NEM Engineering Framework

Initial Roadmap

December 2021

Executive Summary

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Exceptional change is required to enable the National Electricity Market (NEM) to securely and efficiently transition to new operational conditions. The instantaneous penetration of renewables is increasing rapidly and, with appropriate preparation, could reach up to 100% at times by 2025. Urgent and extensive industry collaboration and effort is needed to engineer the power system to meet these new conditions in a timely and orderly manner, with positive consumer outcomes at the heart of all decision-making.

This Initial Roadmap summarises the breadth of potential efforts and decisions needed to prepare the NEM power system for the futures envisioned in the Integrated System Plan (ISP). It represents a further step in the ongoing collaborative development of the Engineering Framework with stakeholders, and provides the foundation for engagement in early 2022 where organisations need to decide on the priorities of greatest value for them to lead or contribute towards.

The purpose of this Initial Roadmap document is to:

- Stimulate open and transparent collaboration with stakeholders on the actions required to operate the NEM under future Operational Conditions[1].
- Summarise the outcomes, insights, and potential priorities from the recent gap identification process undertaken in collaboration with stakeholders.
- Highlight key strategic decisions required in the near term to enable a secure and efficient transition to the six identified future Operational Conditions[1].
- Highlight the need to come together as an industry in 2022 to determine how our respective organisational efforts can be most valuably applied to determine priority gaps and priority actions.

This report is presented using an interactive format. To navigate through this document:

(home icon)	Click here to return to the contents page.
(arrow icon)	Click on the navigation pane at the bottom of each page to navigate to any part of the publication.
Link	Click on teal underlined text to go to another resource or jump to a linked part of this report. Some graphics also include links. An index of links is provided at the end of this report. Numbers like this[25] refer to the index of links.
Headings in the Summary of potential gaps	On the Summary of potential gaps pages (17-19), clicking on a column heading will take you to the full list of potential gaps for that heading in the Appendix.

Important notice:

This document is subject to an important disclaimer that limits and excludes AEMO's liability for reliance on the information in it. Please read this (on page 24) before you read the rest of this document.

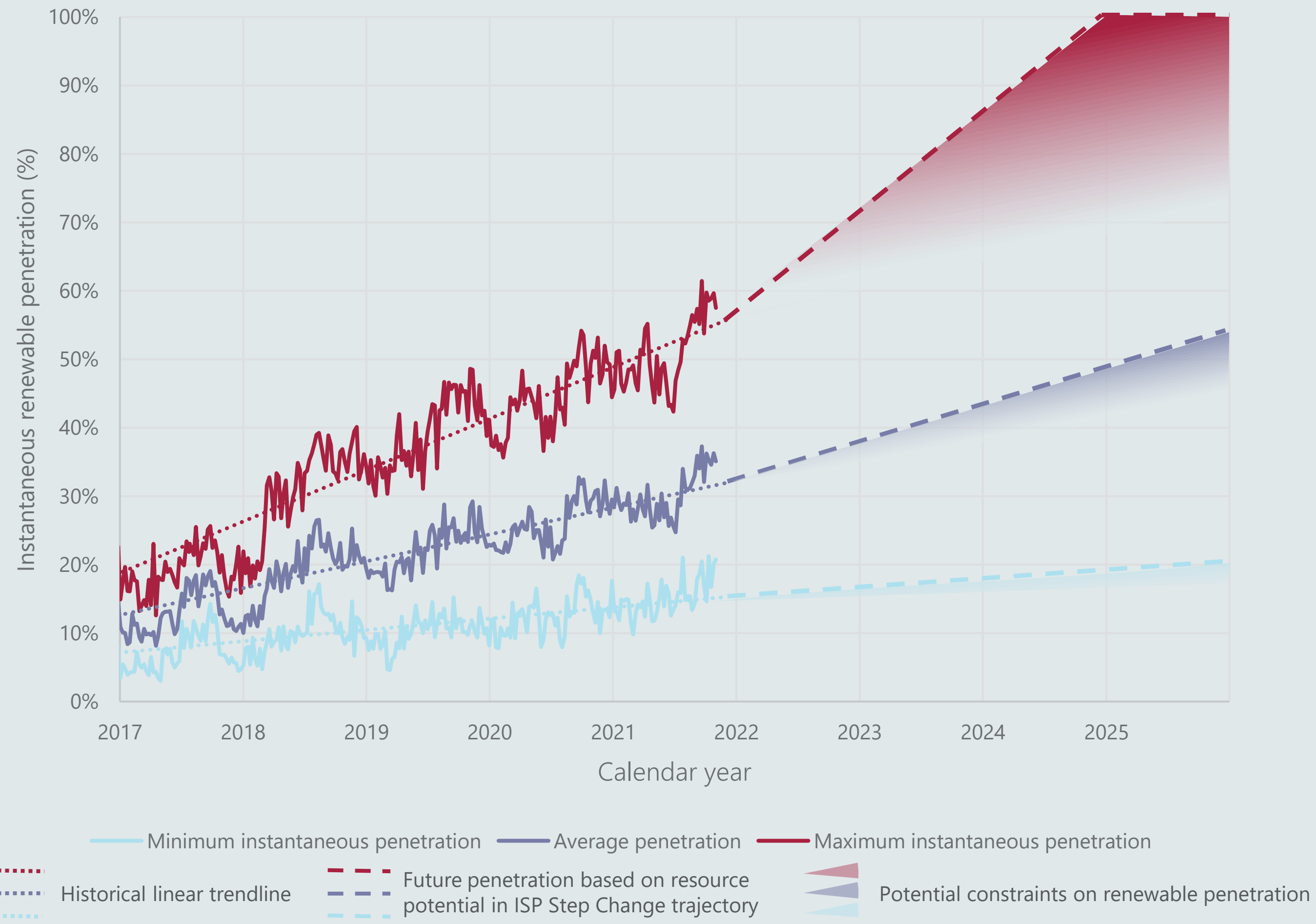
Table of contents

Context

A rapid energy transition

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Figure 1: Historical and projected NEM maximum, average, and minimum instantaneous renewable penetration*



*'Renewable' generation defined as including grid-scale wind and solar, hydro generation, biomass, storage generation and distributed PV (DPV)

The NEM is undergoing profound transformation of an unprecedented scale and pace. It will rapidly cross uncharted operational conditions yet to be experienced here or in comparable power systems internationally.

Figure 1 shows the rapid growth in **maximum instantaneous renewable energy penetration** in the NEM**,** doubling over the last three years and reaching a record of 61.8% on 15 November 2021, with some regions experiencing higher penetrations. This growth is projected to continue with NEM-wide penetrations potentially as high as 100% at times by 2025, occurring far more often by 2030.

The Engineering Framework examines **operational conditions** expected to emerge in the next five to 10 years as a tool to guide consideration of actions necessary to enable the transformation. These are described further in the July 2021 Operational Conditions Summary[1] and listed below, with an indication of the anticipated pace of change under AEMO's Draft 2022 ISP[2] Step Change scenario.

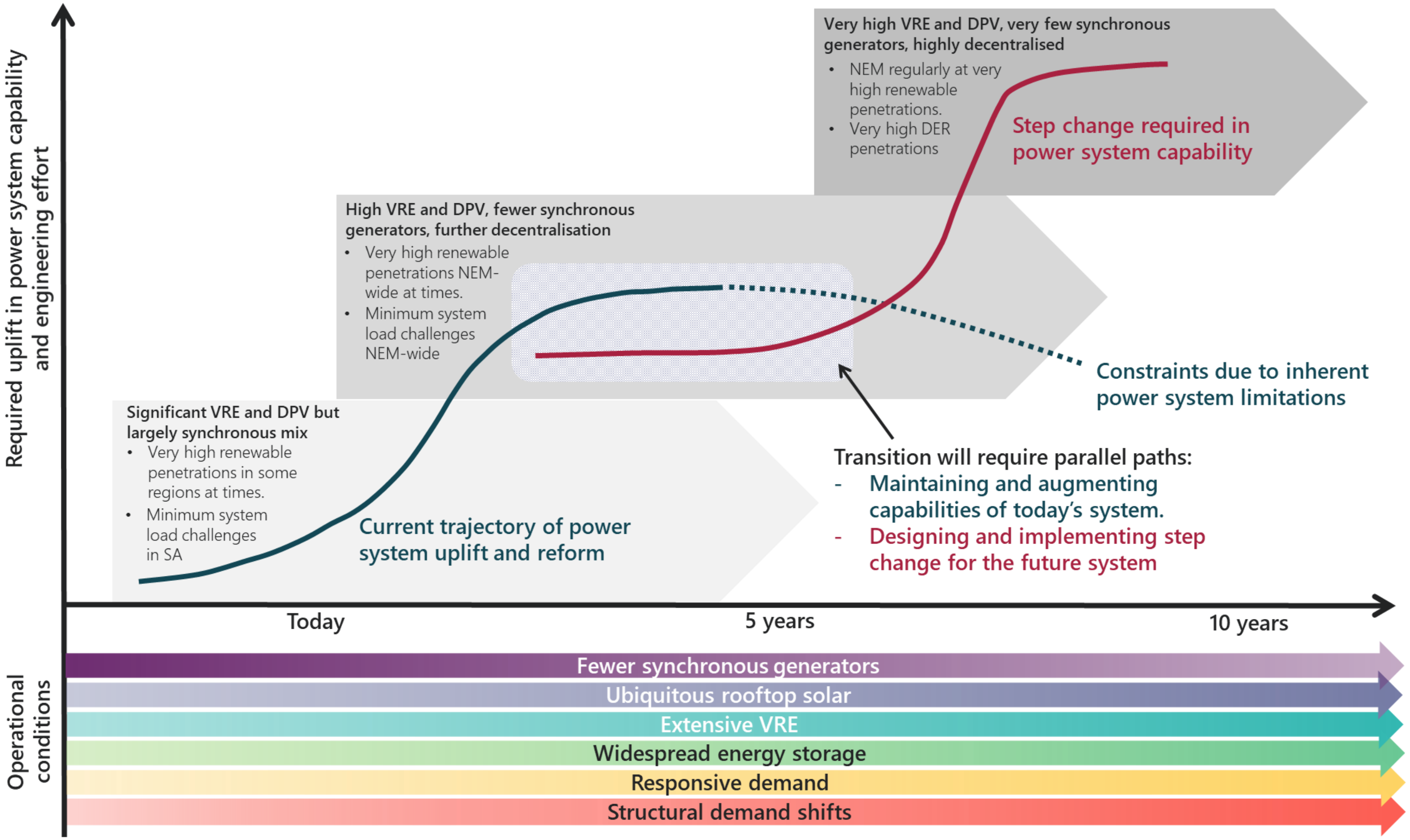
	Fewer synchronous generators *Coal capacity (GW)*	Ubiquitous rooftop solar *Installed DPV (GW)*	Extensive VRE *VRE capacity (GW)*
Today	23	15	15
2025	21	24	23
2030	9.0	35	43

	Widespread energy storage *Storage (GWh)*	Responsive demand *VPP and demand response (GW)*	Structural demand shifts *Electric vehicles (number)*
Today	13	0.7	26 k
2025	20	1.6	225 k
2030	400	6.0	2.3 m

Operational demand	Maximum (GW)	Minimum (GW)
Today	32	15
2025	36	9.4
2030	38	4.9

Notes:
Gigawatt (GW)
Gigawatt hour (GWh)
Variable renewable energy (VRE)
Virtual power plant (VPP)

Figure 2: Uplift in power system capability required as new operational conditions emerge



Adapted from Pacific Energy Institute, A Gambit for Grid 2035 – A systemic look into the disruptive dynamics underway[3], April 2021, p. 23

Transitioning to operational conditions[1] expected to emerge in the next 10 years will require the power system to be intentionally engineered for a step change in capability.

This Initial Roadmap highlights the scale of transformation required. The future power system will need to support increasingly complex dynamics in the transition from mainly synchronous to inverter-based resources (IBR) and balance increasing volumes of variable renewable energy (VRE). It will also need to enable increasingly decentralised operation through the ongoing uptake of distributed photovoltaics (DPV) and other distributed energy resources (DER), and increasingly critical coupling with other sectors through the electrification of industry, transport and other end uses.

The path to the power system of the future will need to be carefully engineered and intentionally designed with both today's power system and the ultimate end state in mind.

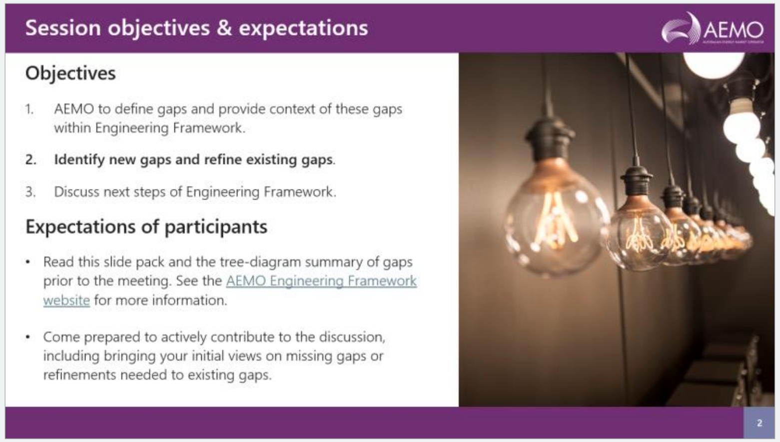
As shown in Figure 2, today's power system and the incremental trajectory of reform were not designed for the disruptive transition underway. Traditional, legacy approaches will need to be maintained in the near term, but inherent structural limitations will eventually constrain the pace of transition. Parallel to this, it is critical that designing a step change in power system capability starts today, due to:

- The extent of work and collaboration required across many areas, including technical engineering, planning, and regulatory reform.
- The pace of change underway and the asymmetric risk to consumers of disorderly, constrained and inefficient transition.
- The risks if timely action is not taken and system operators do not have the tools to securely and reliably manage new operational conditions as they emerge.

Recent stakeholder engagement

Figure 3: Stakeholder engagement undertaken during the development of this report

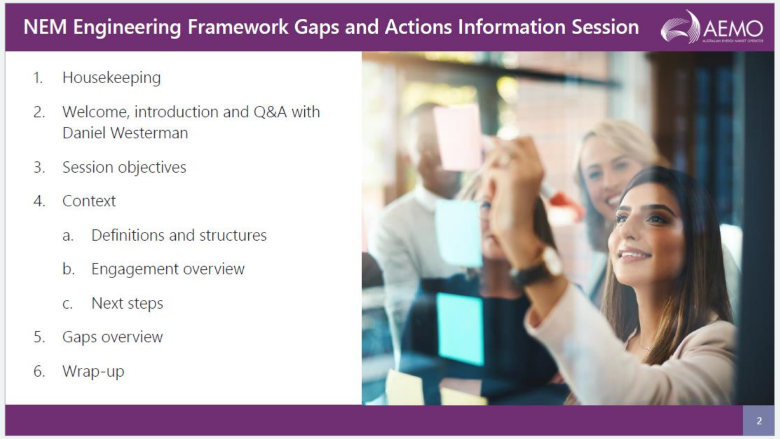
Aug – Sep 2021



Targeted engagement on potential gaps

- AEMO undertook targeted stakeholder engagement to identify potential gaps in the energy transition as part of developing this Initial Roadmap. The engagement leveraged and built on valuable insights contributed by stakeholders during the development of the operational conditions report[1].
- AEMO held 18 external engagement sessions with market participants, network service providers and market bodies.
- This process identified over 300 unique potential gaps.

October 2021



Stakeholder information session

- AEMO held an open-invitation information session on 22 October 2021 to provide an update to stakeholders who had indicated a desire to be kept informed but not engage in targeted discussions.
- This session provided attendees with a progress update on the gap identification process and related next steps
- The session also provided an opportunity for stakeholders to remain informed and contribute to the work undertaken to date.
- The session slides[4] are available on AEMO's website.

Stakeholder engagement is at the core of the Engineering Framework. Collaborating with a broad variety of stakeholders to understand their views on potential gaps in the energy transition is foundational to determining the priority actions required to reach future operational conditions[1] securely and efficiently.

Figure 3 outlines the collaborative approach taken to date to develop the list of potential gaps outlined in this Initial Roadmap. During these discussions, a number of consistent themes were raised, as captured on the Overarching messages page.

The potential gaps identified were grouped and summarised as shown on this page. A full list of the potential gaps identified is in the Appendix.

Continued collaboration

AEMO will continue to collaborate with stakeholders and encourages any interested parties to get involved.

Next steps

A **stakeholder Q&A forum** on 3 February 2022 will provide an opportunity for stakeholders to ask questions about the content included in this report, and explore the critical next step of collaborative prioritisation. **Please register for this session via this link.**

Overarching messages

Throughout the collaborative gap identification process with stakeholders, a number of common messages were identified

Figure 4: Common overarching messages highlighted during stakeholder engagement sessions

Fundamental design decisions are needed

The NEM is a **highly complex 'system of systems'**, originally designed around the physics of large synchronous machines

A **step change** in the ways we produce and consume electricity is underway

Intentional decisions on **power system architecture and resilience** are needed to ensure a secure and efficient transition

Decisions are needed on target outcomes for **customer experience and operational risk tolerance**

Urgent action and alignment is required

The NEM is **changing faster than ever before**

Uncertainty and variability is increasing, while technology and business model innovation outpaces planning and reforms

Decision-makers need to **urgently align on priorities, timing, and approach** for additional key transition efforts beyond work in progress

Approaches to **design, investment decisions, and construction of new assets** need to adapt to keep pace with transition

Parallel paths should be pursued to maximise **optionality and flexibility** while many unknowns exist

Empower participation in the evolving energy system

Consumers, network service providers (NSPs), aggregators and equipment providers all play meaningful roles in the transition and should be fully reflected in regulatory frameworks

Social licence must be sought as a foundational element in developing two-way markets, infrastructure projects, and energy reforms

More **skilled engineers and analysts** are needed to support the transition and increased system complexity

Scalable risk management approaches are needed

Frameworks used to manage connections, planning, and operational analysis need to be scalable and reflect pace of change

A holistic approach to the **control mechanisms that maintain power system physics** is needed

Engineering margin and precision modelling need balance to achieve appropriate risk profile

There is a need for an agreed approach to **testing new system conditions in a controlled environment**

Framework overview

The Engineering Framework

The [Engineering Framework][5] is helping define the full range of operational, technical and engineering requirements needed to deliver the futures envisaged by the ISP[6]. It seeks to facilitate an orderly transition to a secure and efficient future NEM system, with positive consumer outcomes at the heart of all decision-making.

The Engineering Framework collaboratively plans transition efforts across the NEM while simultaneously working toward implementation of these efforts through existing and new programs of work.

Figure 5 shows how the Engineering Framework supports AEMO's near-term reporting on the supply outlook of system needs, and maps a pathway towards the ISP scenario outcomes by focusing on the work required throughout the next 10 years of the energy transition. Engineering Framework interactions with other industry processes are shown on the next page.

This Engineering Framework Initial Roadmap document will inform preparation of the NEM for operation under six identified operational conditions[1], including operation with 100% instantaneous penetration of renewable energy by 2025. It has been built through collaboration with industry, including two months of targeted stakeholder engagement to identify potential gaps in the activities required to ensure an orderly and efficient energy transition.

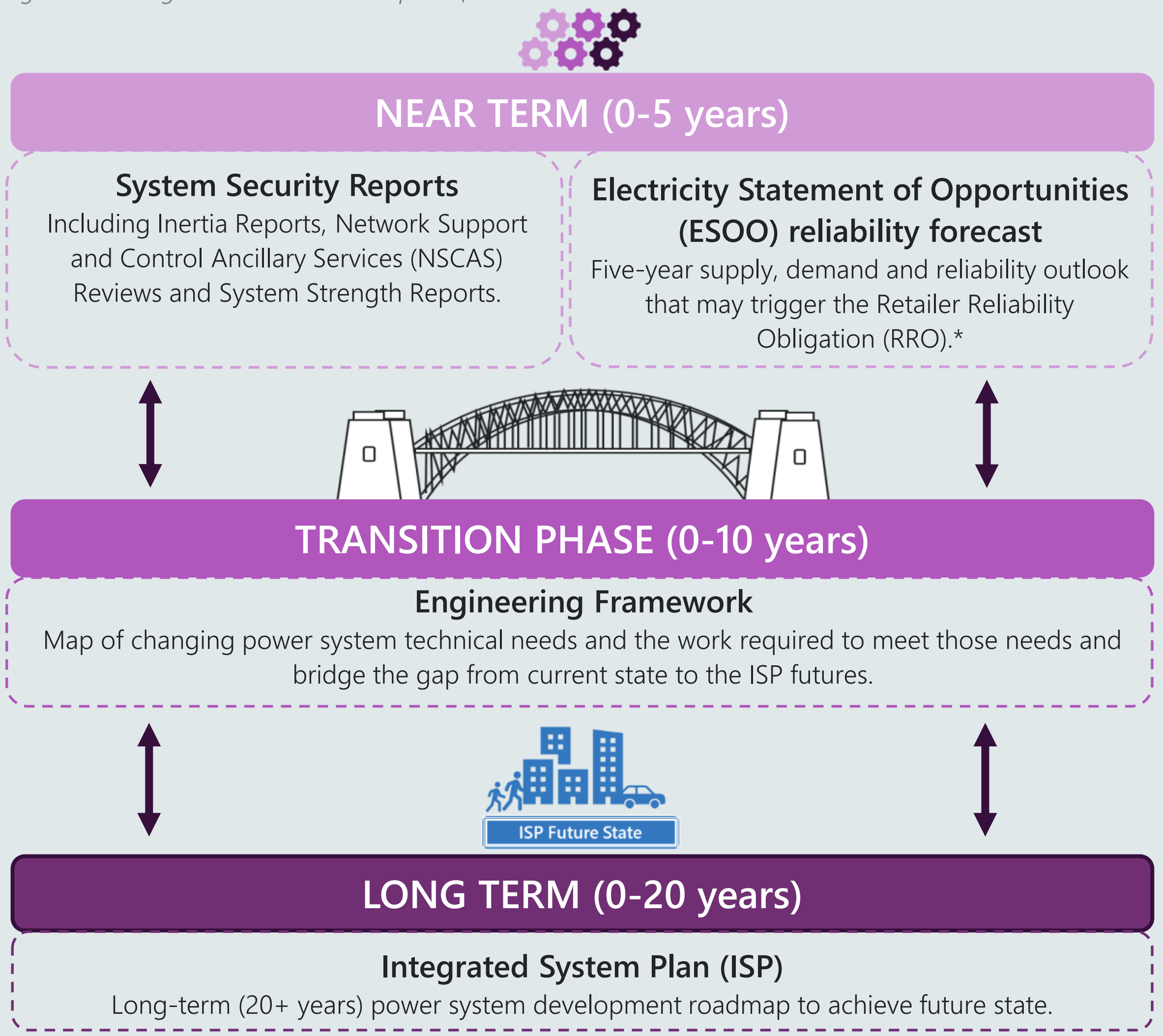
These ***potential gaps*** represent the steps that may be necessary to securely and efficiently 'bridge the gap' between today and future operating conditions. If the potential gaps are not actioned, the energy transition could be inhibited or constrained.

This Initial Roadmap calls industry, government, and market bodies to action by providing targeted views of the potential gaps identified by stakeholders in terms of:

- Key decisions on approach – a high level view of where urgent strategic decisions are needed to determine the best approach for power system transition activities.
- Summaries of potential gaps – an overview of the potential gaps identified through a collaborative process with stakeholders, grouped across Focus Areas defined in the March 2021 report[7].

Following on from this Initial Roadmap, the critical next steps will involve industry evaluation and alignment on which of the identified potential gaps are highest priority, and on the best course of action required to meet these gaps.

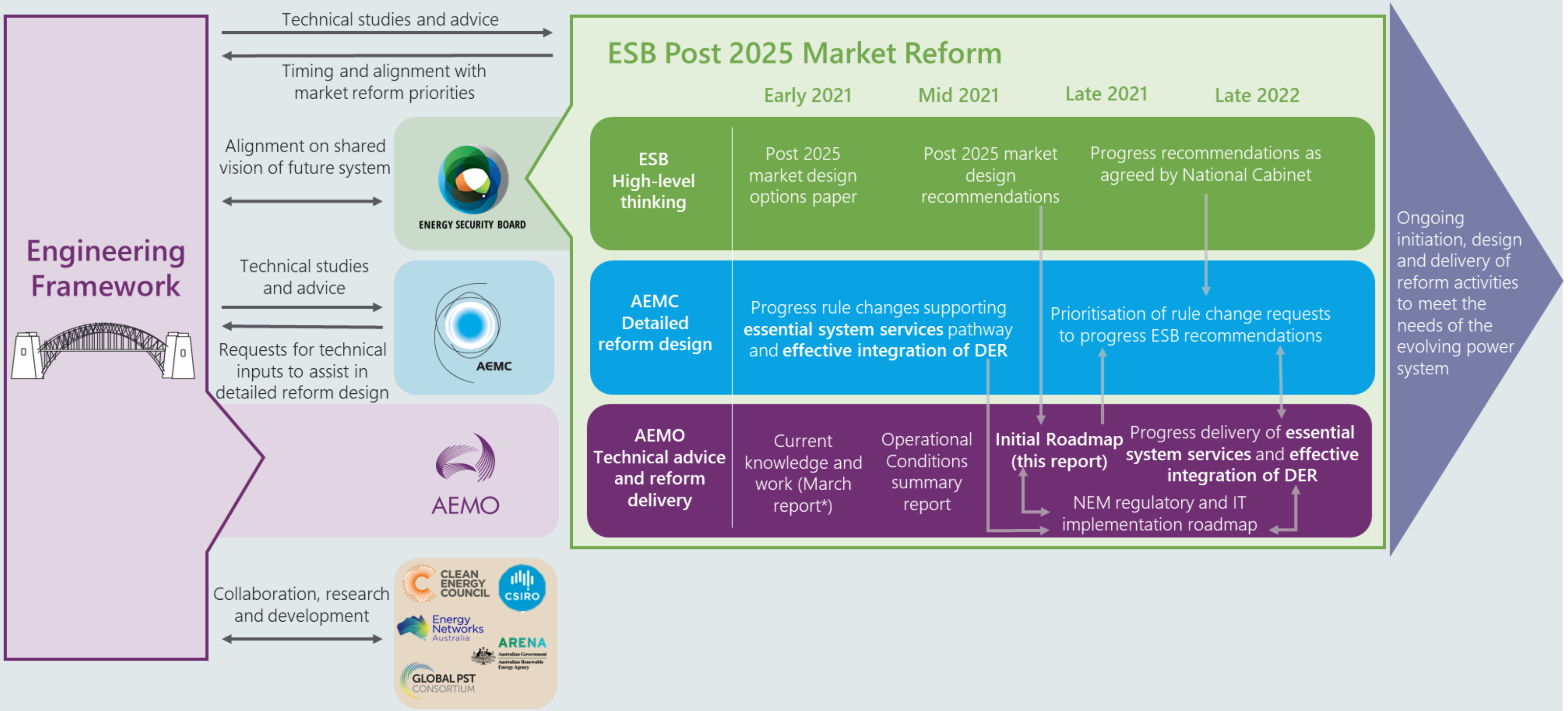
Figure 5: Linkages to other AEMO reports for the NEM



*A 6-10 year indicative ESOO projection also further informs the market and government of any forecast supply gaps.

Coordination with related processes

Figure 6: Coordination of the Engineering Framework with related processes



*AEMO's Engineering Framework March 2021 report[7] includes a complete stocktake of ongoing processes underway as at March 2021.

The Engineering Framework is built on collaboration between AEMO and the energy sector

As shown in Figure 6, actions and insights developed through the Framework will assist the Energy Security Board (ESB), Australian Energy Market Commission (AEMC), Australian Energy Regulator (AER), and AEMO in our collective ongoing development of a shared vision of future system design.

AEMO intends to work with other complementary efforts such as the Connections Reform Initiative, Distributed Energy Integration Program (DEIP), and Global Power System Transformation (G-PST) Consortium to progress actions identified by the framework.

The path to specification and quantification of system services

Many active market reforms are helping prepare for a future where the physical needs of the NEM power system can be procured and scheduled in an efficient and technology neutral way.

This Initial Roadmap report supports this objective by articulating the extent of engineering effort required to define future system needs and assessing the capability of the current and future fleet to provide them.

Subsequently, the Engineering Framework will drive the engineering analysis needed to support the specification and quantification of services for power system security.

AEMO AUSTRALIAN ENERGY MARKET OPERATOR

Figure 7: The Engineering Framework approach

Current knowledge and work (March 2021[7] report)

- AEMO, in consultation with stakeholders, summarised and consolidated the current knowledge base and work underway across industry to provide a shared understanding of the fundamental needs and changes occurring across the NEM.
- The work was categorised into 10 Focus Areas across three groups: Attributes, Operability and Integration.

Potential gaps and actions (this Initial Roadmap)

- AEMO, in collaboration with stakeholders, identified a list of potential gaps to be addressed that 'bridge the gap' between the current and future NEM operational conditions, based around the 10 Focus Areas.
- Further work will be needed to collaboratively assess priorities, develop actions and determine implementation pathways (see prioritisation and commencement of new actions).

Operational Conditions Summary (July 2021[1])

- AEMO, in consultation with stakeholders, developed the concept of "operational conditions" to define a future view of the NEM and defined six operational conditions, using future generation mix and loading combinations.
- Operational conditions represent future periods which will necessitate new approaches to managing secure and efficient operation of the power system.

1. Fewer synchronous generators online
2. Ubiquitous rooftop solar
3. Extensive grid-scale VRE
4. Structural demand shifts
5. Responsive demand
6. Widespread energy storage

The Engineering Framework takes a holistic approach to identify the actions required to facilitate an orderly transition of the NEM over the next 10 years.

As presented in Figure 7, the Engineering Framework considers the transition through the concept of connecting two sides of a bridge.

The approach required a clear definition of both the future operational conditions (the right of the bridge) and the current knowledge and work (the left side of the bridge).

Once these views were agreed and consolidated, potential gaps were identified through collaboration with stakeholders (**the middle section**). These potential gaps represent the steps that may be necessary to securely and efficiently 'bridge the gap' between today and future operating conditions. If the potential gaps are not actioned, the energy transition could be inhibited or constrained.

By considering the target end state first, the Engineering Framework looks beyond incremental adaptations, to instead identify a broader set of actions and decisions that better support a holistic transition.

Roadmap

Elements of the Roadmap

The Roadmap is made up of a number of key elements developed through extensive stakeholder consultation, and presented throughout this section of the report.

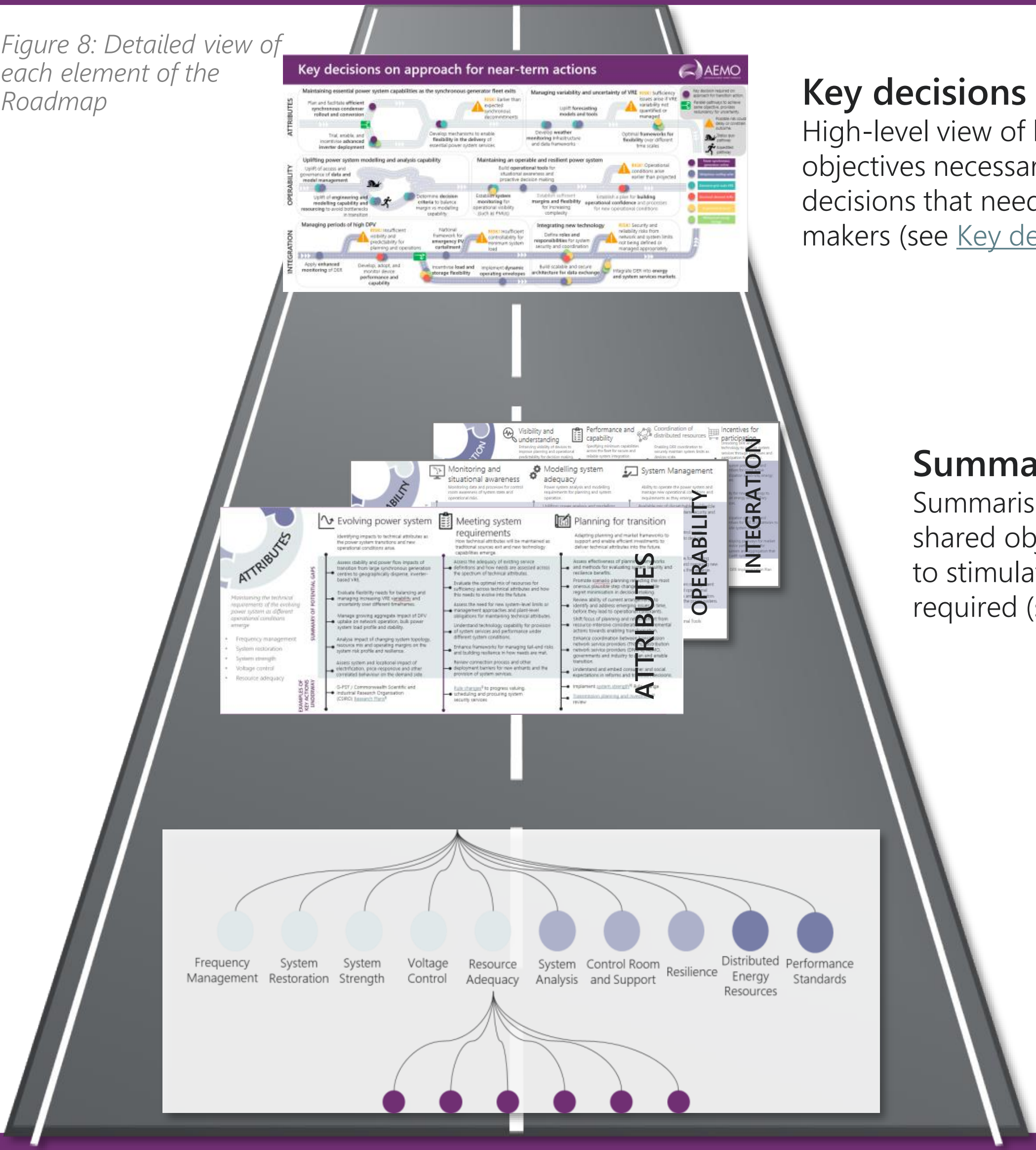
As detailed in the Stakeholder Engagement section, AEMO worked with industry to develop a list of detailed potential gaps that may need to be addressed to transition from the current NEM towards the six future operational conditions.

Stakeholder engagement identified raw potential gaps that represent the steps that may be necessary to securely and efficiently ‘bridge the gap’ between today and future operating conditions. These potential gaps, if not actioned, could inhibit or constrain the energy transition.

These potential gaps were reviewed, cleaned, and consolidated, with over 300 unique potential gaps remaining (see Appendix for final list). It is important to note that the potential gaps documented in this report should not be inferred to be of equal magnitude or urgency. In some cases, it may be identified that existing work programs are already underway that address the gap, or that it is not material enough to warrant action. Through the Engineering Framework process, the potential gaps will be collaboratively assessed and prioritised. See Next steps for future activities and engagements.

For this Initial Roadmap, the array of potential gaps has been progressively refined, summarised and categorised (by Focus Area) to provide a summary of potential gaps, and a final view of the key decisions on approach necessary for the transition.

Figure 8: Detailed view of each element of the Roadmap



Key decisions on approach

High-level view of key decisions on the approach to achieve objectives necessary for the transition. Intent is to clarify decisions that need to be made and inform policy and decision makers (see Key decisions on approach for near-term actions).

Summaries of potential gaps

Summarised view of potential gaps, grouped by shared objective. These summaries are intended to stimulate discussion on further actions required (see Summaries of potential gaps).

Individual potential gaps

Detailed catalogue of potential gaps by focus area. The original list of 500+ potential gaps identified with stakeholders was reviewed, cleaned and consolidated, resulting in 300+ unique potential gaps (see Appendix). This list presents potential gaps raised through a consultative process and does not necessarily represent AEMO’s views.

Key decisions on approach for near-term actions

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

ATTRIBUTES

Maintaining essential power system capabilities as the synchronous generator fleet exits

- Plan and facilitate **efficient synchronous condenser rollout and conversion**
- Trial, enable, and incentivise **advanced inverter deployment**
- Develop mechanisms to enable **flexibility in the delivery** of essential power system services
- RISK! Earlier than expected synchronous decommitments

Managing variability and uncertainty of VRE

- Develop **weather monitoring** infrastructure and data frameworks
- Uplift **forecasting models and tools**
- Optimal **frameworks for flexibility** over different time scales
- RISK! Insufficient flexibility to balance VRE variability

OPERABILITY

Uplifting power system modelling and analysis capability

- Uplift of access and governance of **data and model management**
- Uplift of **engineering and modelling capability and resourcing** to avoid bottlenecks in transition
- Determine **decision criteria** to balance margin vs modelling capability

Maintaining an operable and resilient power system

- Build **operational tools** for situational awareness and proactive decision making
- Establish **system monitoring** for operational visibility (such as PMUs)
- Establish sufficient **margins and flexibility** for increasing complexity
- Establish a plan for **building operational confidence** and processes for new operational conditions
- RISK! Operational conditions arise earlier than projected

INTEGRATION

Managing periods of high DPV

- Apply **enhanced monitoring** of DER
- RISK! Insufficient visibility and predictability for planning and operations
- Develop, adopt, and monitor device **performance and capability**
- National framework for **emergency PV curtailment**
- Incentivise **load and storage flexibility**
- RISK! Insufficient controllability for minimum system load
- Implement **dynamic operating envelopes**

Integrating new technology

- Define **roles and responsibilities** for system security and coordination
- Build scalable and secure **architecture for data exchange**
- RISK! Security and reliability risks from network and system limits not being managed appropriately
- Integrate DER into **energy and system services markets**

Legend

- Key decision required on approach for transition action.
- Parallel pathways to achieve same objective, provides redundancy for uncertainty.
- Possible risk could delay or constrain outcome.
- Status quo pathway
- Expedited pathway

- Fewer synchronous generators online
- Ubiquitous rooftop solar
- Extensive grid-scale VRE
- Structural demand shifts
- Responsive demand
- Widespread energy storage

Grouping and summarising potential gaps

AEMO AUSTRALIAN ENERGY MARKET OPERATOR

Potential gaps have been classified across Focus Areas, grouped into Attributes, Operability, and Integration

Given the breadth of potential gaps that need to be considered, and their interrelated nature, AEMO has sought to distil these into a logical and digestible story. This story is introduced below and summarised across the following three pages, with a consolidated list of potential individual gaps that sit below this story provided in the Appendix.

ATTRIBUTES

Maintaining the technical requirements of the evolving power system as different operational conditions emerge

The Summary of potential gaps – Attributes seeks to identify the impacts to technical attributes occurring across the **evolving power system.** Effort across industry will be required to continue **meeting system requirements** as the power system transitions, such as defining service specifications and system architecture. By **planning for the transition**, actions can be taken to adapt existing planning and market frameworks to satisfy the needs of the changing and uncertain future system.

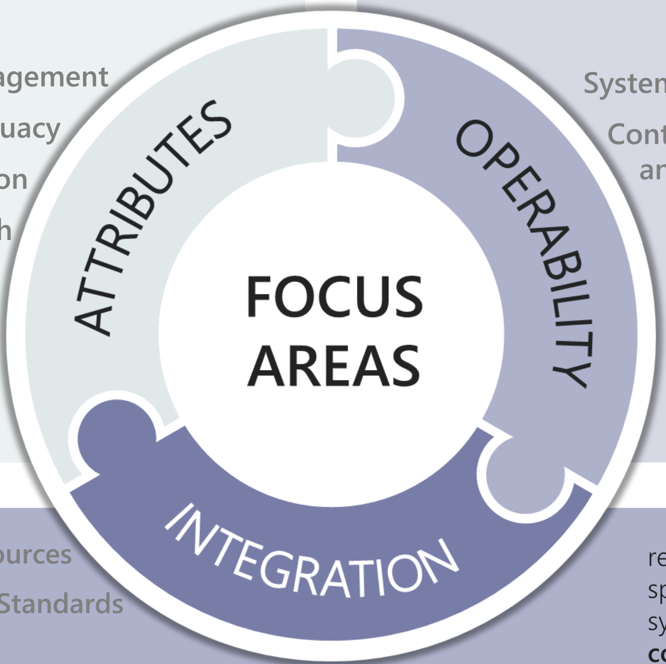
- Frequency management
- Resource adequacy
- System restoration
- System strength
- Voltage control
- Resilience

OPERABILITY

System analysis, operational tools and practices to support and enable increasingly complex power system operation

- System analysis
- Control room and support

The Summary of potential gaps – Operability explores the data and processes for control room **monitoring and situational awareness**, as well as the uplift needed for forecasting, planning and operational analysis to ensure industry retains fit-for-purpose capability for **modelling system adequacy** as technology changes. This will influence the capability of tools used for **system management**, which will require adaptations and development as new tasks, actors, and service providers emerge.



INTEGRATION

Optimally deploying and incentivising new and existing technologies, both grid-scale and distributed, within the power system and market

- Distributed Energy Resources
- Performance Standards

The Summary of potential gaps – Integration considers how new technology (large and small) can best support the power system and deliver desired outcomes for consumers. By establishing **visibility and understanding** of device connections, real-time performance, and behaviours, **performance and capability** specifications of devices can be developed to maintain secure and reliable system operation. A key integration challenge relates specifically to the **coordination of distributed resources** to ensure these have capabilities to support system security as they become increasingly prevalent. To optimise these capabilities, appropriate incentives, participation pathways and technical specifications are needed, **enabling participation** for consumers to unlock opportunities from DER and other new technologies.

Summary of potential gaps – Attributes

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

ATTRIBUTES

Maintaining the technical requirements of the evolving power system as different operational conditions emerge

- Frequency management
- System restoration
- System strength
- Voltage control
- Resource adequacy

Evolving power system

Identifying impacts to technical attributes as the power system transitions and new operational conditions arise.

SUMMARY OF POTENTIAL GAPS

- Assess stability and power flow impacts of transition from large synchronous generation centres to geographically disperse, inverter-based VRE.
- Evaluate flexibility needs for balancing and managing increasing VRE variability and uncertainty over different timeframes.
- Manage growing aggregate impact of DPV uptake on network operation, bulk power system load profile and stability.
- Analyse impact of changing system topology, resource mix and operating margins on the system risk profile and resilience.
- Assess system and locational impact of electrification, price-responsive and other correlated behaviour on the demand side.

EXAMPLES OF KEY ACTIONS UNDERWAY

- G-PST / Commonwealth Scientific and Industrial Research Organisation (CSIRO) Research Plans[8]

Meeting system requirements

How technical attributes will be maintained as traditional sources exit and new technology capabilities emerge.

SUMMARY OF POTENTIAL GAPS

- Assess the adequacy of existing service definitions and how needs are assessed across the spectrum of technical attributes.
- Evaluate the optimal mix of resources for sufficiency across technical attributes and how this needs to evolve into the future.
- Assess the need for new system-level limits or management approaches and plant-level obligations for maintaining technical attributes.
- Understand technology capability for provision of system services and performance under different system conditions.
- Enhance frameworks for managing tail-end risks and building resilience in how needs are met.
- Review connection process and other deployment barriers for new entrants and the provision of system services.

EXAMPLES OF KEY ACTIONS UNDERWAY

- Rule changes[9] to progress valuing, scheduling and procuring system security services

Planning for transition

Adapting planning and market frameworks to support and enable efficient investments to deliver technical attributes into the future.

SUMMARY OF POTENTIAL GAPS

- Assess effectiveness of planning frameworks and methods for evaluating system security and resilience benefits.
- Promote scenario planning reflecting the most onerous plausible step changes to enable regret minimisation in decision-making.
- Review ability of current arrangements to identify and address emerging issues in time, before they lead to operational constraints.
- Shift focus of planning and reform effort from resource-intensive consideration of incremental actions towards enabling transformation.
- Enhance coordination between transmission network service providers (TNSPs), distribution network service providers (DNSPs), AEMO, governments and industry to plan and enable transition.
- Understand and embed consumer and social expectations in reforms and transition decisions.

EXAMPLES OF KEY ACTIONS UNDERWAY

- Implement system strength[10] Rule change
- Transmission planning and investment[11] review

Summary of potential gaps – Operability

OPERABILITY

System analysis, and operational tools and practices to support and enable increasingly complex power system operation

- System analysis
- Control room and support

Monitoring and situational awareness

Monitoring data and processes for control room awareness of system state and operational risks.

Summary of potential gaps

- Establish network and system monitoring for operational visibility, state estimation, analysis and model development.
- Build real-time and forward-looking stability, adequacy and risk assessment tools for situational awareness and proactive decision-making.
- Develop weather monitoring infrastructure, coordination and data frameworks for an increasingly weather-dependent system.
- Explore operational data and communication that could enhance understanding and encourage optimised participant decisions.

Examples of key actions underway

- Progress existing industry efforts to uplift high speed data monitoring systems across the NEM
- Review of Power System Data Communication Standard

Modelling system adequacy

Power system analysis and modelling requirements for planning and system operation.

Summary of potential gaps

- Identify and resource technical studies and analysis necessary for the transition to new operating conditions.
- Uplift forecasting models and tools for adequacy assessment and quantifying risk and uncertainty over different timescales.
- Uplift power system analysis capability by improving existing and developing new models, methods and approaches.
- Enhance coordination between planning and operations so adequacy studies reflect operational realities and constraints.
- Establish engineering criteria for timely decision-making with imperfect information, recognising inherent limitations of modelling.
- Establish responsibilities and governance frameworks for AEMO, NSP and participant access to system and plant models.

Examples of key actions underway

- Progress Connections Reform Initiative[12]
- Implementation of Real-Time Simulator[13]

System Management

Ability to operate the power system and manage new operational conditions and requirements as they emerge.

Summary of potential gaps

- Develop a plan to build operational confidence, processes and tools to manage new operational conditions as they emerge.
- Establish appropriate operating margins and system flexibility to manage increasing complexity and uncertainty.
- Review suitability and scalability of current control room practices with increasing operator demands and complexity.
- Assess ongoing effectiveness of processes for quantifying and managing the technical envelope of the power system and re-evaluate design decisions that increase operational risk.
- Build processes for new system management tasks requiring enhanced coordination with DNSPs and new actors.

Examples of key actions underway

- Develop AEMO Operations Technology Roadmap
- ST PASA (Short Term Projected Assessment of System Adequacy) replacement project[14]

Summary of potential gaps – Integration

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

INTEGRATION

Optimally deploying and incentivising new and existing technologies, both grid-scale and distributed, within the power system and market.

- Performance standards
- Distributed energy resources

Visibility and understanding

Visibility of new and existing technology for planning and operational decision-making.

SUMMARY OF POTENTIAL GAPS

- Establish data collection and access frameworks on new technology uptake for forecasting, planning and operations.
- Enhance operational visibility and monitoring data access frameworks for estimating DER behaviour and system impact.
- Develop methods and tools to represent DER locational and aggregated behaviour in power system studies.
- Assess distribution network and system limits with increasing DER uptake and evaluate technical solutions and opportunities.

EXAMPLES OF KEY ACTIONS UNDERWAY

- Review of regulatory framework for metering services[15]
- Project MATCH[16] collaboration

Performance and capability

Device capability reflecting the changing role and nature of technologies in the power system.

SUMMARY OF POTENTIAL GAPS

- Establish technology performance requirements that minimise customer, network and power system risks.
- Enable last-resort curtailability and fail-safe behaviours for extreme, abnormal system conditions.
- Adopt device interoperability requirements enabling flexibility, tuning and optimisation, service provision and customer choice.
- Establish robust compliance assessment and conformance monitoring over the life of assets.
- Prioritise standards development and adoption, capitalising on established international standards and norms.

EXAMPLES OF KEY ACTIONS UNDERWAY

- DEIP[17] working groups
- Enabling and integrating advanced inverter[18] capability

Coordination and management

Architecture to enable many new actors and increasing volume and complexity of data exchange.

SUMMARY OF POTENTIAL GAPS

- Define roles and responsibilities for system security and operational coordination for a highly decentralised power system.
- Develop scalable operational data communication architectures, data exchange processes and standards.
- Establish system integration and telemetry requirements for management, participation and service provision.
- Design resilient and cyber secure communications architectures and risk management frameworks.

EXAMPLES OF KEY ACTIONS UNDERWAY

- Project EDGE[19] and other industry DER coordination trials
- DNSP implementation of dynamic operating envelopes

Enabling participation

Incentivising technology and consumer participation to provide system-level flexibility and services.

SUMMARY OF POTENTIAL GAPS

- Seek to establish consumer social licence on need for last-resort control and benefits of management options.
- Empower and incentivise optimised consumer decisions in a two-way energy system.
- Technically specify the services different technologies can provide and requirements for participation.
- Develop pathways for VRE, storage, responsive loads and aggregators to participate in the energy market and provide services.
- Remove barriers for network storage to provide system-level flexibility and services.

EXAMPLES OF KEY ACTIONS UNDERWAY

- ESB DER Implementation Plan[20]

Next steps

Engineering Framework stages

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Figure 9: Indicative future activities of the Engineering Framework

Operational conditions

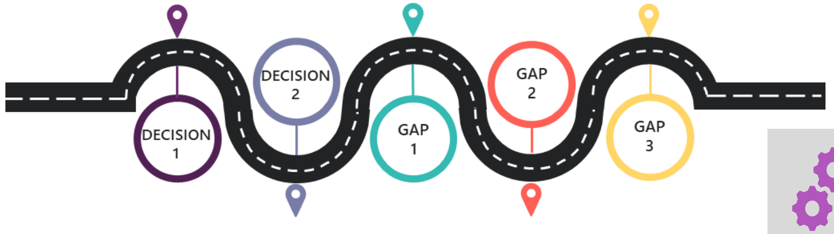
Define future generation mix and loading combinations for the NEM.

Potential Gaps

Working with stakeholders, identify potential gaps that, if not addressed, may make it difficult to manage the energy transition efficiently and securely.

Initial Roadmap

Summarises the breadth of potential gaps, and decisions needed to begin prioritising action and establishing workplans.



Prioritisation and commencement of new actions

Industry collaboration to address key decisions and convert potential gaps to priority actions.

Iterative evolution of actions and workplans

Implementation Workplans

Collaboration with stakeholders to integrate, align, and coordinate prioritised actions across a variety of industry workplans, both existing and new. These workplans are set based on complex regulatory and commercial frameworks, and will in many cases include activities beyond those identified by the Engineering Framework alone. Subject to funding availability, the Engineering Framework will seek to initiate additional workplans where priority actions are not covered elsewhere.

Application of Advanced Grid-scale Inverters in the NEM

To be identified

Engineering Framework identified workplans

Integrate, align and coordinate

Australian Energy Regulator · DEIP Distributed Energy Integration Program · Energy Networks Australia · CSIRO · Global PST Consortium · Clean Energy Council · AEMO · Energy Security Board · AEMC · ARENA Australian Government Australian Renewable Energy Agency + other coordinating efforts

Existing workplans and initiatives

Monitor actions

Monitor progress towards resolution of identified priority gaps, and overall preparedness for each operational condition.

Prioritisation and commencement of new actions

The critical next step of the Engineering Framework is to collaboratively determine priority actions in the near term, and agree respective organisational responsibilities. Early commencement of priority actions will be needed in many cases.

The next stage of the Engineering Framework begins in Q1 2022, with industry evaluation and alignment on which of the identified potential gaps are highest priority, and on the best course of action required to meet these gaps.

AEMO will table industry perspectives and suggestions on priorities for consideration, however respective organisations will determine how their efforts can be applied toward priority actions in accordance with their functions. In Figure 10, AEMO proposes some guiding principles for prioritisation as a starting point. Once agreed, these can be used to help guide prioritisation decisions.

Given the anticipated volume of work that would be required to address all the potential gaps identified in this paper, and the limited time and resources available across industry, difficult decisions will need to be made on which priorities are highest. Some actions will be critical and require immediate commencement or already be underway, while others may be determined by industry as not necessary or sufficiently valuable to progress.

Actions will be ultimately managed by relevant organisations under implementation workplans, and their progress can be monitored to track industry preparedness for each Operational Condition.

As workplans progress, further potential gaps and actions may be identified, prioritised and added to implementation workplans. This will form the *living Engineering Framework process*.

Figure 10: Next steps in prioritisation and utilising potential gaps to develop actions

Agree prioritisation principles

Proposed prioritisation principles

- Adding value for:
  - Consumers
  - Market
  - Power system security
- Urgency:
  - When will the issue arise?
  - How long will the work take to complete?
  - Timing of inputs needed for committed industry activities
- Minimising regrets:
  - Will the gap definitely arise even if timing is uncertain?
- Leveraging existing processes:
  - Can existing processes be leveraged if early action taken?
- Funding and resourcing:
  - Can funding be made available?
  - What are the resource implications for all stakeholders?

Convert potential gaps to actions

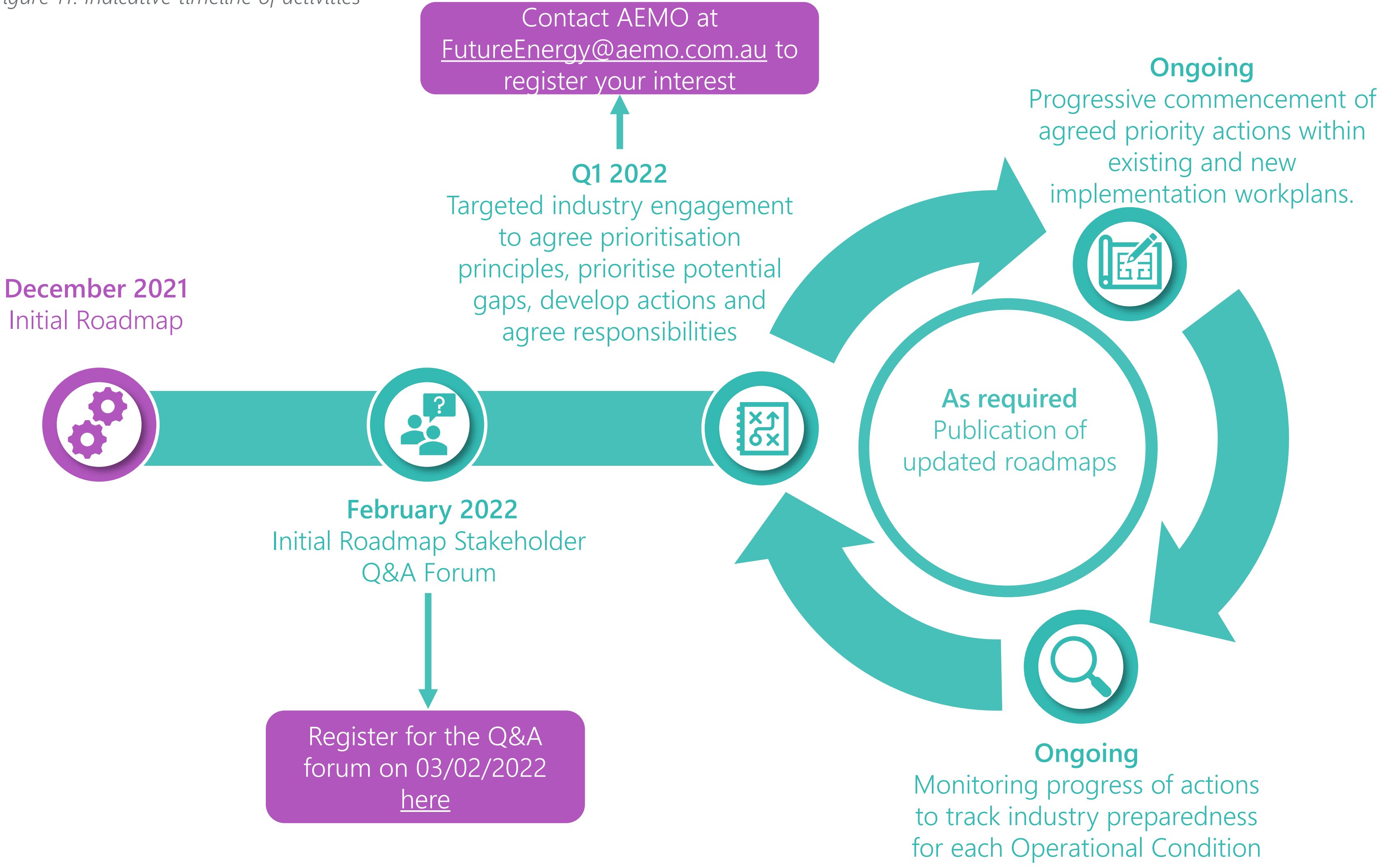
- Agree approach to key energy transition decision points
- Leverage agreed prioritisation principles to collaboratively prioritise potential gaps and convert to priority actions
- Coordinated decisions on action ownership

Commence early works

- Early works should commence urgently on low-regret priority actions
- Opportunities should be taken to maximise benefits from existing processes, such as proposed reforms where consultation is underway
- Early actions can influence future-proofing of investment decisions, such as enabling the inclusion of advanced functionality in new grid-scale batteries and synchronous condenser capability in new synchronous generators

Get involved

Figure 11: Indicative timeline of activities



Industry alignment is critical to the development and commencement of prioritised actions and implementation workplans to address the potential gaps identified in this report.

In the next stage of the Engineering Framework, it is key that stakeholders come together to prioritise potential gaps and actions, and align them to organisational efforts. AEMO will hold targeted discussion sessions in Q1 2022 to begin this process. The aim of these sessions will be to set prioritisation principles, and apply them to make decisions on action priority and sequencing.

This engagement will inform the development of updated Engineering Framework roadmaps, and the mapping of actions to both existing and new implementation workplans.

Upcoming involvement opportunities:

As per Figure 11, in February AEMO will provide interested stakeholders with an opportunity to ask questions about the content included in this report, and explore the next step of collaborative prioritisation. **If you would like you attend the stakeholder Q&A forum on 03/02/2022 please register via the link here.**

AEMO will soon be reaching out to stakeholders to commence the targeted action discussions in Q1 2022. **If you are interested in attending one of these sessions, please get in touch with AEMO at FutureEnergy@aemo.com.au.**

Important Notice

Purpose

The purpose of this publication is to summarise the breadth of potential efforts and decisions needed to prepare the NEM power system for the operational conditions which may arise in the next 5 to 10 years.

AEMO publishes this NEM Engineering Framework Initial Roadmap in accordance with its functions, including as National Transmission Planner and to maintain and improve power system security under section 49 of the National Electricity Law. This publication is generally based on information available to AEMO as at 26 November 2021, noting that, across industry a lot of work is both in progress and upcoming.

Disclaimer

AEMO has made reasonable efforts to ensure the quality of the information in this publication but cannot guarantee that information, forecasts and assumptions are accurate, complete or appropriate for your circumstances. This publication does not include all of the information that an investor, participant or potential participant in the national electricity market might require, and does not amount to a recommendation of any investment.

Anyone proposing to use the information in this publication (which includes information and forecasts from third parties) should independently verify its accuracy, completeness and suitability for purpose, and obtain independent and specific advice from appropriate experts.

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

- make no representation or warranty, express or implied, as to the currency, accuracy, reliability or completeness of the information in this publication; and
- are not liable (whether by reason of negligence or otherwise) for any statements, opinions, information or other matters contained in or derived from this publication, or any omissions from it, or in respect of a person's use of the information in this publication.

Acknowledgement

AEMO acknowledges the support, co-operation and contribution of all stakeholders who assisted in providing data and information used in this publication.

Appendix of potential gaps

This Appendix presents the catalogue of individual **potential gaps** identified in collaboration with stakeholders.

These potential gaps represent the steps that may be necessary to securely and efficiently 'bridge the gap' between today and future operating conditions that, if not actioned, could inhibit or constrain the energy transition.

Potential gaps were identified through consideration of operational conditions across the different focus areas and include areas such as: technical understanding, engineering design and analysis, technology capability, operational systems and processes, as well as market and regulatory frameworks.

AEMO consulted extensively to collate a list of potential gaps, which was then summarised, consolidated and categorised resulting in the list as presented in this section. Please note:

- The list is a collation of potential gaps raised through a consultative process and **does not necessarily represent AEMO's views**.
- The potential gaps presented are those identified with stakeholders and have **not been prioritised for magnitude or urgency**.
- **Stakeholder consultation continues to be required** during the next stages of the Engineering Framework to verify that a gap indeed exists (and is not already being addressed) and the scope of any gap.
- During the collection process each gap was assigned a unique ID number for internal review tracking. The unique ID references the order in which the gap was added to the listing, and is not intended to infer any further meaning. Through the process some gaps were identified as duplicates and were removed, reworded, or consolidated into others, so **not all ID numbers will be utilised in the listing** presented in this Appendix.

Evolving power system

Identifying impacts to technical attributes as the power system transitions and new operational conditions arise.

Assess stability and power flow impacts of transition from large synchronous generation centres to geographically disperse, inverter-based VRE.

- ID010: Reduction in inertia and frequency response as synchronous generation reduces
- ID013: Reduction in reactive power reserves as synchronous generation reduces
- ID057: Low availability of raise FCAS in periods with high VRE online operating without headroom
- ID062: Increased reactive support requirements for VRE power transfer over long distances to load centres
- ID069: Reduced availability of SRAS-capable units
- ID194: Low availability of lower FCAS service when synchronous generators are at minimum load
- ID275: Small signal oscillation modes will change as the system topology, inertia and control systems evolve
- ID355: Congestion in DNSP sub-transmission networks due to sub-30 MW generator connections
- ID465: Reduction in negative sequence fault current injection impacting distribution network protection schemes
- ID466: Reduction in fault levels impacting distribution network plant and protection coordination

Evaluate flexibility needs for balancing and managing increasing VRE variability and uncertainty over different timeframes.

- ID002: Need for firm and flexible capacity to manage VRE variability and demand ramps
- ID032: Increasing system-wide and locational load ramps due to DPV variability
- ID056: Need for local FCAS to manage VRE ramping impact on interconnector flows within limits
- ID060: Potential need for regionalised FCAS requirements and periodic review as VRE penetrations increase

Manage growing aggregate impact of DPV uptake on network operation, bulk power system load profile and stability.

- ID034: Growth in DPV generation reducing system load below minimum secure synchronous generation levels
- ID035: Reducing UFLS effectiveness due to DPV impact on load available for shedding
- ID037: Increasing impact of DPV on distribution network voltage profile, power flows and protection coordination
- ID038: Uncontrollable DPV reducing the availability of stable load blocks for system restart
- ID040: Increasing contingency sizes due to DPV disconnection during bulk power system disturbances
- ID052: DPV that is not enabled to provide narrowband PFR is displacing frequency-responsive plant
- ID293: Transmission voltage control challenges from ongoing reduction in load due to DPV.

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Evolving power system

Identifying impacts to technical attributes as the power system transitions and new operational conditions arise.

Analyse impact of changing system topology, resource mix and operating margins on system risk profile and resilience.

- ID030: Potentially less geographic diversity in future system service provision reducing resilience and causing scarcity during outage or island conditions
- ID122: Risks from increasing reliance on interconnectors and major intra-regional paths for provision of system services and power transfer
- ID132: Reduced investment in physical assets impacting resilience by increasing risk of maloperation and reducing operating margins
- ID155: Risk of large aggregate changes due to the unintended common-mode response of equipment with the same or unknown settings
- ID384: Increasing likelihood of coal fleet instability with units increasingly dispatched at minimum levels
- ID404: Reducing diversity in fuel and technology mix across regions
- ID418: Increased contingency risks associated with loss of flow paths connecting significant REZs to main transmission system
- ID435: Increasing criticality of emergency management and crisis response with increasing electrification
- ID475: Increasing cybersecurity risks as level of interconnected, actively-managed DER increases.
- ID493: Reducing system strength margins impacting resilience making recovery from non-credible events more challenging

Assess system and locational impact of electrification, price-responsive and other correlated behaviour on the demand side.

- ID081: Potential risk of increasing contingency sizes associated with unexpected disconnection of new large loads and other local stability and power quality impacts
- ID090: System flexibility to balance large correlated, aggregated impact of responsive demand
- ID360: Price responsive sub-5MW generators contributing to intra-day frequency bias
- ID361: Semi-dispatch caps introduce asymmetry in forecast error increasing with VRE uptake impacting raise regulation requirements
- ID461: Increasing local and aggregated power quality impacts from the sudden switching of larger domestic loads and DER devices
- ID481: Step changes in demand from electrification introducing new large loads
- ID485: Stability impact of large load developments connecting in weak grid areas, far from generation centres

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Meeting system requirements

How technical attributes will be maintained as traditional sources exit and new technology capabilities emerge.

Assess the adequacy of existing service definitions and how needs are assessed across the spectrum of technical attributes.

- ID022: System service requirements need to be better defined with flexibility to adjust with the reduction in synchronous generation
- ID029: Holistic assessment required across the range of system services in addition to inertia and system strength
- ID160: Need to assess adequacy of FCAS arrangements when most providers are fast
- ID448: Need to assess adequacy of voltage management frameworks for enabling new providers of reactive support

Evaluate the optimal mix of resources for sufficiency across technical attributes and how this needs to evolve into the future.

- ID006: Need to determine appropriate mix of proportional and switched FCAS
- ID113: Need to review long-term protection and control philosophy as fault levels continue to reduce with fewer synchronous machines
- ID290: Need for diverse resource mix in REZ development in a world with minimal thermal synchronous plant
- ID298: Need to review the optimal mix of frequency control measures as the system and technology evolves
- ID299: Need to assess the comparative trade-off between rooftop and large-scale solar in costs and capacity factor
- ID328: Need to evaluate the right balance in system strength provision between distribution and transmission for a high-DER power system
- ID363: Need to focus on the mix of technologies that could provide grid-forming capability, not just IBRs
- ID454: Need to study the optimal mix of grid-forming and grid-following IBRs as the power system evolves

Assess the need for new system-level limits or management approaches and plant-level obligations for maintaining technical attributes.

- ID007: Potential need for NEM mainland inertia floor under system intact conditions
- ID009: Potential need for inertia dependent contingency FCAS under system intact conditions as inertia reduces
- ID012: Potential need for system RoCoF limits and other operational requirements as inertia reduces
- ID123: Need for consistent standards on temperature withstand requirements for system elements and generators
- ID144: Current specification of minimum threshold level of inertia (MTLI) doesn't consider credible islanding
- ID211: Need to review temporary undervoltage limits for generators

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Meeting system requirements

How technical attributes will be maintained as traditional sources exit and new technology capabilities emerge.

- ID336: Need to consider retrospectivity in new grid code requirements and risks associated with grandfathering the existing fleet, with potentially more onerous requirements for new plant
- ID343: Provision for PFR headroom and footroom management may be necessary in the future
- ID366: Need to determine effective allocation of responsibilities for VRE variability between balancing at the system-level and potential obligations on plant owners
- ID450: Need to understand how requirements for fault levels might support legacy plant
- ID496: Need to evaluate the ongoing effectiveness of the semi-scheduled category when most of the fleet is variable

Understand technology capability for provision of system services and performance under different system conditions.

- ID024: Demonstrate capability of new technology to provide SRAS
- ID064: Need a pathway for testing and demonstration of grid-forming projects at scale, to enable timely connections.
- ID103: Greater enablement of grid forming capabilities from new storage technologies
- ID147: Need to understand the response of existing generators to extended under/over frequency
- ID164: Understanding of practical minimum operating load of thermal plant
- ID212: Need to understand differences in post-contingency voltage support capability between synchronous plant and VRE
- ID226: Need to understand capability of grid and small-scale batteries to participate in system restart
- ID259: Need to understand relative costs and benefits of reactive support technologies, including other services they can provide
- ID292: Need to investigate different power flow control options
- ID307: Need to explore the role of microgrids and community batteries for enhancing network and system resilience
- ID326: Unknown potential for brownfield conversion of synchronous generators to synchronous condensers
- ID329: Need to study system strength contribution of many decentralised grid-forming inverters compared to fewer, larger systems
- ID334: Need to better understand coal plant limitations at minimum load levels

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Meeting system requirements

How technical attributes will be maintained as traditional sources exit and new technology capabilities emerge.

- ID409: Need to understand operating ranges, deadbands and other practical restrictions for different technologies providing system services
- ID439: Need to understand impact of extreme weather on the performance and capability of different energy storage technologies
- ID449: Opportunity to better utilise reactive support from DER
- ID512: Need to understand synchronous machine stability and performance from operating under high leading power factors with fewer synchronous machines online

Enhance frameworks for managing tail-end risks and building resilience in how needs are met.

- ID031: Rules framework does not set clear expectations for regional self-sufficiency
- ID059: Need to review alignment of NER framework with regional contingency FCAS requirements for non-credible events
- ID076: Contingency event framework needs to be reviewed to capture large unforecast VRE changes, undesirable control scheme interactions and DER disconnection risks.
- ID121: Consider and clarify interactions between the Security of Critical Infrastructure Act and the resilience framework.
- ID133: Absence of over generation management scheme in each NEM region
- ID158: Limited ability to pre-emptively manage non-credible event risk in operational timeframes resulting in increasing reliance on special protection schemes
- ID463: Stronger incentives for storage and other technologies to contribute to managing tail-event risks
- ID494: Difficult to justify network investment to improve resilience under current framework

Review connection process and other deployment barriers for new entrants and the provision of system services.

- ID168: Synchronous condenser designs are bespoke, leading to high cost and long deployment times
- ID338: Need to encourage and provide guidance for existing synchronous generator conversion decisions
- ID369: Hybrid systems face a complex registration and connection process
- ID398: Need to explore opportunities to enhance efficiency of the GPS negotiation and connection process

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Planning for transition

Adapting planning and market frameworks to support and enable efficient investments to deliver technical attributes into the future.

Assess effectiveness of planning frameworks and methods for evaluating system security and resilience benefits.

- ID146: Need to assess effectiveness of system strength framework for identifying and addressing distribution network impacts of reducing fault levels
- ID277: Difficult to quantify benefits and risks of operational mitigation measures in RIT-T assessments for reactive support
- ID300: Risks of high-impact, low-probability events and benefits of resilience improvement are difficult to quantify in investment tests
- ID314: Consistent assessment approaches and benefit calculation metrics required for voltage management project investment cases
- ID340: Definition, consistent metrics and assessment methodologies required to assess resilience
- ID344: Need to assess suitability of network planning framework for considering system security issues as minimum daytime demand reduces with DPV uptake
- ID414: Limited extent to which assessments of system service requirements can consider outage conditions beyond N-1

Promote scenario planning reflecting the most onerous plausible step changes to enable regret minimisation in decision-making.

- ID083: Scenario planning could more explicitly assess the risk of the sudden or short notice closure of large industrial loads
- ID295: Scenario planning could more explicitly assess the risk of sudden exit or withdrawal of coal units
- ID405: Planning needs to consider potential supply shortages due to increased dependence on gas supplies for last resort generation
- ID421: Planning for reducing minimum demand should consider different scenarios for the growth in load and storage flexibility to soak up excess DPV in the daytime
- ID455: Planning could better consider risks and dependencies associated with project delays
- ID483: Plausible electrification futures to be considered in network and system planning scenarios

Review ability of current arrangements to identify and address emerging issues in time, before they lead to operational constraints.

- ID285: Need for a more coordinated approach to network planning to manage coal exits in a more structured way
- ID289: Transmission development not keeping pace with VRE entry and synchronous exits.
- ID508: Need better-defined processes and responsibilities for addressing small-signal stability issues as the system evolves
- ID513: Need to review planning processes to identify and address voltage issues and opportunities for better coordination for voltage control in a timely manner

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Planning for transition

Adapting planning and market frameworks to support and enable efficient investments to deliver technical attributes into the future.

Shift focus of planning and reform from resource-intensive consideration of incremental actions towards enabling power system transformation.

- ID330: Need for future system architecture consideration to guide and inform policy development and planning
- ID337: Need pathways to capture and consider issues considered out of scope in rule changes
- ID356: More long-term view of UFLS approach needed as incremental measures will be of limited effectiveness as DPV uptake continues
- ID378: Extended, resource-intensive consideration of incremental reforms may not be geared for the pace of transition and extent of transformation required
- ID429: Potentially reduced relevance of the energy market for generators in the future, and increasing importance of system service revenue streams, may result in diminishing value from further reforms to real-time markets
- ID431: Stakeholder perception that reform processes are mainly focussed on incremental changes with limited long-term benefit and not adequately considering fundamental changes needed for transition

Enhance coordination between TNSPs, DNSPs, AEMO, governments and industry to plan and enable transition.

- ID016: Participant and TNSP provision of system strength could be better coordinated and scale-efficient
- ID055: Ongoing need to enhance coordination of generation & transmission development
- ID126: Better-integrated planning from distribution to system level for EV uptake and structural demand shifts
- ID174: Potential for system strength solutions in the distribution network to be better optimised with transmission options
- ID195: Enhanced coordination between DNSP and TNSP planning for better optimised voltage control strategies
- ID282: More centralised reactive power support may be more effective and sufficient than one REZ at a time
- ID296: Better integration between DNSP and AEMO planning for DER uptake
- ID316: Need for consistency across TNSP-DNSP joint planning arrangements in the NEM
- ID484: Coordination, stakeholder engagement and planning for new large loads and electrification
- ID504: Need for enhanced role for inter-jurisdictional agencies in transmission planning at the national level

Understand and embed consumer and social expectations in reforms and transition decisions.

- ID352: Need to establish social licence for transmission developments required for energy transition
- ID381: Need to consider consumer and industry costs to enable affordable transition

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Monitoring and situational awareness

Monitoring data and processes for control room awareness of system state and operational risks.

Establish network and system monitoring for operational visibility, state estimation, understanding power system behaviour and model development

- ID011: Limited understanding and predictability of PFR enablement makes it difficult to model frequency recovery following contingency events.
- ID114: Automated, accurate data collection processes required for post-event analysis
- ID118: Insufficient high-speed monitoring across the NEM with limited streamed PMU data for real-time stability monitoring and operational security assessments
- ID182: Insufficient monitoring and data on changing power factor of system load
- ID265: Communications infrastructure with sufficient bandwidth needed for high-speed data streaming to control rooms and control schemes
- ID280: DNSPs require greater LV network visibility and data to plan and manage an increasingly wide range of conditions, implement control room automation to enhance network flexibility and asset management.
- ID507: Need for increasing monitoring, reporting and analysis of small signal stability as NEM topology, inertia and control systems change

Build real-time and forward-looking stability, adequacy and risk assessment tools for situational awareness and proactive decision-making.

- ID099: Intra-day and longer-term resource adequacy assessment may need to consider availability of hydro and storage stored energy
- ID130: Proactive forward looking control room system and tool development is required for NSPs and AEMO
- ID341: Framework for learnings from incidents and near-misses to feed into situational awareness tools and alarms
- ID423: Look ahead process may be needed for ramping adequacy assessment

Develop weather monitoring infrastructure, coordination, and data frameworks for an increasingly weather-dependent system.

- ID073: Real-time VRE performance monitoring tools and processes may be required
- ID117: Weather observation infrastructure requires uplift to deliver high-resolution data at targeted locations
- ID370: AEMO needs improved access to emergency weather situational awareness notifications produced on a state-by-state basis
- ID372: REZ development will require supporting weather observation infrastructure and data access frameworks for forecasting, management and situational awareness
- ID373: Weather monitoring data is gathered by independent parties that is not shared and used to improve forecasts

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Monitoring and situational awareness

Monitoring data and processes for control room awareness of system state and operational risks.

- ID374: Lack of optionality or redundancy in weather satellite infrastructure
- ID375: Need for more granular weather observation data, specific to VRE generation and major load centres

Explore operational data and communication that could enhance participant understanding and encourage response aligned with system needs.

- ID376: Need to better communicate forecast uncertainty to support operational and market decisions
- ID438: Provision of weather forecasting data could enable better optimised demand response

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Modelling system adequacy

Power system analysis and modelling requirements for planning and system operation.

Identify and resource technical studies, new analysis and modelling tasks required for the transition to new operating conditions.

- ID063: Need to study changing and stability dynamics as grid-forming IBRs displace conventional plant to inform operational practices, protection design and device control specification.
- ID068: Need to update SRAS modelling and procurement to manage fragmented restart process with greater capability requirements
- ID085: Control room tools and processes may need to adapt to evolving load characteristics and behaviour
- ID108: Increasingly complex studies are required in the operational timeframe as part of the outage assessment
- ID139: Responses of VRE generators to FCAS and negative energy prices not fully accounted for in operational forecasting models
- ID165: Need to develop and understand different viable end state configurations for the future power system
- ID183: MVAr forecasts may be required as load characteristics continue to evolve
- ID199: Impact of synchronous generator exit on transfer limits is not well understood
- ID207: Generator or load fault ride through behaviour should be investigated to understand implications for FCAS calculations
- ID266: Further studies required to assess minimum fault level requirements for distribution network protection
- ID271: Insufficient engineering resources and skills available in Australia to undertake the studies necessary for transition
- ID303: Explore improvements to how climate change impacts are captured in long-term resource adequacy assessment
- ID317: Increasing complexity and wider range of conditions to consider in distribution network planning
- ID320: DNSP planning functions not resourced to study emerging technical issues
- ID510: Need to assess NEM mainland minimum inertia requirements under system intact conditions

Uplift power system modelling and analysis capability, improving existing and developing new models, methodologies and approaches.

- ID004: Frequency models are unable to simulate post-contingent frequency outcomes based on generator unit dispatch
- ID151: UFLS is not represented in PSCAD and PSSE models of most NEM regions
- ID206: Control schemes are not represented in PSCAD and PSSE models of most NEM regions
- ID208: Generator models could be improved to better represent RoCoF withstand capabilities
- ID284: Limitations on time-domain PSCAD studies for control system stability assessment

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Modelling system adequacy

Power system analysis and modelling requirements for planning and system operation.

- ID511: Additional metrics besides fault level required to manage system strength and IBR stability

Uplift forecasting models and tools for adequacy assessment and quantifying risk and uncertainty over different timescales.

- ID072: Operational forecasting needs to consider a wider band of scenarios to effectively quantify uncertainty
- ID243: Need for operational forecasting processes to estimate system and locational impact of responsive demand
- ID297: Limited predictability of price responsive movements by load and non-scheduled generation
- ID359: Ability to forecast unconstrained VRE generation restricted by availability of data
- ID362: Operational forecasts need to evolve to incorporate a two-way price responsive market
- ID367: Need a concerted plan to identify and implement operational forecasting tasks and system uplifts necessary to facilitate enable the transition
- ID428: Weather modelling uplift not keeping pace with increasing operational forecasting needs for high-resolution, fast-updating weather models and advanced visualisation

Enhance coordination between planning and operations so adequacy studies reflect operational realities and constraints.

- ID177: Convergence of operational and planning timeframes in rapidly changing power system means planning studies now need to account for emerging operational risks
- ID181: Need to explore how investment tests and planning studies can better reflect real-time operational constraints as the system evolves
- ID348: Industry perception of a disconnect between planning studies and operational challenges
- ID430: Requirement to consider Protected Events, once declared, as credible in planning studies not aligned with operational reality and intention of protected event framework
- ID442: Need to clarify processes for identifying and addressing medium-term issues, falling between short-term operational and longer-term planning

Establish engineering criteria for decision-making with imperfect information, recognising inherent limitations of modelling.

- ID134: Challenge accurately representing the connection queue in dynamic studies over the planning time horizon given different levels of project commitment
- ID190: Inability to identify some power system oscillations, through modelling, prior to their occurrence
- ID291: Inability to model, foresee and identify all potential modes of instability and unknowns in VRE connection studies

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Modelling system adequacy

Power system analysis and modelling requirements for planning and system operation.

- ID397: Additional tolerance margins could be introduced to connection requirements to reduce the onus on complex, highly-specified models
- ID415: Challenging for probabilistic simulation approaches to quantify high-impact, tail event risks, consistently with how often these events occur in practice
- ID495: Inability to undertake PSCAD studies over planning timeframes due to limited access to models for new connections

Establish responsibilities and data governance frameworks for AEMO, NSP and participant access to system and plant models.

- ID075: Participant access to EMT models is limited for confidentiality reasons leading to inefficiencies in connection studies
- ID188: Process improvements may be needed for standardising and pre-approving OEM generator models
- ID191: Need to strengthen governance and management processes for participant provision of data and models to AEMO and NSPs
- ID202: Availability of comprehensive generator models to AEMO and NSPs can be limited by intellectual property constraints
- ID273: Model updates not available for assets built by OEMs that are no longer in business
- ID327: Need better understanding and models for grid-forming IBR response during large faults
- ID339: Performance of existing synchronous plant is not well understood for extreme disturbances
- ID342: Synchronous generator models provided for NER S5.3.9 process may not be fit for assessing plant operation outside normal conditions
- ID349: Need adequate process for connection studies to incorporate future network state given uncertainty over prospective grid reconfigurations
- ID357: Need for consistent models for generators connecting below schedule NER S5.2 size threshold
- ID388: Proprietary generator models produced in specific software packages may not be compatible with future modelling tools
- ID392: Need to clarify roles and responsibilities for power system modelling between TNSPs and AEMO
- ID402: Dependence on proprietary platforms for dynamic simulation potentially restricts long-term flexibility across platforms and approaches
- ID469: Need more accurate models of IBR short circuit performance for protection studies
- ID509: New generators not providing models necessary for small signal stability assessment

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

System management

Ability to operate the power system and manage new operational conditions and requirements as they emerge.

Develop a plan to build operational confidence, processes and tools to manage new operational conditions as they emerge.

- ID170: Need for a comprehensive plan outlining the operational tests and trials to support the transitioning NEM
- ID171: Operational experience needs to be built for emerging system conditions guided by studies and analysis to determine and progress through hold points over time
- ID175: New processes, constraints and procedures will need to be developed for system operation with few or no synchronous units online
- ID491: Need to build experience and processes for new operational voltage management practices required as new VRE enters and synchronous units exit.
- ID499: Limited experience and understanding of system operation with many synchronous condensers

Establish appropriate operating margins and system flexibility to manage increasing complexity and uncertainty.

- ID021: Increasing operational burden and costs of maintaining minimum synchronous generation levels during high DPV periods
- ID053: New and uplifted tools required to better manage increasing complexity of intra-day supply-demand balance
- ID066: Ability to optimise above minimum system strength levels might alleviate inefficient constraints on IBR
- ID149: A means of ensuring minimum level of scheduled capacity may be needed during periods of high passive DER penetration
- ID408: Increasing reliance on fewer synchronous units for directions
- ID411: Limited flexibility to adjust network operating points and protection to meet fluctuating demand
- ID506: Risk of decreasing headroom in the system restricting operability and constraining the pace of transition

Review suitability and scalability of current control room practices with increasing operator demands and complexity.

- ID043: Limited opportunities to schedule maintenance of key system elements due to their criticality for security as margins reduce
- ID071: Increasingly frequent need for operational forecasting support for the control room to explicitly assess adequacy implications of a wider span of weather scenarios
- ID209: Increasingly complex outage planning within and across regions with greater need for explicit limit advice and instructions
- ID434: Risk that increased interventions to commit units for system services leads to unmanageable operational burden

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

System management

Ability to operate the power system and manage new operational conditions and requirements as they emerge.

- ID453: Increasingly difficult to manage VRE and demand variability and uncertainty over different time horizons
- ID476: Need processes to maintain operator situational awareness and understanding with increasing automation in control room operations

Assess ongoing effectiveness of processes for quantifying and managing the technical envelope of the power system and re-evaluate design decisions that increase operational risk.

- ID161: FCAS need assessment and operational processes need to account for DPV disconnection risk and beneficial FFR support
- ID178: Need for greater flexibility in generator recall times for short-term resource adequacy assessment
- ID210: Need to assess suitability of growing reliance on reclassification framework to address increasing operational risk and uncertainty
- ID264: Significant effort required to integrate increasing use of SPSs into the system to ensure they do not interact in undesirable ways
- ID269: Generation and limits within DNSP sub-transmission network may need to be explicitly considered in security constrained dispatch
- ID412: Dynamic assessment across the range of system security requirements may be needed in operational timescales

Build processes for new system management tasks requiring enhanced coordination with DNSPs and new actors.

- ID311: DNSP control rooms require enhanced situational awareness to consider broader range of scenarios
- ID319: DNSPs will need to play a more active role in operational voltage management, requiring coordination with VAr dispatch
- ID323: Enhanced DNSP control room and AEMO-DNSP operational coordination will be required to securely manage and optimise increasing WDR and DER aggregation

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Visibility and understanding

Visibility of new and existing technology for planning and operational decision-making.

Establish data collection and access frameworks on new technology uptake for forecasting, planning and operations.

- ID086: Need for visibility of evolving load categories and consumer behaviours
- ID135: Need visibility of new large load blocks actively being progressed but not yet committed.
- ID234: Need a register and data collection process for new EVs, typical charging locations and EVSE.
- ID487: Opportunity to validate DER register data through comparative data analysis of other sources

Enhance operational visibility and monitoring data access frameworks for estimating DER behaviour and system impact.

- ID104: Need for monitoring data of battery behaviour for model development and operational visibility.
- ID106: Need to improve understanding and define the performance of home battery systems to provide grid services
- ID235: Need for EV monitoring data for modelling typical EV charging profiles and locational impacts
- ID248: Need for consistent operational visibility and monitoring data of 100 kW to 5MW DER
- ID288: Test and develop models for long-term behaviour of DPV systems as they age
- ID424: Improved consistency and availability of DPV generation data required to improve operational forecasts
- ID488: DNSP access to advanced metering infrastructure (AMI) and other DER monitoring data

Develop methods and tools to represent DER locational and aggregated behaviour in power system studies.

- ID041: Need accurate models of DER and load behaviour under different conditions for steady state and dynamic power system studies
- ID119: Need for aggregated models sub 5 MW projects where in close proximity to each other
- ID245: Consistent representation of DER location within physical network topology so impacts can be assessed in studies
- ID260: Need enhanced modelling tools and data for DNSP LV network DER hosting capacity assessment and state estimation utilising available monitoring data

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Visibility and understanding

Visibility of new and existing technology for planning and operational decision-making.

Assess distribution network and system limits with increasing DER uptake and evaluate technical solutions and opportunities.

- ID124: Need to study locational and system wide impact of DER on load.
- ID163: Need to reassess stability limits to account for DPV and other DER tripping impact on contingency sizes
- ID192: Critical need to model impact of increasing DPV on emergency frequency control scheme efficacy
- ID225: Need to assess security and consequence of high-impact, low probability events during increasingly high DPV penetrations periods
- ID422: Need to estimate aggregate impact of the total solar eclipse in July 2028 to inform operational planning for flexibility, security and resilience during the event
- ID452: Improved coordination to study impacts of sector coupling influence on electricity and gas sectors
- ID470: Need to assess impact of increasing DPV on existing feeder protection schemes

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Integration | Performance and capability (1/2)

Performance and capability

Device capability reflecting the changing role and nature of technologies in the power system.

Establish technology performance requirements that minimise customer, network and power system risks.

- ID018: Limited prescription of performance requirements for NSP-operated synchronous condensers
- ID216: Need to assess need for for augmenting VRE performance standards with other capabilities as it becomes the dominant source of generation
- ID227: Need for performance standards reflecting energy and response capabilities of different storage technologies
- ID230: Disturbance withstand, grid support and network connection requirements for EVs and different EV charging arrangements
- ID247: Need for an uplift and consistent disturbance withstand requirements for 100kW to 5 MW generators in the distribution network
- ID283: Inconsistent performance standards for sub-30 MW generators in the distribution network
- ID446: Minimum equipment and networking cyber-security controls required for remote interactions with devices
- ID447: Limited prescription of performance requirements for MNSP-operated plant

Enable last-resort curtailability and fail-safe behaviours for extreme, abnormal system conditions.

- ID033: DPV generation not curtailable even under extreme abnormal system conditions
- ID249: No minimum controllability requirements for 100 kW to 5 MW DER in the distribution network even under extreme conditions
- ID312: Need to specify fail-safes and permissible behaviour for DER and other equipment during communications outages and other contingency scenarios

Adopt device interoperability requirements enabling flexibility, tuning and optimisation, service provision and customer choice.

- ID088: Need device-level interoperability requirements for DER devices and responsive loads to enable integration with site-level, aggregator and DNSP management systems
- ID094: Need for device response performance standards for price responsive DER and load
- ID200: Under-utilisation of potential for adjusting or tuning generator controls in real-time or over the life of the connection
- ID233: Device-level interoperability requirements for EV and charging infrastructure to enable coordinated charging

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Performance and capability

Device capability reflecting the changing role and nature of technologies in the power system.

Establish robust compliance assessment and conformance monitoring over the life of assets

- ID127: Need to improve process for identifying and addressing generator non-compliances for reactive power provision given overlap with NSP voltage control responsibilities
- ID193: Need for stronger compliance monitoring and enforcement of generator performance standards
- ID222: Need for robust governance and compliance arrangements for DER devices, firmware updates and installation
- ID394: Need clearer accountabilities for developers and OEMs in the validation of equipment performance in the field
- ID420: Need to monitor compliance with and effectiveness of new disturbance withstand requirements for DER inverters
- ID477: Enhanced and better defined processes for site testing, commissioning, monitoring and compliance required
- ID492: Need stronger compliance monitoring and enforcement of VRE generator performance and firmware updates

Prioritise standards development and adoption, capitalising on established international standards and norms.

- ID308: Need an international standards based approach to device interoperability to encourage major international vendors and reduce barriers to adoption
- ID315: Need greater collaboration with international standards processes to ensure Australian requirements are embedded
- ID387: Need to carefully consider case for bespoke Australian standards given most OEMs design for major US and EU standards
- ID489: Need national policy direction and industry alignment on device interoperability requirements
- ID490: Opportunity to capitalise on EV standards work in more developed international markets

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Coordination and management

Architecture to enable many new actors and increasing volume and complexity of data exchange.

Define roles and responsibilities for system security and operational coordination for a highly decentralised power system.

- ID048: Power system security responsibilities for a high DER world not clearly defined
- ID237: Aggregator-DNSP-AEMO operational coordination for situational awareness and congestion management
- ID241: Telemetry and visibility requirements for aggregated DER provision of energy, local network and system services
- ID242: Aggregator bids reflecting impact of network limits and prioritisation of other grid support responses
- ID444: Management of nested risks and appropriate responsibilities across different parties in the DER chain

Develop scalable operational data communication architectures, data exchange processes and standards.

- ID399: Review scalability of AEMO power system data ingestion processes as many smaller new entrants connect
- ID400: More standardised approaches required for exchanging operational data and power system information
- ID403: Assess the suitability of operational data communication architecture with many smaller new entrants and aggregators generators connecting
- ID502: Need better coordinated planning for the communication and data exchange systems enabling physical power system operation
- ID503: Long term strategy and standards for operational data exchange required for new forms of participation

Establish system integration and telemetry requirements for management, participation and service provision.

- ID232: Data exchange and system integration requirements for coordinated EV charging
- ID238: Specification of telemetry and visibility requirements for aggregated DER participation
- ID294: Modelling, data exchange and systems integration requirements for DNSPs to implement dynamic operating envelopes
- ID306: Need to consider standards for the coordination of multiple behind-the-meter devices at a single connection point and how responses interact

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Coordination and management

Architecture to enable many new actors and increasing volume and complexity of data exchange.

Design resilient and cyber secure communications architectures and risk management frameworks.

- ID157: Cyber security and communication failure risks associated with plant operators located overseas
- ID304: Communications failure and cyber security risks of internet-based remote interactions with DER devices
- ID417: Cyber security responsibilities for a high DER power system are unclear
- ID498: Understanding and specification of permissible DER behaviour during communication failure and other contingency scenarios
- ID500: Need to understand operational risks and dynamic operating envelope capability under internet and communication outage scenarios

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Enabling participation

Incentivising technology and consumer participation to provide system-level flexibility and services.

Seek to establish consumer social license on need for last-resort control and benefits of management options.

- ID049: Need to establish consumer social license on the need for DER curtailability and consumer benefits of energy management options
- ID464: Understanding of consumer preferences and willingness for devices to be coordinated during scarcity events

Empower and incentivise optimised consumer decisions in a two-way energy system.

- ID046: DER consumer incentives better aligned with network and system needs
- ID091: Low uptake of demand response despite large volume of flexible loads, not keeping pace with increasing need for flexibility
- ID097: Consumer access to usage monitoring and other data to make informed decisions
- ID236: Consumer and aggregator participation pathways for managed EV charging and service classification to enable value-stacking
- ID251: Incentives for upward load flexibility in the daytime to soak up excess DPV generation
- ID419: Need for consumer price signals incentivising flexibility as feed-In-tariffs expire or discontinue

Technically specify the services different technologies can provide and requirements for participation.

- ID065: Clear specification of grid-forming inverter capability and performance requirements
- ID089: Specification of services new large loads can provide and associated grid connection requirements
- ID231: Technical specification of services EVs can provide and associated telemetry requirements
- ID239: Technical specification of the services aggregated DER can provide and associated device and aggregation-level requirements
- ID244: Need to manage potentially conflicting objectives between aggregator participation in market versus local network security
- ID250: Technical specification of the community, network, system and energy services different forms of storage can provide

Develop pathways for VRE, storage, responsive loads and aggregators to participate in the energy market and provide services.

- ID058: Stronger incentives needed for VRE and batteries to provide the range of system services they are capable of providing
- ID229: Incentives and technical requirements for large loads to be scheduled and provide system services
- ID364: Current incentives structures leading to grid scale batteries mainly providing FCAS rather than participating in the energy market

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Enabling participation

Incentivising technology and consumer participation to provide system-level flexibility and services.

- ID433: No incentive for VRE on long-term energy-only PPAs to provide security services

Remove barriers for network storage to provide system-level flexibility and services.

- ID261: Regulatory barriers for TNSPs investing in and utilising grid storage
- ID325: Pathways for sub-5MW and community batteries in the distribution network to provide regulation FCAS

Note: this list of consolidated potential gaps was identified in consultation with stakeholders, it does not necessarily represent AEMO's views, has not been assessed to verify whether the gap exists or is already being addressed and has not been prioritised for magnitude or urgency.

Acronyms and links

Acronyms

Acronym	Name in full
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AMI	Advanced Metering Infrastructure
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEIP	Distributed Energy Integration Program
DER	Distributed Energy Resources
DNSP	Distribution Network Service Provider
DPV	Distributed Photovoltaic
EMT	Electromagnetic Transient
ESB	Energy Security Board
ESOO	Electricity Statement of Opportunities
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
GPS	Generator Performance Standards

Acronym	Name in full
GPS	Generator Performance Standards
GW	Gigawatt
GWh	Gigawatt hour
G-PST	Global Power System Transformation
IBR	Inverter-based Resources
ISP	Integrated System Plan
kW	kilowatt
LV	Low Voltage
MNSP	Market Network Service Provider
MTLI	Minimum Threshold Level of Inertia
MVAr	Mega Volt-amperes reactive
MW	Megawatt
NEM	National Electricity Market
NER	National Electricity Rules
NSCAS	Network Support and Control Ancillary Services
NSP	Network Service Provider
OEM	Original Equipment Manufacturer
PFR	Primary Frequency Response
PMU	Phasor Measurement Unit

Acronym	Name in full
PPA	Power Purchase Agreement
PSCAD	Power System Computer Aided Design
PSSE	Power System Simulator for Engineering
PV	Photovoltaic
REZ	Renewable Energy Zone
RIT-T	Regulatory Investment Test for Transmission
RoCoF	Rate of Change of Frequency
RRO	Retailer Reliability Obligation
SPS	Special Protection Scheme
SRAS	System Restart Ancillary Services
ST PASA	Short Term Projected Assessment of System Adequacy
TNSP	Transmission Network Service Provider
UFLS	Under Frequency Load Shedding
US	United States
VAr	Volt-amperes reactive
VPP	Virtual Power Plant
VRE	Variable Renewable Energy
WDR	Wholesale Demand Response

Index of links

1. AEMO, Operational Conditions Summary, July 2021, available at https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-july-2021-report

2. AEMO, 2022 Integrated System Plan, available at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2022-integrated-system-plan-isp

3. Pacific Energy Institute, A Gambit for the Grid 2025 - a systemic look into the disruptive dynamics underway, April 2021, available at https://pacificenergyinstitute.org/wp-content/uploads/2021/08/A-Gambit-for-Grid-2035-final-version.pdf

4. AEMO, Engineering Framework Gaps and Actions Information Session, October 2021, available at https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/gaps-and-actions-information-session-presentation.pdf?la=en

5. AEMO, Engineering Framework, available at https://aemo.com.au/initiatives/major-programs/engineering-framework

6. AEMO, Integrated System Plan (ISP), available at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp

7. AEMO, Engineering Framework, March 2021 Report, available at https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/nem-engineering-framework-march-2021-report.pdf?la=en

8. CSIRO, CSIRO recruits Australia's top research agencies in global push for low emissions power systems, April 2021, available at https://www.csiro.au/en/news/news-releases/2021/csiro-recruits-australias-top-research-agencies-in-global-push-for-low-emissions-power-systems

9. AEMC, Capacity commitment mechanism for system security and reliability services, available at https://www.aemc.gov.au/rule-changes/capacity-commitment-mechanism-system-security-and-reliability-services

10. AEMC, Efficient management of system strength on the power system, available at https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

11. AEMC, Transmission Planning and Investment Review, available at https://www.aemc.gov.au/market-reviews-advice/transmission-planning-and-investment-review

12. Clean Energy Council, Connections Reform Initiative, available at https://www.cleanenergycouncil.org.au/advocacy-initiatives/energy-transformation

13. AEMO, Real Time Simulator, available at https://aemo.com.au/en/initiatives/trials-and-initiatives/real-time-simulator

14. AEMO, ST PASA Replacement project, available at https://aemo.com.au/en/initiatives/trials-and-initiatives/st-pasa-replacement-project

15. AEMC, Review of the regulatory framework for metering services, February 2021, available at https://www.aemc.gov.au/market-reviews-advice/review-regulatory-framework-metering-services

16. University of New South Wales, Project MATCH, available at http://www.ceem.unsw.edu.au/project-match

17. ARENA, DEIP working groups, available at https://arena.gov.au/knowledge-innovation/distributed-energy-integration-program/

18. AEMO, Application of Advanced Grid-scale Inverters in the NEM, August 2021, available at https://aemo.com.au/-/media/files/initiatives/engineering-framework/2021/application-of-advanced-grid-scale-inverters-in-the-nem.pdf

19. AEMO, Project EDGE, available at https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/der-demonstrations/project-edge

20. ESB, DER Integration Roadmap and Workplan, September 2020, available at https://prod-energycouncil.energy.slicedtech.com.au/sites/prod.energycouncil/files/DER%20Integration%20Roadmap%20and%20Workplan.pdf

For more information

please visit www.aemo.com.au

AUSTRALIAN ENERGY MARKET OPERATOR