new secure operating points as the power system portfolio evolves, the transition can be approached as a series of carefully planned and executed operational transition points – identifying and addressing potential issues before they emerge operationally.

The *Transition Plan for System Security* will also include information about AEMO's technical understanding of power system security requirements under high penetrations of renewables, the technical capabilities and specification uplift that may be required to facilitate the transition, and the outcomes of any trials enabled through the use of new Transitional Services arising from the ISF Rule change.

Figure 14 **Proposed horizons for *Transition Plan for System Security***

The Engineering Roadmap and *Transition Plan for System Security* sit alongside other AEMO publications such as the ISP, the Electricity Statement of Opportunities (ESOO), the General Power System Risk Review (GPSRR), and ancillary service specifications and reports for inertia, system strength and network support and control ancillary services (NSCAS). Research engagements interact with the broader G-PST Research Agenda[21].

[21] See https://globalpst.org/wp-content/uploads/042921G-PST-Research-Agenda-Master-Document-FINAL_updated.pdf.

The Transition Plan for System Security

The *Transition Plan for System Security* and the Engineering Roadmap are closely aligned publications but remain separate at this time to reflect the need for separate focus on the engineering activities required to enable the transition, and the specific planning and operational tasks required to maintain a secure system throughout the transition. The "progressing operational readiness" focus area described in Section 2.3 will contribute much of the content for the initial *Transition Plan for System Security*. Over time, the transition plan is expected to incorporate a greater depth of detail on the specific requirements of the transitioning power system, and AEMO will continue to engage with stakeholders to inform its ongoing development.

3.2 Stakeholder engagement

Coordinated and collaborative engagement across the entire energy sector is vital to deliver an effective, efficient, and timely transition plan. Targeted engagement is underway with organisations who may be directly impacted by development of the *Transition Plan for System Security*, such as transmission and distribution network service providers, who will require resourcing and efforts beyond current activities to plan and facilitate the navigation of operational transition points. Further to this, AEMO is seeking feedback from any interested stakeholders on the following points to inform development of the inaugural Transition Plan for System Security.

Questions

1. What information should AEMO include in the *Transition Plan for System Security* to help stakeholders navigate upcoming Operational Transition Points as renewable penetration continues to increase?
2. Where is additional coordinated effort required for the system to maintain security while transitioning to higher penetration of renewables?
3. What actions are required to accelerate renewable penetration towards 100%?
4. How would you like to be engaged with for the development and publication of the *Transition Plan for System Security*?

Interested parties are encouraged to submit feedback to these questions to futureenergy@aemo.com.au by 5 September 2024.

There will be further opportunities to engage with AEMO and inform the content and approach of both the Engineering Roadmap and *Transition Plan for System Security*. Interested parties are encouraged to contact futureenergy@aemo.com.au to register for updates.

A1. FY2024 Action status

Table 1 FY2024 completion statements

Roadmap Action	Committed action for FY2024	Status of FY2024 AEMO commitment as at 30 June
Enabling high penetrations of distributed energy resources		
Short-term measures to improve installation compliance of new DPV inverters to AS/NZS4777.2:2020, reducing potential DPV disconnection during disturbances (including amendment of the Standard).	Pursue further short-term measures to improve installation compliance of new DPV inverters to AS/NZS4777.2:2020 (through an amendment to the Standard to remove legacy grid code options for selection) and continued engagement with industry to encourage further action (for example, with OEMs and DNSPs).	AEMO's analysis found significant improvement in compliance, increasing from just under 40% compliance in early 2022 to an estimated 75-80% compliance in early 2023. AEMO has published an update to its original April 2023 report[22]. In order to achieve >90% compliance, analysis indicates that mandatory technical regulation and governance arrangements are required. AEMO is now engaging with DNSPs (via the AEMO-DNSP Executive CER Forum) to drive further work on compliance monitoring and management capabilities (noting the engagement outlined in the following row).
Establish strong governance frameworks for assessing and enforcing ongoing compliance of DER inverters to meet performance requirements.	Work with market bodies and jurisdictions to promote effective, enduring regulatory arrangements for small-scale DER standards implementation and compliance.	This task was adapted mid-year to focus on active collaboration with the CER Working Group and Commonwealth Department of Climate Change, Energy, the Environment and Water (DCCEEW) to support the development of the National CER Roadmap[23]. AEMO is supporting the CER Taskforce, which has been established to implement the Roadmap. The Energy and Climate Change Ministerial Council (ECMC)[24] has committed to a national regulatory framework for CER to be prioritised in this package of reforms. The implementation of the Roadmap is expected to therefore see a key workstream focused on technical regulation and governance. Further work to develop and finalise such arrangements will proceed upon adoption of the National CER Roadmap by ECMC.
Establish minimum DER device requirements for interoperability (including EVs and Electric Vehicle Supply Equipment (EVSE).	Promote minimum DER device capability for coordination and aggregation. Actively participate to establish interoperability requirements within AS/NZS4777 and AS4755, including alignment with CSIP-Aus.	Proactive AEMO engagement within national standardisation efforts underway, with the scale and scope of a high DER future in mind, to promote the need for foundational capabilities to enable more active DER participation. Includes participation in: • Standards Australia committee EL-062 on interoperability of AS/NZS4777 inverters. • Distributed Energy Integration Program (DEIP) process on updates to CSIP-Aus to map to inherent AS/NZS4777.2 physical capabilities to IEEE2030.5 functions, and standardise how these can be utilised in Australia.

[22] See https://aemo.com.au/-/media/files/initiatives/der/2023/oem_compliance_report_2023.pdf.

[23] The National CER Roadmap was published in July 2024, see national-consumer-energy-resources-roadmap.pdf. More information can be found in the National Energy Performance Strategy, at https://www.dcceew.gov.au/sites/default/files/documents/national-energy-performance-strategy.pdf, p14, and in the ECMC March 2024 communique https://www.energy.gov.au/sites/default/files/2024-03/ECMC%20Communique%201%20March%202024.docx.

[24] See https://www.energy.gov.au/energy-and-climate-change-ministerial-council.

Appendix A1. FY2024 Action status

Roadmap Action	Committed action for FY2024	Status of FY2024 AEMO commitment as at 30 June
		• Driving DCCEEW consideration of interoperability policy across the key facets: physical capability, information model, and communication protocol as part of the development of the National CER Roadmap. Early engagement with DNSPs through DEIP on approaches to consistent nodal representation of DER devices in network models, and non-topological groups.
AEMO to collaborate with DNSPs to establish effective and consistent disturbance withstand performance standards for <5 MW connections in the distribution network.	Define AEMO's minimum requirements for disturbance withstand and grid support capability for <5 MW connections. Identify possible pathways for minimum requirements to be applied.	AEMO has drafted a report on high voltage (HV)-connected* DER (200kW-5MW) following engagement with DNSPs, project proponents and equipment manufacturers. The report includes AEMO's performance requirements for grid support capabilities for connections below 5MW capacity. The report and recommendation are being prepared for public consultation in Q3 2024. Note: * formerly referred to as "medium voltage (MV)-connected DER". Changes to AS/NZS4777 have prompted a change to the reference used (HV vs MV), however, system size (200kW-5MW) remains within scope.
Establish effective emergency DPV shedding schemes, operational roles and procedures in each NEM region, before minimum system load challenges emerge.	Specify functional requirements and operational processes for robust and reliable emergency backstop mechanisms. Continue to engage with jurisdictions and DNSPs on implementation, as well as market bodies towards nationally aligned approaches and associated roles and responsibilities. Collaboratively assess and progress actions necessary to meet functional requirements. This includes clarity on operational boundaries between the distribution network and bulk power system operation, as well as operational coordination, and data exchange between AEMO, NSPs and other parties (such as retailers and aggregators).	Functional requirements for Emergency DPV Curtailment have been defined and communicated to DNSPs, to establish clear roles and responsibilities and guide the effective design and development of emergency DPV curtailment schemes. This process has been facilitated through an Executive-level AEMO-DNSP CER Forum, established through the functional requirements work. Jurisdictional policies for emergency DPV curtailment are now in place across Queensland, South Australia and Victoria. AEMO is engaging with DNSPs and Governments in the NSW Regions of the NEM (New South Wales and the Australian Capital Territory). AEMO is engaging with DNSPs and Government in the Queensland Region to support timely expansion of backstop capabilities. Operating processes are defined and operational in Queensland and South Australia and are currently being developed in Victoria. Functional requirements and insights from recent events are being used to inform and enhance capability considerations across regions. The ECMC has released a National CER Roadmap[25], which includes the establishment of backstop capabilities by Spring 2025.
Establish roles and responsibilities between AEMO, DNSPs, TNSPs and participants for managing bulk power system security in a high DER future, and associated planning and operational processes.	Define functional requirements for securely and reliably operating a high DER power system, including visibility and predictability, performance, and controllability. Collaboratively assess and progress actions necessary to meet functional requirements. This includes clarity on operational boundaries between the distribution network and bulk power system operation, as well as operational coordination, and data exchange	AEMO's functional requirements for securely and reliably operating a high DER power system (which includes high levels of consumer energy resources) have been defined. A Functional Requirements Status and Gap Analysis report has been completed and shared with DNSPs to identify additional DNSP requirements for a high DER future and to collaboratively assess and advance the necessary actions, including further stakeholder engagement, to meet these functional requirements. The engagement process with NSPs has been initiated through the establishment of an Executive-level AEMO-DNSP CER Forum. This group is helping guide a collaborative process with DNSPs on functional requirements. The first two topics identified as top two priority in consultation with DNSPs were: • Emergency DPV curtailment. • CER performance during disturbances.

[25] See https://www.energy.gov.au/sites/default/files/2024-07/national-consumer-energy-resources-roadmap.pdf

Roadmap Action	Committed action for FY2024	Status of FY2024 AEMO commitment as at 30 June
	between AEMO, NSPs and other parties (such as retailers and aggregators).	AEMO has undertaken deep dive sessions with the DNSPs on these two topics and received feedback and shared learnings on the requirements and DNSP capability.
Define performance standards for DER cyber security and interoperability.	Continue to educate industry on the growing power system security risks due to cyber compromise with increasing DER uptake. Promote the need for clear policy leadership to develop DER cyber security responsibilities.	AEMO participated in a workshop held with the Australian Cyber Security Centre (ACSC) international experts focused on Cyber security in the Power System with session led by AEMO on cyber for CER in May 2024 (13 to 15th May 2024). AEMO continues to advocate for Cyber Security of CER including smart appliances in the development of drafting standards by participating in workshops within EL-054 Standards Australia Committee.
Conducting future power system studies		
Undertake a program of power system studies to assess power system security in the NEM at times of 100% renewable generation and assess future system requirements with fewer large synchronous generators.	Perform targeted future system dynamic studies, identify emerging phenomena, and interactions between phenomena.	AEMO engaged Vysus Group to complete targeted system modelling and simulation studies to investigate the role of inertia and its relationship with frequency and angular stability using a NEM-like power system. The findings have been published on the AEMO website[26]. AEMO continues to focus on quantifying inertia from grid-forming inverters. AEMO conducted the following dynamic studies as part of this year's GPSRR[27]: • Studies of under-frequency load shedding (UFLS) adequacy in 2028-29. • Studying the impacts of losing future double-circuit HumeLink 500 kilovolts (kV) lines to a non-credible contingency. AEMO is also conducting studies on dynamic voltage control to explore and characterise potential future risks associated with increasing generation and demand variability. Additionally, AEMO has engaged academic research to undertake a conceptual review of power system stability phenomena for interconnected networks to identify factors that may impact stability of the power system as it transitions to future operating conditions.
Perform targeted planning studies to assess system security issues across all power system phenomena with lower levels of synchronous fossil fuel generation.	Conduct screening studies of fault level requirements over a range of 100% renewable energy system conditions.	A range of power system analysis studies were conducted and published as part of the December 2023 Network Support and Control Ancillary Services report[28]. These studies considered the need for system strength, inertia, and voltage control services (both static and dynamic) when meeting 100% renewable penetration at times of high system demand. These complemented earlier studies in December 2022 that explored security needs under low demand conditions. This is an ongoing (multi-year) activity, and further boundary conditions may be necessary to explore in future years.
AEMO to assess system restart requirements and capability with increasing aggregate DPV impact.	Conduct system restoration studies for high DPV conditions.	AEMO has been assessing system restart plans for all regions, including consideration of probability of exceedance (POE) 90 demand scenarios. This has involved AEMO engaging with DNSPs and analysing historical data from FY2022 through to FY2024. It was concluded that within the near-term operational time horizon (18 months to 2 years), system restart ancillary services are sufficient and there is no need for additional system restart support services. This work has progressed as part of the system restart working

[26] See https://aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports.

[27] See https://aemo.com.au/-/media/files/electricity/nem/system-operations/general-power-system-risk-review/2024-draft-gpsrr-report.pdf.

[28] See https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/system-strength-requirements/2023-nscas-report.pdf.

Roadmap Action	Committed action for FY2024	Status of FY2024 AEMO commitment as at 30 June
		groups with the NSPs with the objective to update the present system operating procedures (July 1st, 2024). This engagement will continue, and further analysis will be conducted as more information is made available.
Ongoing AEMO assessment of minimum load and DPV contingency thresholds for system security.	Further assessment of system security issues associated with increasing penetrations of DPV.	Following investigation of curtailment activities, and engagement with relevant NSPs, AEMO has updated Victorian and South Australian operating procedures for handling minimum demand processes. Other regions are not likely to experience minimum demand levels requiring intervention prior to spring 2024. AEMO will continue to monitor and assess system security thresholds under high DPV conditions and projections for these regions.
Review and assess appropriate mix of frequency control measures and adequacy of Frequency Control Ancillary Services (FCAS) arrangements with reducing synchronous inertia, increasing variability, and as the system topology evolves.	Review NEM frequency control performance following implementation of recent reforms and determine any required changes to existing measures.	The Q4 2023 Frequency Report[29], published on 13 February 2024, details the frequency performance for Q4 2023 following the launch of the Very Fast FCAS markets on 9 October 2023. The report highlights the initial 50 MW cap and bi-weekly review of capacity commitments for cap adjustments in the very fast FCAS markets. Insights gained from this monitoring will contribute to the development of a technical insights paper scheduled for publication in December 2024.
Enabling new solutions to address system needs		
Trial and understand grid-forming inverter technology to support / provide system strength.	Utilise existing and proposed grid-forming projects to build knowledge and consensus on the system support capabilities of this technology, throughout the development, connection application, commissioning, and operation phases.	AEMO has built knowledge and consensus on system support capabilities for GFM inverter technologies across all project phases. • Operational Phase: A report has been drafted (to be published in FY2025) to showcase model alignment with the operational Dalrymple battery under an island scenario. • Connection Phase: Hybrid plants, where GFM inverter technologies are being utilised for system strength self-remediation, are being progressed through the connection phase. During this process, AEMO, NSPs, and connection proponents have gained an understanding of the complexity of transient interactions between grid-following and grid-forming resources behind a single point-of-connection. Development Phase: AEMO has been working with TNSPs to understand and reduce barriers to procuring system support capabilities from GFM inverter technologies. Through this work AEMO and TNSPs have better aligned the Voluntary Specification[30] and associated Test Framework[31] with other support service specifications published across the industry.
Technically define power system support capabilities for grid-forming inverters to	Collaboratively develop resources to support the practical application of the voluntary grid-forming inverter specification, including research and analysis to quantify the benefits	The Grid Forming Inverters: Core Requirements Test Framework document was published on 18 January 2024. This document provides a framework for testing equipment and control modes in simulation, to

[29] See https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/frequency-and-time-error-reports/quarterly-reports/2023/frequency-monitoring-q4-2023.pdf.

[30] See https://aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports.

[31] See https://aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports.

Roadmap Action	Committed action for FY2024	Status of FY2024 AEMO commitment as at 30 June
guide OEMs and developers.	and limits of the power system support capabilities of this technology.	determine whether they can meet the requirements of the core capabilities listed in the Voluntary Specification for Grid-Forming Inverters[32].
Identify and progress opportunities (where economic) for common solutions to address inertia requirements in conjunction with identified system strength needs, such as adding flywheels to synchronous condenser installations.	Promotion of inertia provision as part of system strength solutions (of any technology type), where this would lead to more efficient/timely deployment of capability to meet future system needs.	AEMO provided input into the AEMC's final determination for the Improving of Security Frameworks rule change, published on 28 March 2024. The rule includes a continuous (system normal) inertia obligation on TNSPs alongside clarifications to existing requirements. This will allow better co-optimisation with system strength investments (without the need for declared inertia shortfalls). These changes take effect from 1 December 2024, and TNSPS are considering how best to apply these in their current System Strength regulatory investment test for transmission (RIT-T). The rule also aligns timetables between the System Strength and inertia obligations to further improve interactions[33]. AEMO continues to facilitate a System Strength Service Providers working group (SSSPWG) to improve joint planning between regions; and to advocate for efficient security investment in regional RIT-Ts.
Building operational readiness		
Processes to monitor risk exposure, with 'roll back' measures in place if risk exceeds operational risk tolerance.	Collaborate with industry participants and relevant stakeholders on a plan for initial operation of South Australia with fewer synchronous generators online.	AEMO has collaborated with ElectraNet to determine the technical requirements that provide for a secure South Australia system. A plan for optimal secure operation of the South Australia system is under finalisation, including completion of all relevant documentation, processes and tools.
Detailed assessment of system needs and required services to transition into and out of high renewable generation periods.	Pending outcomes of preliminary scoping, explore system requirements to support operation of Tasmanian region with 100% IBR generation.	The *100% Inverter Based Resource Study - Tasmania Region*[34] was published on 21 March 2024. The report concluded that operation at 100% IBR penetration would be achievable in theory but is not possible with the current resource mix, and that additional assets would be required to make this operating condition feasible. AEMO is continuing to explore options for enabling this trial in the future.
Deploy weather monitoring infrastructure to support participant and AEMO forecasting requirements for renewable energy zones (REZs), DPV generation within load centres and other key network locations.	Collaboration between Bureau of Meteorology and AEMO to develop a sustainable business model for acquiring, curating and releasing new weather observations that will provide enhanced nowcasts and forecasts for the energy sector. This aims to improve the management of the energy system, VRE generation and prospective REZs.	A business case has been developed and drafted which delivers a proposed options analysis to examine the costs, benefits and risks associated with the different options for achieving AEMO's goals related to improved weather forecasts, operational forecasts (intermittent generation and demand) and situational awareness. AEMO continues to collaborate with the Bureau of Meteorology (BOM) to complete an initial quality assessment of the observation data received from wind and solar farms (Energy Conversion Model (ECM) supervisory control and data acquisition (SCADA) data). A more comprehensive assessment is expected to be completed in FY2025.

[32] See https://www.aemo.com.au/-/media/files/initiatives/engineering-framework/2023/grid-forming-inverters-jan-2024.pdf.

[33] See https://www.aemc.gov.au/rule-changes/improving-security-frameworks-energy-transition.

[34] See https://aemo.com.au/initiatives/major-programs/engineering-roadmap/engineering-roadmap-execution-reports

A2. Priority Engineering Roadmap Actions for FY2025

AEMO is currently delivering an extensive list of activities to accelerate readiness of the NEM towards achieving 100% renewable energy. Priority actions included in this appendix highlight the critical engineering actions necessary for maximising renewable penetration. These actions will be reviewed periodically under a governed process to identify industry challenges and opportunities, and to re-prioritise as necessary. An established change process is in place to navigate this evolving landscape effectively. These actions are allocated across six workstreams, detailed below.

A2.1 DER governance

The rapid rate of DER capacity growth is expected to continue with increasing penetration of DPV, small-scale batteries, and EVs and their associated EVSE. Consequently, it is essential to ensure appropriate enduring accountability across industry to meet ongoing technical requirements. Target outcomes for this workstream include:

- Supporting efficient and compliant integration of DER in the system.
- Reducing the need for AEMO to require additional operating margins to manage times of high DER penetration.

Table 2 FY2025 actions for DER governance

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_1	Establish roles and responsibilities between AEMO, DNSPs, TNSPs and participants for managing bulk power system security in a high DER future, and associated planning and operational processes.	Assess and progress actions necessary to meet agreed functional requirements in collaboration with DNSPs and TNSPs. Feed into and participate in national reform processes focussed on operational roles and responsibilities.	Progress through National CER Roadmap workstream on roles and responsibilities for power system operation. Continued engagement with TNSPs and DNSPs on Transmission and Distribution (T-D) coordination actions necessary to meet functional requirements.
FY25_2	Determine appropriate EV and EVSE technical standards for grid operation.	Establish disturbance ride-through and other performance standards for EV and EVSE to consider opportunities where there may be benefits offered by these devices to bulk power system operation.	Identify requirements, and initiate pathways to incorporate bulk power system needs into international and domestic standards committee discussions for EVs and EVSE.
FY25_3	Emergency backstop for DPV across NEM mainland regions.	Collaborate with stakeholders to identify options to enable and implement robust and reliable emergency DPV curtailment for all systems to manage system	Pathways in place for emergency backstop mechanisms across all NEM mainland regions, with appropriate measures to ensure effectiveness, including compliance frameworks.

Appendix A2. Priority Engineering Roadmap Actions for FY2025

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
		security during times of high DPV penetration in all NEM mainland regions.	
FY25_4	Governance frameworks for DER compliance with AS/NZS4777 & backstop.	Advocate for establishing strong governance frameworks for assessing and enforcing ongoing compliance of DER inverters to meet technical performance requirements, through the *National CER Roadmap*[35]. Includes governance of compliance with disturbance ride-through requirements as well as compliance with backstop functions.	Clear pathway in place towards establishing governance frameworks that will deliver enduring solution(s) to DER performance management. Recommendations and next steps (e.g. regulatory change) determined.
FY25_5	Mechanisms for active CER to be recognised and integrated within power system and market operation.	Foundational requirements for enabling: • Visibility, predictability, and controllability of active CER for power system operation. • Coordination across parties to effectively integrate and respond to active CER participation within market operation through customer relationships. • Industry and market actors to be able to deliver this integration from customer to system and wholesale market.	National CER roadmap reform priorities relating to: roles and responsibilities for power system and market operation and fata sharing arrangements to inform planning, enable future markets, and support effective power system operation. Progress Integrating Price Responsive Resources rule change[36] supporting enhanced transparency regarding behaviour of aggregated CER and other currently non-scheduled price responsive resources.
FY25_6	Participation pathways and incentives encouraging active CER participation.	Establishing frameworks and incentives to encourage uptake of CER responding to market, network, and tariff signals. Examples include: • Aggregated CER participating in the energy market. • DNSP provision of flexible export options for CER customers. • Arrangements for community batteries and managed EV charging.	Progress Unlocking CER Benefits for Flexible Trading rule change[37] enabling flexible CER to be identified and managed separately from other 'passive' consumer loads. Progress Integrating Price Responsive Resources rule change enabling aggregated CER participation in central dispatch and scheduling processes and consideration of appropriate incentives. National CER Roadmap national reform priorities relating to enabling new market offers and tariff structures to extract greater benefits from CER, accelerating DNSP implementation of flexible export arrangements and consumer access to information to empower informed decision making.

[35] Energy and Climate Change Ministerial Council. National Consumer Energy Resources Roadmap: Powering decarbonised homes and communities July 2024. Available at: https://www.energy.gov.au/sites/default/files/2024-07/national-consumer-energy-resources-roadmap.pdf

[36] AEMC, Integrating price-responsive resources into the NEM, Available at: https://www.aemc.gov.au/rule-changes/integrating-price-responsive-resources-nem

[37] AEMC, Unlocking CER benefits through flexible trading, Available at: https://www.aemc.gov.au/rule-changes/unlocking-CER-benefits-through-flexible-trading

A2.2 Operational DER integration

With the NEM currently experiencing world-leading levels of DER, many issues are emerging in operational timeframes (now – 2 years ahead) and require increased active monitoring and management by AEMO operationally.

Target outcomes for this workstream include:

- Setting up processes (pilot or permanent) to enable system operation during high DER conditions.
- Reducing the need for AEMO to require additional operating margins to manage times of high DER penetration.

Table 3 FY2025 actions for operational DER integration

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_7	Trial the integration of dynamic operating envelopes (DOE) into the NEM dispatch engine (NEMDE).	Investigate integration of SA Power Network's Flexible Exports implementation with NEMDE, utilising DOE capability within transmission-level constraints.	Pilot feasibility outline completed for processes and systems to integrate DOEs into AEMO scheduling for South Australia.
FY25_8	Integrate DER & load models into AEMO systems.	Integrate DER & Load models into AEMO operational systems so they can be used consistently & robustly for operational studies.	Support DER and load models to provide improved accuracy and data in the AEMO Modelling Platform (AMP). Established capabilities, for AEMO to assess future network conditions, and identify remedial actions.
FY25_9	Improve post event data collection for DER - device level data & high-speed data.	Identify sources of DER device level active/reactive power datasets, and suitable high-speed data from distribution levels, for disturbance analysis, incident review & AEMO analysis tools.	Pilot feasibility outline completed for provision of DER device-level active and reactive power datasets and high-speed datasets for disturbance analysis.
FY25_10	Assessment and short-term rectification of DER compliance with AS/NZS4777.	Uplift of tools and datasets for monitoring and reporting of DER compliance with AS/NZS4777 to i) reduce uncertainty associated with times of high DER penetration; and ii) reduce operating margin required. Collaborate with stakeholders to improve compliance under present frameworks as much as possible in the near term.	Regularly updated DER compliance data, streamlined tools & processes. Improved compliance with AS/NZS4777 ride-through requirements.
FY25_11	Compliance with AS/NZS4777 - coordinate DNSP uplift.	Coordinate with the Energy Networks Association (ENA) and DNSPs to implement consistent best practice approaches and work programs to monitor and improve compliance with AS/NZS4777 to necessary levels.	Effective & consistent DNSP practices implemented for managing AS/NZS4777 compliance is commenced. Establish compliance monitoring framework.

Appendix A2. Priority Engineering Roadmap Actions for FY2025

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_12	Apply Power System Simulator for Engineering (PSSE) DER and load models in operational processes.	Integrate the latest dynamic DER and load models into studies informing operational limits advice and FCAS requirements. Establish processes for ongoing update to reduce required operating margin. Support TNSPs in updating their limits.	Updated operational limits advice and established processes for ongoing update. Support for TNSPs in doing the same.
FY25_13	Operational assessment of system security thresholds under high DPV conditions.	Operational assessment thresholds relating to minimum synchronous generation unit commitment required for system security and managing risk of DPV disconnection during disturbances. Assessment of current operational ability to manage the system within these thresholds.	Updated thresholds for all NEM regions across the plausible range of operational conditions. Suitable procedures & operational tools to operate the system with high penetrations of DPV, in regions where thresholds are likely to be crossed.
FY25_14	Improvements to Operational Forecast to integrate backstops and flexible export limits (FELS).	Complete scoping and feasibility study for integrating backstops and flexible export limits into operational forecasts and nowcasts.	A completed summary of findings, strategic options and recommendations for designing, implementing and operating robust systems to facilitate secure inter-operation of DER (including FELS and backstops) by AEMO.
FY25_15	Improve DER Register data quality.	Work with DNSPs to improve the quality of data input to the DER Register. Ensure data is fit for purpose following close of small-scale renewable energy scheme (SRES) datasets, and add data on DER replacements. May require improvements to governance arrangements.	Improved quality of data in the DER register on new installations and DER replacements.
FY25_16	DNSP data on DPV installed at each transmission node.	Automate collection of DNSP data on aggregate DPV installed at transmission-distribution interface points, and input to AEMO's Energy Management System (EMS).	Automated updates of EMS data on DPV installed capacity received from DNSPs on a regular basis (e.g. monthly).

A2.3 Future power system phenomena

As the power system moves into high renewable operating conditions, new behaviours and system phenomena need to be explored and studied due to the changing configuration of the power system including the dynamics of inverter-based resources as an increasingly prevalent portion of the generation mix. These phenomena include but are not limited to:

- Transient and small signal stability.
- Dynamic voltage management.

- New modes of device interaction and instability.
- Frequency control across all time horizons.
- Grid reference[38].

Operating the NEM under these conditions will test the bounds of the power system knowledge of today, including assumptions that have historically underpinned power system modelling. Key outcomes for this workstream include:

- Identifying emerging risks associated with system operation under high renewables.
- Early initiation of changes to the regulatory landscape or planning processes.
- Signalling for additional power system services to be delivered from the market.
- Uncovering new phenomena not previously identified due to the limitations of power system modelling, aiding timely risk identification and mitigation.
- Establishing operational confidence and experience to manage risks associated with operating under unfamiliar power system conditions.

The attainment or development of appropriate models and tools to enable the study of a high renewable power system is an inherent pre-requisite to conducting such studies. As such, AEMO anticipates a secondary outcome from this workstream of improvements to power system modelling capability within AEMO and NSPs.

Table 4 FY2025 actions for future power system phenomena

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_17	Transition to fewer synchronous generators (South Australia).	Detailed design of a trial of South Australia where generation and load characteristics enable evaluation of operational needs for operation of a part of the NEM supported majority by IBR and synchronous condensers.	Full transition plan for trial operation in South Australia, outlining the tests to be performed while under this controlled environment.
FY25_18	Study new forms of stability phenomena at high renewable penetrations.	Targeted stability studies to better understand power system performance during times of high renewable and low synchronous generation.	Technical insights paper to inform the development of future power system performance and stability under high IBR conditions.

[38] AEMO Transition to Fewer Synchronous Generators in South Australia: Grid Reference Assessment, at https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/congestion-information/sa-transition-to-fewer-synch-gen-grid-reference.pdf.

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_19	Study voltage control at high renewable penetrations.	Investigation of voltage control studies for a high IBR NEM. This will consider impacts of IBR voltage control capability in the power system compared to capability of synchronous machines.	Technical insights paper outlining assumptions, methodology and assessment outcomes for voltage control analysis under high IBR conditions.
FY25_20	Determine future Emergency Under Frequency Response (EUFR) requirements.	Confirmation of suitability of existing UFLS arrangements for VIC, NSW, QLD.	Initial assessment that reviews UFLS scheme in critical NEM regions, which can be used to provide insight into reducing risk associated with high IBR and CER conditions.
FY25_21	Evaluate system restart capability and options during periods where large synchronous generation is offline.	Investigate system restart requirements during periods where large synchronous generators are not available to initiate and/or support the restart process, assess options to meet those requirements using new technology and approaches.	Insights paper detailing system requirements and options assessment, potential for holistic review of System Restart regulatory environment.
FY25_22	Monitor and review of frequency control landscape.	Review NEM frequency control performance following implementation of recent reforms and determine any required changes to existing measures in light of anticipated higher IBR conditions. Conduct study to estimate future available primary frequency response (PFR) on the system following decommitment of synchronous generation and replacement with IBR.	Insights paper on performance of current frequency control landscape and potential changes required for future conditions.

A2.4 New technology capabilities

To enable new technologies to be integrated into the power system, both desktop investigations and real-world trials are required. This helps to develop assumptions regarding new technology capabilities by validating desktop investigation assumptions in the real world and provide insights on the practicality of using such technologies to meet system needs. Target outcomes for this workstream focus on utilising new technology to more efficiently meet system needs in a high IBR, renewable power system.

Table 5 FY2025 actions for new technology capabilities

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_23	Investigation of synthetic inertial response.	Investigate the ability of GFM inverter BESS to provide synthetic inertial response and thereby displace or reduce requirements for synchronous inertia.	Technical insights report on synthetic inertial response and development of AEMO's view of the ability of synthetic inertial response to deliver power system needs.

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_24	Review of Connection Study Analysis and Tools Requirements.	Review AEMO's power system modelling tools, their interoperability, and processes used to assess new and modified connections to the NEM. The objective is to describe fit for service tools and systems that allow AEMO; to continue to efficiently assess connections, to operate the power system securely, store, manage and secure data efficiently.	Draft report and implementation plan on the preferred tools and systems.
FY25_25	Impedance scan based frequency-domain controller design and implementation.	Implementation of a new impedance-scan-based frequency-domain controller-design approach to optimise the connection process of IBR. Implementation will validate the potential of impedance scan-based design in the frequency domain to ensure robust control settings which may ultimately reduce issues arising during wide area simulation studies and plant operation.	1. Development of a frequency-domain controller design proof of concept. 2. Engagement with NSPs to understand challenges with frequency domain controller design.
FY25_26	Quantification of system strength provision beyond the connection point.	Conduct studies, undertaking modelling and analysis on the quantification of System Strength Services (SSS). Connections developers are requesting the ability to remediate system strength impacts in front of their connection point, which is not currently possible under the System Strength Impact Assessment Guidelines (SSIAG). These studies and analysis will investigate and quantify this provision.	Technical note on the provision of system strength in front of the connection point. Consultation undertaken for amendments to the SSIAG.
FY25_27	Performance of GFM BESS.	Continuation and expansion of the GFM-BESS program which focused on studying the behaviour patterns of GFM-BESS and sharing the learnings with industry to assist in the generator connections process. This includes additional studies for GFM-BESS OEMs not selected in the original program. This will provide the industry with information to assist in overcoming technical challenges in connecting GFM-BESS to the grid.	1. Technical findings report on the studies performed. 2. Stakeholder Reference Group established to share findings. 3. Public Knowledge Sharing Report summarising Grid-Forming performance.

A2.5 RTO and operations support

Targeted uplift is required for the capability of AEMO's RTO and supporting functions to adapt to the needs of a high renewables power system. Key factors include:

- More generators and control systems.
- Higher weather-dependency of generation output.

- Greater geographic distribution of generation.
- Increased IBR penetration.
- Growing network complexity.

Target outcomes for this workstream include:

- Enabling AEMO to manage a wider range of high VRE system conditions with greater certainty.
- Supporting faster commissioning processes for new connections.

Table 6 FY2025 actions for RTO and operations support

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_28	Uplift in NEM short-term planning and outage management.	Uplift in short term planning and outage management to facilitate a grid with increasing numbers of new connections so that AEMO's procedures, processes and tools transition as the network evolves.	Reviewed and realigned current operational procedures, processes, and tools to capture changes in the network.
FY25_29	Conduct scoping study for automated compliance monitoring processes.	Uplift of compliance monitoring process to improve efficiency of process with increasing number of generators in system and greater complexity of non-compliance.	Project scope developed to deliver an automated platform and storage system to replace current manual compliance monitoring process.
FY25_30	Observation Hub – Improved weather data for Operational Forecasts.	Uplift operational forecasting through partnering with a weather forecast provider to enhance weather modelling capability and situational awareness.	Options analysis developed that examines the costs, benefits, and risks of acquiring, curating and releasing existing and new weather observations to provide enhanced nowcasts and forecasts for the energy sector. Funding proposal(s) submitted if required.
FY25_31	Operator training uplift across industry.	Collaborate with NSPs and participants to develop standardised, industry accredited operator training modules for an increasingly decentralised and renewable power system.	Delivery of Pilot Power systems operator training course (11 courses).
FY25_32	Conduct scoping study for RTO renewables scheduling desk.	Develop business case to employ dedicated control room staff to manage efficient scheduling of resources to meet system needs for secure operation of a VRE based power system.	Feasibility study report and plan for next steps.

A2.6 Operational transition planning

AEMO anticipates that the power system will encounter several critical system configurations that will test the boundaries of power system operation. Some examples may include:

- Secure operation of South Australia under conditions where there is a reduction of minimum synchronous generators online.
- Reduction in synchronous generation availability (for example, the retirement of Eraring Power Station in New South Wales).
- Increases in renewable penetration (for example, NEM-wide solar generation exceeding 70% – 80% – 90% of demand).
- Widespread deployment of new technologies with similar characteristics (such as grid-forming BESS with synthetic inertial response).

These "operational transition points" will require dedicated attention, study, sequencing, and governance to ensure secure system operation can be maintained. Target outcomes from this workstream include:

- Timely risk identification and management of real-world conditions as the system transitions to higher renewables.
- Increased confidence of system behaviour to make better informed decisions during power system operation.
- Enabling AEMO to manage a wider range of high VRE system conditions with greater certainty.

Table 7 FY2025 actions for operational transition planning

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_33	Future operational transition point identification – key coal stations.	Assess system preparedness for changing operational patterns of key coal power stations in the NEM in the upcoming 5 years, including decommitment, potential outage, and retirement.	Evaluation of operational preparedness and risks associated with changing operations of key coal stations. This will identify critical system configurations, with findings reported in the Transition Plan for System Security and/or other relevant AEMO publications.
FY25_34	Develop governance process for system operational transitions.	Develop standardised governance process for identification of and preparation for operation of the system through operational transition points such as critical low synchronous machine, high IBR configurations.	Standardised governance process for the identification of and preparation for operational transition points. This governance approach will be shared with industry stakeholders for feedback.

Appendix A2. Priority Engineering Roadmap Actions for FY2025

Priority Action 2025 ID	Activity Name	Description	Proposed Outputs for FY2025
FY25_35	Preparing and implementing operational transition points (within South Australia[39]).	Operational transition planning, detailed operations procedures, operational constraints, engagement with NSPs and stakeholders in South Australia.	Processes and procedures are developed and communicated that detail how AEMO intends to securely navigate Operational Transition Points for all operational transition activities related to South Australia.
FY25_36	Preparing and implementing operational transition points (outside South Australia).	Operational transition planning, detailed operations procedures, operational constraints, engagement with NSPs and stakeholders (outside South Australia).	Processes and procedures are developed and communicated that detail how AEMO intends to securely navigate Operational Transition Points for all other operational transition activities (outside South Australia).
FY25_37	Implement screening studies of future system operational transition points.	Identify upcoming operational transition points in the NEM by undertaking screening studies to identify potential operational readiness risks.	Screening study outcomes of future operational transition points are reported in the Transition Plan for System Security and/or other relevant AEMO publications.

[39] Separate activity tracked for South Australia given transition planning work currently underway, and the immediacy of operational challenges in the region.

A3. Abbreviations

Abbreviation	Term in full	Abbreviation	Term in full
ACSC	Australian Cyber Security Centre	**GW**	gigawatt/s
AEMC	Australian Energy Market Commission	**HV**	high voltage
AEMO	Australian Energy Market Operator	**IBR**	inverter-based resources
AMP	AEMO Modelling Platform	**IEEE**	Institute of Electrical and Electronics Engineers
ARENA	Australian Renewable Energy Agency	**ISF**	Improving Security Frameworks
AS/NZ4777.2	Australian Standards for Grid connection of energy systems via inverters – inverter requirements	**ISP**	Integrated System Plan
BESS	Battery Energy Storage System	**kV**	kilovolt/s
BOM	Bureau of Meteorology	**kW**	kilowatt/s
CEC	Clean Energy Council	**MV**	medium voltage
CER	consumer energy resources	**MW**	Megawatt/s
CIGRE	Conseil International des Grands Réseaux Electriques, International Council on Large Electric Systems	**NEM**	National Electricity Market
CRI	Connections Reform Initiative	**NEMDE**	NEM dispatch engine
CSIP-Aus	Common Smart Inverter Profile – Australia	**NEMOC**	National Electricity Market Operations Committee
DCCEEW	Department of Climate Change, Energy, the Environment and Water	**NER**	National Electricity Rules
DEIP	Distributed Energy Integration Program	**NREL**	National Renewable Energy Laboratory
DER	distributed energy resources	**NSCAS**	Network support and control ancillary services
DNSP	distribution network service providers	**NSP**	network service provider
DOE	Dynamic operating envelopes	**OEM**	original equipment manufacturer
DPV	distributed photovoltaics	**PFR**	Primary frequency response
ECM	Energy Conversion Model	**POE**	probability of exceedance
ECMC	Energy and Climate Change Ministerial Council	**PSSE**	Power System Simulator for Engineering
EMS	Energy Management System	**REZ**	renewable energy zones
ENA	Energy Networks Association	**RIT-T**	regulatory investment test for transmission
ESIG	Energy Systems Integration Group	**RTO**	real time operations
ESOO	Electricity Statement of Opportunities	**SCADA**	Supervisory Control and Data Acquisition
EUFR	Emergency Under Frequency Response	**SRES**	small scale renewable energy scheme
EV	electric vehicle	**SSIAG**	System Strength Impact Assessment Guidelines
EVSE	electric vehicle supply equipment	**SSS**	System strength services
FCAS	Fast Frequency Control Ancillary Services	**SSSPWG**	System Strength Service Providers working group
FELS	Flexible export limits	**SWIS**	South West Interconnected System
FY	financial year	**TNSP**	transmission network service provider
GFM	grid-forming	**UFLS**	under-frequency load shedding
GPSRR	General Power System Risk Review	**VPP**	virtual power plant
G-PST	Global Power Systems Transformation	**VRE**	variable renewable energy