2024 Integrated System Plan

For the National Electricity Market

A roadmap for the energy transition

AEMO
AUSTRALIAN ENERGY MARKET OPERATOR

Important notice

Purpose

AEMO publishes the 2024 *Integrated System Plan* (ISP) pursuant to its functions under section 49(2) of the National Electricity Law (which defines AEMO's functions as National Transmission Planner) and its supporting functions under the National Electricity Rules. This publication is generally based on information available to AEMO as at 1 May 2024 unless otherwise indicated.

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Version control

Version	Release date	Changes
1.0	26/6/2024	Initial release.

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

CEO preface

'Journey of Unity: AEMO's Reconciliation Path' ***by Lani Balzan***

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

Following two years of extensive consultation, analysis and review, I am pleased to present AEMO's 2024 *Integrated System Plan* (ISP) for the National Electricity Market (NEM).

The ISP is a plan for investment in the NEM to ensure a reliable and secure power system through Australia's transition to a net zero economy.

This plan has benefitted from the thoughts, input and review of more than 2,100 stakeholders, representing government, industry, consumer and community perspectives.

Australia's energy system is rapidly changing, and the transition is well underway.

After more than half a century, Australia's coal-fired generators are reaching the end of their service life. Up to 90% of the NEM's coal-fired power stations are projected to retire before 2035, and the entire fleet before 2040.

As coal-fired power stations retire, renewable energy connected with transmission and distribution, firmed with storage, and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses through Australia's transition to a net zero economy.

Investment is needed urgently. New generation, storage and firming must be in place before coal power stations retire, and to meet Australia's growing demand for electricity.

Already this decade, 12.5 gigawatts (GW) of new utility-scale generation and 1.3 GW/1.8 gigawatt hours (GWh) of storage has entered the NEM and 490 km of transmission has been built. A further 20 GW of generation and storage, and 2,090 km of transmission, are progressing from planning to delivery.

But risks to the transition are emerging and must be carefully managed.

I would like to acknowledge and thank the many people at AEMO and our stakeholders who created this plan to help Australia navigate through the energy transition.

Daniel Westerman
Chief Executive Officer

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Executive summary

A plan for investment in the energy transition

Australia needs an energy system that delivers secure, reliable and affordable electricity. In the past, we have depended on coal-fired generation. Now, the way Australia generates electricity is changing – from fossil-fuelled to low emissions and renewable energy.

With coal retiring, renewable energy connected with transmission and distribution, firmed with storage and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy.

Governments have set 2050 as the target for a net zero economy, with each jurisdiction having interim emissions and renewable energy targets to meet that deadline. Federal Government policy is a 43% reduction in 2005-level emissions by 2030, with 82% of electricity supplied from renewable sources.

This energy transition, well underway, is by far the biggest transformation of the National Electricity Market (NEM) since it was formed 25 years ago. As well as the shift from coal to firmed renewables and low emissions sources, it will treble capacity to meet future demand, and facilitate a two-way flow of electricity across the networks.

Published every two years, AEMO's *Integrated System Plan* (ISP) is a roadmap for the transition of the NEM power system, with a clear plan for essential infrastructure that will meet future energy needs.

Previous iterations of the ISP outlined an ambitious pace for investment to meet targets. Projects now need to be delivered, as planned. About 90% of the NEM's coal fleet is forecast to retire before 2035 in the most likely future scenario, and the entire fleet before 2040. Replacement investments are needed for Australia's electricity system to remain secure, reliable and affordable.

This ISP is the result of a two-year industry-wide journey with consumer and community representatives, governments, energy market authorities, investors and developers, network planners, industry bodies and science and technology institutions.

The 2024 ISP is a robust plan that calls for urgent investment in generation, storage and transmission to deliver secure, reliable and affordable electricity through the energy transition.

- The energy transition is already well underway. Utility-scale and consumer renewables are breaking records and creating economic opportunities, while tensions arising from these rapid changes are being managed. The ISP is a roadmap to complete the NEM's transition (Part A).
- The ISP's optimal development path sets out the needed generation, firming and transmission to transition to net zero by 2050 through current policy settings. The transmission elements would repay their investment costs, save consumers a further $18.5 billion in avoided costs, and deliver emission reductions now valued at $3.3 billion (Part B).
- Action needed to deliver the transition is urgent, with risks in the market and policy settings, social licence, project delivery and supply chain to be actively monitored and issues quickly addressed (Part C).

AEMO thanks stakeholders for their input into the preparation of the 2024 ISP, and will continue to work with industry, governments and other stakeholders to deliver the energy transition and support a secure, reliable and affordable energy future for Australia.

An essential transition is well underway

The ISP is a roadmap through an energy transition that is already well underway, with renewable generation records being broken, and fossil fuelled generation reaching end of life and retiring.

Australia's electricity system transition is essential.

The NEM must almost triple its capacity to supply energy by 2050 to replace retiring coal capacity and to meet increased electricity consumption as other sectors decarbonise through electrification. Coal-fired generators, the ageing workhorses of Australia's electricity supply, are now retiring. They are less reliable, more difficult to maintain, and less competitive against firmed renewable supply. Households will be more energy efficient and draw considerably from batteries and rooftop solar, and will also need more electricity for appliances and especially for electric vehicles. Businesses and industry will double their grid electricity consumption to serve a growing, decarbonising economy, and for green energy products such as hydrogen.

The shift to renewables is well underway.

Renewables accounted for almost 40% of the total electricity delivered through the NEM in 2023, momentarily reaching up to a 72.1% share on 24 October 2023. Rooftop solar alone contributed more electricity to the grid in the first quarter of 2024 (13%) than did grid-scale solar, wind, hydro or gas. At the same time, investments in grid-scale renewables, connecting transmission and firming technologies continue to gain momentum.

All NEM governments are supporting the transition.

The Federal Government has expanded the Capacity Investment Scheme, launched a Future Gas Strategy and funded the Future Made in Australia plan. The Australian Capital Territory has emissions reduction targets in place. New South Wales' Electricity Infrastructure Roadmap is underpinned by its renewable energy zones (REZs). Queensland's SuperGrid and pumped hydro energy storage feature in its Energy and Jobs Plan. South Australia is pursuing a Hydrogen Jobs Plan, and Tasmania has long had strong renewable energy targets. Victoria has set its Transmission Investment Framework, Renewable Energy and Storage Targets, including explicit offshore wind development targets, and Gas Substitution Roadmap.

Consumers will play a major role.

Many households and businesses are taking steps to shape their own energy futures. They are adopting innovative ways to reduce and manage their demand, investing in what the industry collectively refers to as 'consumer energy resources' (solar systems, batteries, electric vehicles), and contributing to virtual power plants (VPPs) to bring them together. These innovations and resources – supported by distribution, system operators and third parties – are playing a transformative role in the energy transition and will be a valuable resource in the future energy system. If they are well coordinated ('orchestrated'), they help deliver reliable and secure energy, offset the need for grid-scale investment, and reduce costs for consumers as well as energy sector emissions. The ISP assumes this orchestration will occur at varying levels across each of AEMO's scenarios.

Distribution will also play a major role.

In addition to connecting consumers, distribution networks will host consumer energy resources (CER) and some utility-scale renewable and storage projects – facilitating coordinated two-way flow of electricity between grids. The ISP assumes upgrades and other investments needed to enable distribution networks and their operation will occur through other mechanisms, ultimately facilitating forecasted levels of consumer energy resources and their coordination.

The transition will have undeniable benefits.

Lower cost, lower emission renewables will offer homes and businesses the electricity they need, with greater insulation from international price shocks that can put unwelcome pressure on the cost of living. NEM regions are forecast to need over 60,000 people in jobs to build and maintain energy infrastructure over the next 20 years. As both global trade and Australian policies press for low-emission products, new opportunities may emerge in hydrogen, data services, agriculture, aluminium and steel production and minerals processing.

But the transition is complex, with four inherent tensions to be managed.

The NEM must operate safely and reliably today while being refitted steadily but surely for tomorrow. It must integrate new technologies piece by piece while keeping the whole system stable. It must deliver reliable and affordable electricity for the population, while addressing the concerns of people that host new infrastructure. And Australia must see its transition through as the rest of the world also races to decarbonise.

Determining the path for the future

The ISP draws on a comprehensive set of inputs.

AEMO consulted extensively to prepare the inputs to the ISP, which were published in the 2023 *Inputs, Assumptions and Scenarios Report*. These inputs include all relevant federal and state government policies for emissions reduction (now updated to include an explicit value of emission reduction), demand-side actions (including significant consumer investment in their own energy systems, energy efficiency, electrification of transport, heating, cooling and cooking, hydrogen industry development), costs for new transmission, generation and storage technologies, and inclusion of projects already underway for delivery.

AEMO's integrated modelling seeks the optimal path.

The ISP modelling approach applies the inputs to four separate yet integrated analytical models to find the optimal mix of generation, storage and transmission. The objective is to determine an 'optimal development path' (ODP) that will meet the NEM power system's reliability and security needs, that is aligned with government emissions reduction and other policies, doing so at the lowest long-run cost to consumers. The ODP sets out the optimal size, place and timing for the NEM's future assets. AEMO considered over 1,000 potential development paths in all, narrowing them down to the 25 ‘candidate development paths’ (CDPs), including the development path of generation development with no additional transmission at all.

The ISP adopts a scenario-based planning approach to inform the most robust forward plan.

Candidate paths were tested against three future scenarios, through to 2050:

- *Step Change*, which fulfils Australia’s emission reduction commitments in a growing economy,
- *Progressive Change*, which reflects slower economic growth and energy investment with economic and international factors placing industrial demands at greater risk and slower decarbonisation action beyond current commitments, and
- *Green Energy Exports*, which sees very strong industrial decarbonisation and low-emission energy exports.

All three scenarios acknowledge that coal power stations will continue to retire over the coming years, and all three scenarios align with government net zero commitments.

After extensive consultation, AEMO assigned likelihoods of 43% for *Step Change*, 42% for the similar *Progressive Change* and 15% for *Green Energy Exports*. This took in the views of over 30 expert panellists representing industry, government, network service providers, researchers, academics, and consumers. *Step Change* therefore is the ISP’s most likely scenario.

The leading candidate paths were tested against changes in scenario assumptions.

Some of these tests looked at greater electricity demand in the NEM and other influences which would increase the benefits of transmission (more rapid industry decarbonisation, faster coal retirements, reduced energy efficiency, lower orchestration of consumer energy resources, industry demand enabled by green energy). Others considered the impact of slower delivery of infrastructure, and other influences which would reduce the benefits of transmission (higher costs of capital, more constrained supply chains, weaker host community acceptance for new infrastructure).

The optimal development path is the lowest-cost, resilient, pragmatic path to the NEM’s energy future of net zero by 2050, while also meeting government policies.

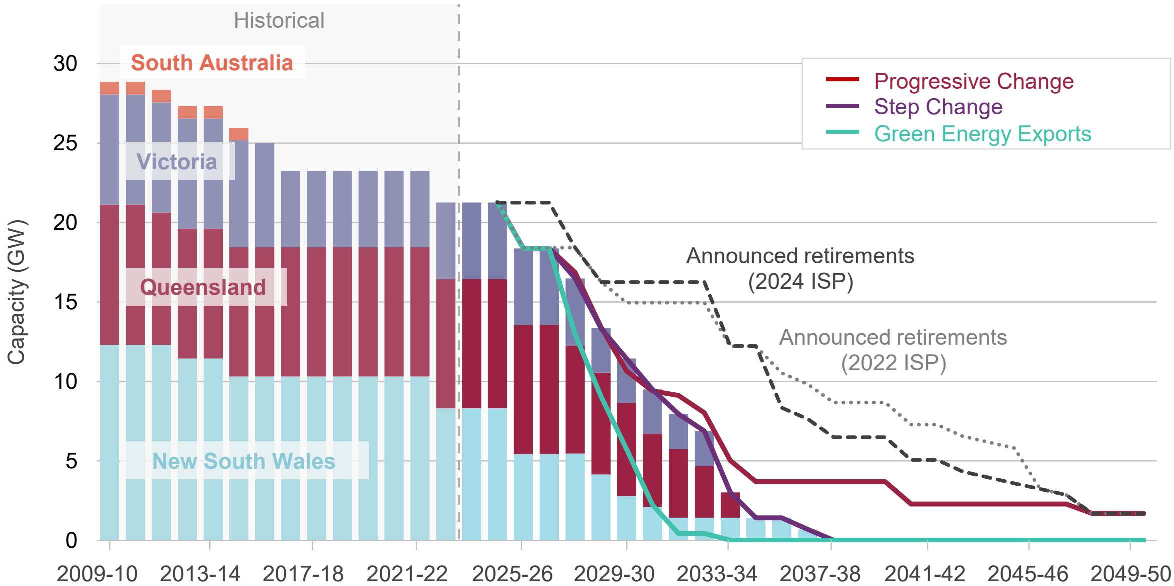
The potential development paths included different balances between generation, storage and transmission. AEMO has consulted extensively to prepare the inputs, assumptions and scenarios used to develop the optimal development path. Alternative paths result in higher consumer costs, and many substantially so, and demonstrate less robustness to the uncertainties anticipated in this transition. Future ISPs will continue to respond to material changes in technologies, costs and policies.

Coal power stations are rapidly retiring

Ten large coal-fired power stations have closed since Munmorah ceased operations in 2012, the latest being Liddell in April 2023. Retirements have been announced for all but one of the remaining fleet, with about half by 2035 and the rest by 2051, continuing the steady rate of retirement since 2012: see Figure 1.

However, to meet government policy objectives, the ISP forecasts that the remaining coal fleet will close two to three times faster than those announcements. In *Step Change*, the most likely scenario, about 90% of the current 21 gigawatts (GW) of coal capacity would retire by 2034-35, and all before 2040. Even in *Progressive Change*, only 4 GW of coal generation would remain in 2034-35.

Figure 1 Coal capacity, NEM (GW, 2009-10 to 2049-50)



Coal retirements are occurring faster than announced dates, and may occur even faster than these forecasts. Ownership has become less attractive, with higher operating costs, reduced fuel security, high maintenance costs and greater competition from renewable energy in the wholesale market. Coal power station owners are only required to give three and a half years' notice of a closure, which gives very little time for the NEM to react. Replacement capacity is needed in advance of these closures to ensure reliability is not compromised for energy consumers. A new orderly exit mechanism is being designed under the guidance of energy ministers to act as a backup while investment in clean technologies and transmission networks continue as fast as possible.

Generation and storage investments in the optimal development path

With coal retiring, renewable energy connected with transmission and distribution, firmed with storage and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy:

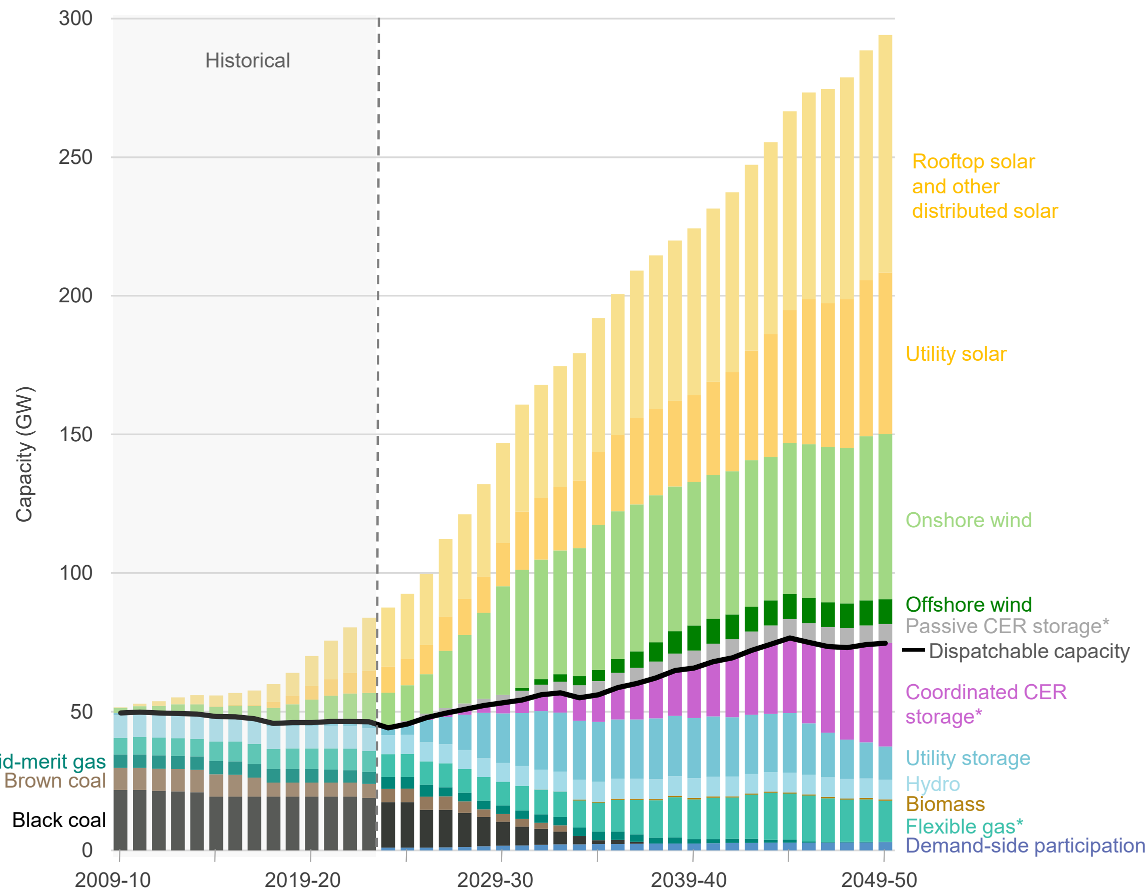
- low-cost renewable energy will take advantage of the abundant wind, solar and hydro resources that Australia has to offer,
- firming technology like pumped hydro, batteries, and gas-powered generation will smooth out the peaks and fill in the gaps from that variable renewable energy,

- new transmission and modernised distribution networks will connect these new and diverse low-cost sources of generation to our towns, cities and industry, and
- upgraded power systems will be capable of running, at times, entirely on renewable energy.

AEMO has selected an optimal development path (ODP) that sets out the capacity of new grid-scale generation, firming, storage and transmission needed in the NEM through to 2050.

The resulting NEM capacity through to 2050 in the *Step Change* scenario is shown in Figure 2 below.

Figure 2 Capacity, NEM (GW, 2009-10 to 2049-50, *Step Change*)



Notes: "Flexible gas" includes gas-powered generation and potential hydrogen capacity.
"CER storage" means consumer energy resources such as batteries and electric vehicles.
Projections for "Rooftop solar and other distributed solar" and "CER storage" are forecast based on unit costs, consumer trends and assumptions about payments received to participate in the electricity market.

Under the forecasts for the *Step Change* scenario, the ODP calls for investment that would:

- **Triple grid-scale variable renewable energy (VRE) by 2030, and increase it six-fold by 2050**.
  - About 6 GW of capacity would need to be added every year, compared to the current rate of around 3 to 4 GW. Wind would dominate installations through to 2030, complementing installations of rooftop solar systems, and by 2050 grid-scale solar capacity would be 58 GW and wind 69 GW.

- **Focus grid-scale generation in REZs,** selected to access quality renewable resources, existing and planned transmission, and a skilled workforce. REZs will support better grid reliability and security; reduce transmission, connection and operation costs for individual assets; and promote regional expertise and employment at scale.
- **Almost quadruple the firming capacity** from sources alternative to coal that can respond to a dispatch signal, using grid-scale batteries, pumped hydro and other hydro, coordinated consumer energy resources as VPPs, and gas-powered generation. This includes 49 GW/ 646 gigawatt hours (GWh) of dispatchable storage, as well as 15 GW of flexible gas.
- **Support a forecast four-fold increase in rooftop solar capacity** reaching 72 GW by 2050, highlighting the impactful role of consumer energy resources in the energy transition.
- **Leverage system security services and operational approaches** to ensure that the NEM stays reliable and secure even as the renewable share of generation approaches 100%, as identified in AEMO's *Engineering Roadmap to 100% Renewables*.

Transmission investments in the optimal development path

Transmission connects diverse generation and storage to our towns, cities and industry. It brings electricity where it is needed, when it is needed, and improves the power system's resilience. Transmission planners make the most of the existing network before considering new projects, for example working with distribution planners to use capacity in the lower-voltage network, and by using real-time weather monitoring to maximise line use. In many cases, new transmission will complete a network that can take advantage of the NEM's geographic diversity, allow REZs to transfer their future energy to where it is needed, and maintain a secure and reliable power system.

Consistent with previous ISPs, close to 10,000 km of new transmission would be needed by 2050 under the *Step Change* and *Progressive Change* scenarios. Transmission investments have also been tested against the more transformational *Green Energy Exports*, which forecasts over twice as much transmission, delivered at a much faster pace, should that economic growth and export scenario be pursued.

The ODP contains largely the same major transmission projects as in the 2022 ISP. Five committed and anticipated projects are well underway for delivery. Five previously actionable projects remain actionable and are advancing, and seven more projects have now progressed to actionable status. These projects are now included as actionable with recognition of additional time and engagement associated with the initial investigation of these projects.

AEMO recognises the impact that new transmission infrastructure has on landholders and their communities, which is why there is a clear need for earlier engagement to allow for more coordinated and effective consultation.

Table 1 and Figure 3 on the following pages set out the:

- **committed and anticipated transmission** projects already underway,
- **actionable projects**, which should be delivered urgently, and
- **future ISP projects**, which may include the need for the transmission network service providers (TNSPs) to undertake preparatory activities.

Benefits of the optimal development path

The selected ODP sets out the capacity of new grid-scale generation, firming, storage and transmission needed in the NEM through to 2050.

It would:

- guide $142 billion in upfront capital investment needed for essential electricity infrastructure, to sustain and grow Australia's $2 trillion annual economy,
- reduce costs for consumers by delivering transmission that would repay its $16 billion investment cost, save consumers a further $18.5 billion in avoided costs, and deliver emissions reductions valued at a further $3.3 billion,
- connect emerging areas of renewable generation to regional industries and to urban businesses and households,
- firm up variable renewable energy with batteries, hydro and gas-powered powered generation,
- create new economic and job opportunities, particularly in regional areas, and
- add energy self-reliance and insulation from global shocks to the price or supply of fossil fuels.

The annualised capital cost of all utility-scale generation, storage, firming and transmission infrastructure in the ODP has a present value of $122 billion (*Step Change* scenario to 2050)[1]. The equivalent upfront capital cost has a present value of $142 billion (as some technical life remains after 2050 for the long-lived assets). Of the annualised cost, transmission projects amount to $16 billion[2] or 13% of the total.

Without these projects, consumers would pay more for electricity.

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[1] This value includes transmission augmentation, and utility-scale generation and storage capex, and does not include the cost of commissioned, committed or anticipated projects, consumer energy resources or distribution network upgrades. The value increased from $121 billion in the Draft 2024 ISP to $122 billion due to modelling changes listed on page 19.

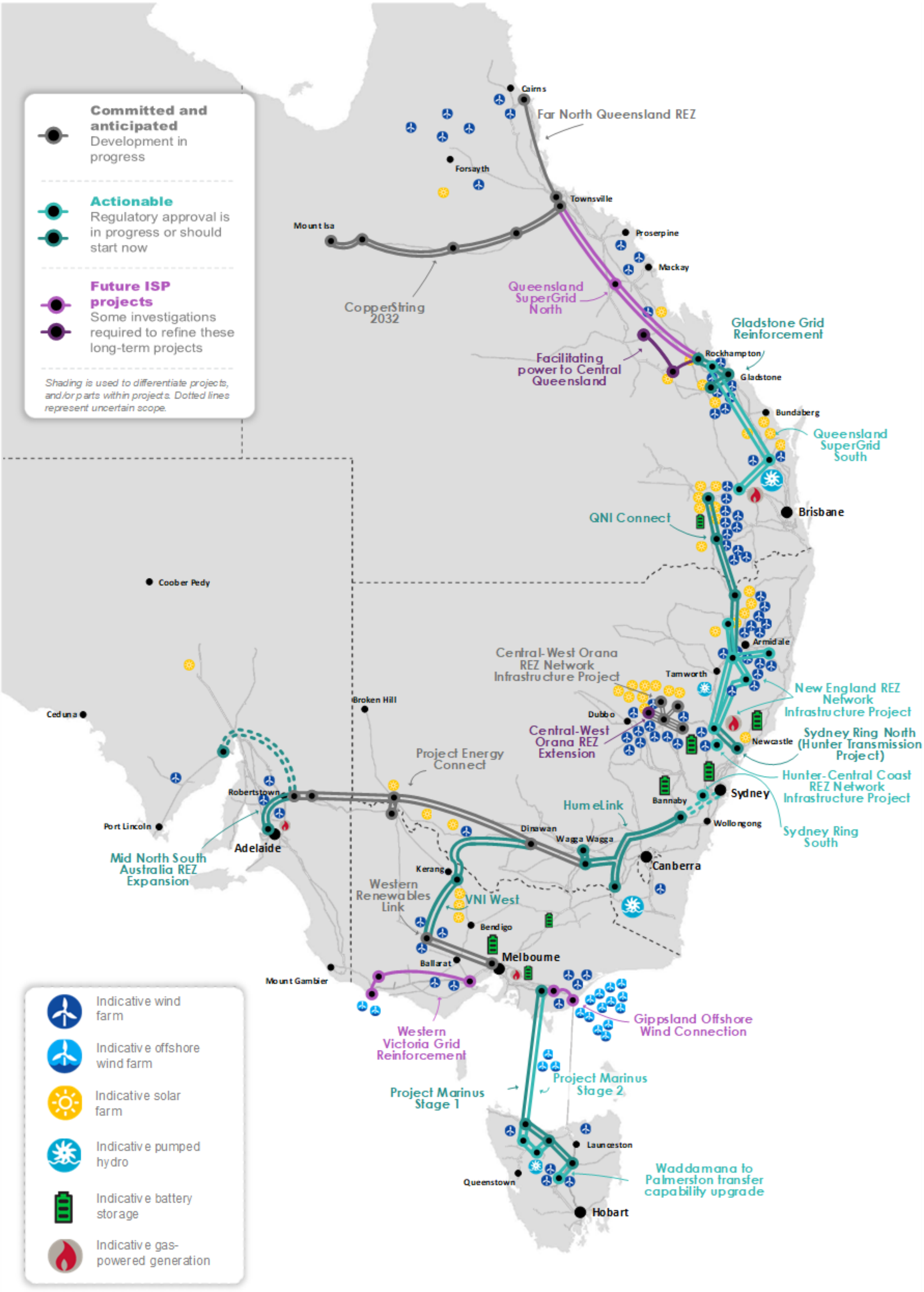
[2] This value is the net present value of capital costs for transmission augmentation up to 2049-50 only, and does not include the cost of commissioned, committed or anticipated projects.

Table 1 Network projects in the 2024 ISP optimal development path

Committed and anticipated ISP projects		In service timing advised by proponent	Full capacity timing advised by proponent[A]
Far North Queensland REZ		June 2024	June 2024
Project EnergyConnect		Stage 1: September 2024 Stage 2: May 2026	Stage 1: December 2024 Stage 2: July 2027
Western Renewables Link (uprated)[B]		July 2027	July 2027
Central West Orana REZ Network Infrastructure Project		January 2028	August 2028
CopperString 2032		June 2029	June 2029
Already actionable projects *(confirmed in this ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent[A]**
HumeLink	ISP	Northern: July 2026 Southern: December 2026	Northern: July 2026 Southern: December 2026
Sydney Ring North (Hunter Transmission Project)	NSW[C]	December 2028	December 2028
New England REZ Network Infrastructure Project	NSW[C]	Part 1: June 2031 Part 2: June 2033	Part 1: June 2031 Part 2: June 2033
Victoria – New South Wales Interconnector West (VNI West)	ISP	December 2028	December 2029
Project Marinus[D]	ISP	Stage 1: June 2030 Stage 2: June 2032	Stage 1: December 2030 Stage 2: December 2032
Newly actionable projects *(as identified in this ISP)*	**Actionable framework**	**Earliest feasible in service timing**	**Earliest feasible full capacity timing[A]**
Hunter-Central Coast REZ Network Infrastructure project	NSW[C]	December 2027	December 2027
Sydney Ring South	ISP	September 2028	September 2028
Gladstone Grid Reinforcement	QLD[E]	March 2029	March 2029
Mid North South Australia REZ Expansion	ISP	July 2029	July 2029
Waddamana to Palmerston transfer capability upgrade	ISP	July 2029	July 2029
Queensland SuperGrid South	QLD[E]	September 2031	September 2031
Queensland – New South Wales Interconnector (QNI Connect)	ISP	April 2032	March 2033
Future ISP projects			
New South Wales	Central West Orana REZ Expansion, Cooma-Monaro REZ Expansion.		
Queensland	Darling Downs REZ Expansion, Facilitating Power to Central Queensland, North Queensland Energy Hub Expansion, Queensland SuperGrid North[E].		
South Australia	Mid North South Australia REZ Extension.		
Tasmania	North West Tasmania REZ Expansion, Central Highlands REZ extension.		
Victoria	Western Victoria Grid Reinforcement, Eastern Victoria Grid Reinforcement, Gippsland Offshore Wind Connection.		

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. The scope of this project, which will unlock renewable energy resources, reduce network congestion, and improve utilisation of existing assets in western parts of Victoria, was updated as an outcome of the VNI West options analysis, resulting in a higher capacity and harnessing 1,460 megawatts (MW) of renewable capacity rather than the original design of 600 MW.
C. These projects will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.
D. Project Marinus is a single actionable ISP project without decision rules.
E. These projects will progress under the *Energy (Renewable Transformation and Jobs) Act 2024* (Qld) rather than the ISP framework.

Figure 3 Transmission projects in the optimal development path



This map shows indicative new generation and storage in 2040, and transmission projects that include new transmission lines, increase capacity by 500 MW or more, and are required in all scenarios by 2050.

Risks to delivery of the ODP and to the energy transition

AEMO has identified the ODP as the most efficient path to maintain reliable and secure electricity supply as coal retires and to deliver the energy system needed for a net zero economy. Any delay to delivery of the ODP increases the likelihood of interruptions and higher costs.

While significant progress is being made, challenges and risks are already being experienced. Unplanned coal generator outages are becoming more common as the fleet ages. Planned projects are not progressing as expected, due to the time needed for approval processes, investment decision uncertainty, cost pressures, social licence issues, supply chain issues and workforce shortages.

The possibility that replacement generation is not available when coal power stations retire is real and growing, and a risk that must be avoided. The sooner firmed renewables are connected, the more secure the energy transition will be.

Risks that market and policy settings are not yet ready for coal's retirement

Four sets of market and policy settings need to be in place if the NEM is to keep the energy transition on track, and in particular be ready for coal generator retirements.

Risk of insufficient infrastructure investment

The energy transition depends on timely investment decisions, which are hampered by uncertainty. Delays and uncertainties in energy regulation, environmental and planning approvals increase the complexity faced by electricity infrastructure investors and add to the risk of project delay. As well, the need for higher levels of flexible gas capacity will challenge Australia's existing gas supply infrastructure.

Several government initiatives aim to reduce these uncertainties. AEMO strongly supports further market reforms that will expedite investment and effectively balance timely investment with assessment rigour across all forms of infrastructure.

Even if there is greater market certainty, the need for investment does not guarantee that investment will flow. The levels of investment in electricity infrastructure required will remain high for approximately 15 years, and Australia is competing for global investment.

Risk of early coal retirements

While almost all owners of coal generators have announced their long-term retirement plans, they are only required to give three and a half years' notice of a closure. This leaves the NEM very little time to respond if replacement investments are not planned and delivered. Closures with short notice increase the risk of near-term reliability challenges and price shocks for consumers, and further accelerate the need for new generation. These risks are best mitigated through agreed latest closure timeframes and delivery of the planned investment in generation capacity.

Risk that markets and power system operations are not yet ready for 100% renewables

Renewable generation is being installed rapidly, but the NEM's energy markets, networks and operations must evolve to be ready for very high penetrations of renewable energy. Continued action is needed to make sure that system services, resource adequacy and operational capability are in place in time for coal retirements.

The Australian Energy Market Commission (AEMC) has released a system security transition plan as part of a suite of rule changes aimed at addressing these risks. AEMO also continues to work with governments, market bodies and industry on the technical requirements for a secure power system capable of operating at 100% renewables, and subsequent evolution of market frameworks and settings to deliver those requirements in both investment and operational timeframes.

Risk that consumer energy resources are not adequately integrated into grid operations

Many households and businesses are adopting innovative ways to reduce and manage their demand, investing in consumer energy resources (CER), and contributing to VPPs. As more consumers do so, and if they allow these resources to be well coordinated, they will help deliver more reliable and secure energy, at lower cost for all consumers, and contribute to lower emissions. In the ISP this is assumed to occur. Without effective coordination of consumer batteries, around $4.1 billion of additional grid-scale investment would be needed, increasing the costs that are reflected in consumer bills.

NEM policy, market, and system settings could secure this potential for CER, to ensure they can serve consumer energy needs without exacerbating any system security risks. The networks need to maintain safe operating margins; information needs to be shared across devices in a safe, consistent manner; and devices need to respond to market signals visibly and predictably.

Ultimately, consumers who own these systems will choose how they are used. They will need transparency and material benefits to ensure they support, with confidence, their systems being coordinated with the power system.

AEMO will continue working with governments, market bodies and consumer groups for these benefits to be realised.

Risks that social licence and supply chains are not secured for project delivery

The policy, market and operational settings noted above are largely in the hands of governments and the energy industry. Even if they are in place, the ODP and the energy transition would not be guaranteed.

To deliver the transition on time, industry and governments must work together with communities throughout the NEM to ensure there is the needed social acceptance, with global supply chain partners to secure equipment and materials, and with governments in Australia to secure the workforce needed.

Risk that social licence for the energy transition is not being earned

Community acceptance or social licence is needed for new infrastructure development, for the ‘orchestration’ of consumer-owned energy resources, and for national investment in the energy transition itself. Local communities are concerned with a range of community, social, cultural, environmental and economic values. NEM affordability and reliablity is essential for community acceptance on each of these dimensions. AEMO recognises the importance of early engagement with communities who will host infrastructure, and has extended the time required for this engagement when considering which projects should be actioned in this ISP.

Energy institutions, developers and communities are working hard to build the relationships of trust that underpin social licence. Their experience is being captured by the National Guidelines for Social Licence for Transmission, the Australian Energy Infrastructure Commissioner’s review of community engagement practices, the Victorian Transmission Investment Framework (VTIF), and the New South Wales First Nations Guidelines for consultation and negotiation with local Aboriginal communities, among other initiatives. These and like initiatives are critical to building the trust-based relationships needed for the energy transition.

AEMO is working with stakeholders to better understand new and diverse perspectives, to develop new analyses that account for levels of social acceptance for future ISPs.

Risk that critical energy assets and skilled workforces are not being secured

On top of record-breaking investment in consumer energy resources, the energy transition depends on thousands of grid-scale generators and batteries, high voltage transmission lines and cables, synchronous condensers and transformers. Australia needs to be able to access these assets over the next 15 years in particular. Countries around the world are competing for these assets as they transform their power systems in the global race to net zero.

Similarly, a large and skilled workforce is needed for the enormous task ahead. The demand for energy sector workers is forecast to grow from approximately 32,000 people in 2024 to a peak of over 60,000 across the horizon to 2050, in the *Step Change* scenario. This workforce is needed across every discipline, not just engineering.

Early investment will mitigate against supply chain risks in future, retain Australia’s spot in global queues for essential equipment and materials, and ensure the NEM is able to respond to future market and climate events.

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AEMO thanks all stakeholders for their input into the preparation of the 2024 ISP. AEMO will continue to work with all industry, governments, consumer representatives and other stakeholders to deliver the energy transition and ensure a secure, reliable, affordable energy future for Australia.

Key changes from the Draft 2024 ISP

The 2024 ISP sets out how AEMO has identified the ODP for the NEM. The ISP is adjusted as economic, physical and policy environments change. AEMO notes the following key differences between the Draft 2024 ISP and this final 2024 ISP.

Greater recognition of the role of consumer resources and distribution networks

- **Adding 'distribution networks' to where renewable resources are connected**. In so doing, the ISP explicitly recognises CER as a significant resource in the transition and the contribution it makes, while also calling out more explicitly the input assumptions regarding orchestration and alternative costs if this does not occur to the level assumed.

Updates to inputs and assumptions used to analyse the ODP

- **Additional renewable energy and emissions reduction policies have been included**, with all scenarios now including updated targets for New South Wales and Queensland, the Federal Government's expanded Capacity Investment Scheme, and the application of Energy Ministers' value of greenhouse gas emissions reduction.
- **Updates to transmission projects,** including updated timing for several committed and anticipated transmission projects listed in Table 1, and new smaller options for Sydney Ring South and Mid North South Australia REZ Expansion.
- **490 MW of additional generation and 3.7 GW/10.8 GWh of storage have progressed** sufficiently to be considered committed or anticipated, and so are included in the ISP in all futures.

Further analysis to inform the ODP

- **Sensitivity analysis exploring the impact of low CER orchestratio**n, finding that $4.1 billion of additional grid-scale investment would be needed without effective coordination of consumer batteries.
- **Analysis considering the capability of gas infrastructure** to back up renewable supply during long periods of dark and still weather, estimating $230 million for fuel and fuel storage – potentially including hydrogen, green gases and other liquid fuels.

Changes to the speed or scale of the ODP

- **None** – AEMO continues to find that the entire coal fleet is retired by 2038 in *Step Change*, and that there is a need for 6 GW of new renewable energy per year until 2030.

Changes to investment in the ODP

- **Net market benefits of transmission investment have increased to $22 billion**. Benefits due to avoided costs grew from $17 billion in the Draft 2024 ISP to $18.5 billion, and a further new benefit of $3.3 billion was calculated due to the application of the Energy Ministers' value of greenhouse gas emissions reduction.
- **Five transmission projects have progressed to actionable status, in addition to the two projects identified as actionable in the Draft 2024 ISP** – Sydney Ring South, Mid North South Australia REZ Expansion, Waddamana to Palmerston Transfer Capability Upgrade, Hunter-Central Coast REZ Network Infrastructure project and QNI Connect. The first two have become actionable due to the identification of smaller options, the third has been brought forward slightly, the fourth was identified after closer investigations through joint planning, and the fifth needs to start earlier to allow for more coordinated and effective community consultation.

PART A

The ISP is a roadmap through the energy transition

Part A: The ISP is a roadmap through the energy transition

As Australia's coal-fired generators retire after decades of service, renewable energy connected with transmission and distribution, firmed with storage and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses.

In this Part A:

- **Section 1 – Australia's two-part energy transition will deliver significant benefits.** The National Electricity Market (NEM) is a complex system facing two challenges at the same time: the retirement of coal-fired generation, and the switch to electricity for our future transport, heating, cooling, cooking and industrial needs. If successful, the transition will bring multiple benefits.
- **Section 2 – The transition is well underway.** Consumers, investors and governments are rapidly turning to renewable energy. There are tensions that risk the pace of transition, but these tensions are being managed and the direction is clear.
- **Section 3 – The *Integrated System Plan* (ISP) navigates the energy transition.** The ISP is a roadmap for the NEM power system, prepared in the long-term interests of electricity consumers. Through an exhaustive process, the ISP identifies an optimal development path (ODP) to secure reliable and affordable power for consumers and to meet emission reduction targets.

Part B follows to set out the generation, transmission, storage, gas and system services that would best meet the NEM's needs. Part C explores the real and potential risks faced by the ODP and the broader energy transition.

1 The two-part energy transition and its benefits

Electricity is indispensable to our homes and businesses, and to the transport and communication networks we all rely on. All must have secure, reliable and affordable supply, and be confident it will be there when they need it.

The NEM has delivered that electricity for 25 years. It must now do so while coal generators are retiring, while electricity consumption is forecast to almost double, and in a way that contributes to our national and state emission reduction targets.

This section sets out how and why the NEM is being transformed:

1.1 **The NEM is switching to renewable energy.** Coal generators are retiring. The ISP finds that the lowest-cost replacement is renewables, connected with transmission and distribution, firmed with storage, and backed up by gas-powered generation.

1.2 **The NEM will need to almost triple its generating capacity,** as variable renewable generation typically operates at less than full capacity. At the same time, industry, business and households will need more electricity as they switch from fuel and gas.

1.3 **There will be significant, diverse benefits.** These span greater insulation from international shocks, new jobs particularly in regional and rural areas, and lower emissions.

Section 2 follows to describe how the transition is well underway.

1.1 The essential shift to renewable energy

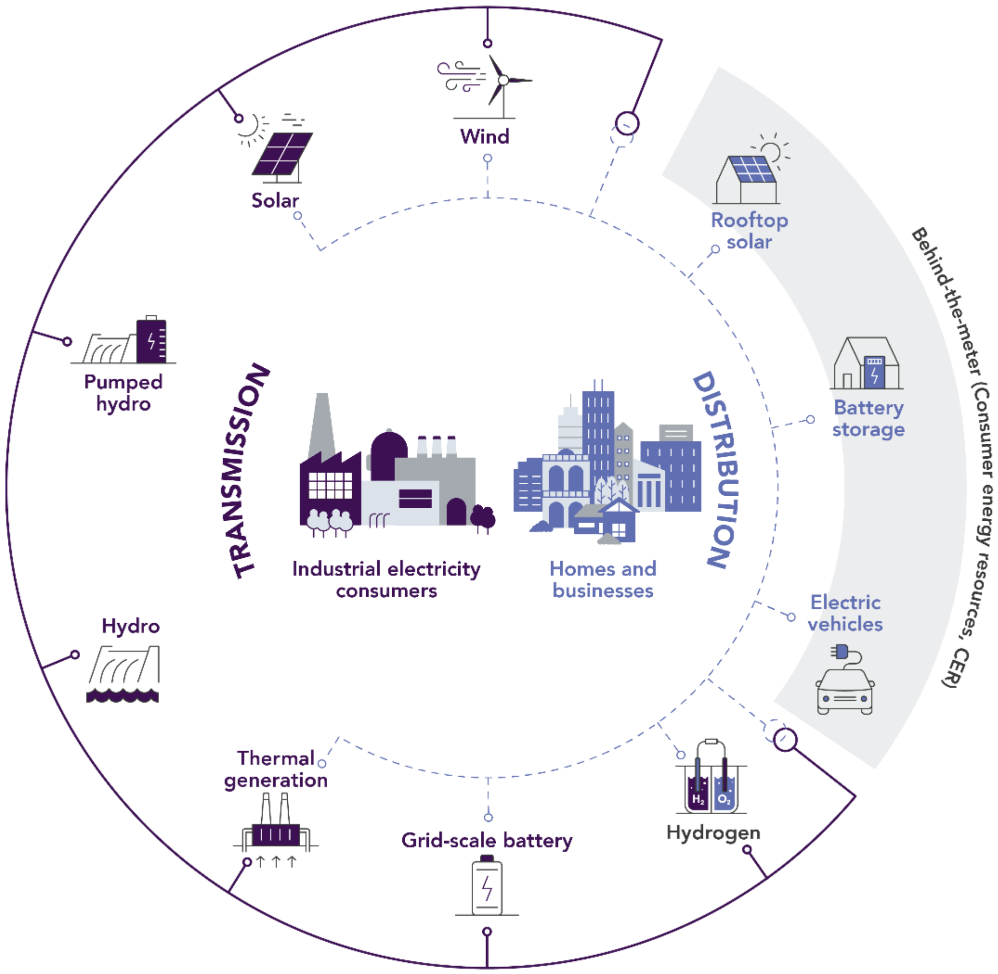
We rely on a complex power system

The NEM is an intricate system of systems, with regulatory, market, policy and commercial parts. At its centre is the physical system that delivers power when and where we need it.

Three types of consumers (heavy industry, business and households) have different needs when it comes to electricity. Figure 4 overleaf illustrates how the NEM meets those needs through generation, storage and transmission, and by supporting distribution and consumers' own energy resources.

Heavy industry like aluminium or iron smelters typically draw their electricity directly from the transmission grid. Business and household consumers have traditionally drawn their electricity from the distribution grid. Now, they are investing in their own 'consumer energy resources' (CER, that is, rooftop solar, batteries and electric vehicles (EVs)). Some EVs may themselves be able to discharge electricity for direct use, to household batteries, or back into the grid.

Figure 4 A power system with both grid and behind-the-meter energy supply



An energy transition is essential

Coal-fired generation has dominated Australia's electricity supply for generations. However, these workhorses are now ageing and becoming less and less reliable, more expensive and difficult to maintain, and less competitive against renewable electricity supply.

In the past decade alone, 10 major coal-fired power stations have retired, starting with Munmorah in 2012 through to Liddell in 2023. Reliability risks were exposed in June 2022, when 3 gigawatts (GW) of coal-fired generation was out of action – 13% of the NEM's coal capacity.

Households, business, industry and governments are also switching to electricity for their transport and energy needs, relying on the power sector to support their low-emission commitments and aspirations.

As coal retires it is being replaced by low-cost renewables, connected by transmission and distribution, firmed with storage and backed up by gas. At the same time, consumers continue to invest in rooftop solar, with EVs and battery systems now becoming more common.

Renewables are not a like-for-like replacement for coal in many respects. A number of different investments are needed for a transition that maximises benefits to energy consumers:

- Low-cost solar and wind generation will take advantage of Australia's abundant solar and wind resources.
- Renewable energy zones (REZs) are being developed across the NEM to tap into high-quality wind and solar areas using economies of scale and providing new employment opportunities.
- Transmission networks, existing and new, will connect the renewable energy from REZs through to consumers, bringing low-cost electrons to heavy industry, businesses and households.
- Firming technologies will smooth out the variations in renewable supply: batteries for everyday variations, and strategic pumped hydro projects for longer-term and seasonal variations.
- Gas-powered generation will provide necessary back up with critical power supply when it is needed, both for 'renewable droughts' of 'dark and still' conditions, or to meet peaks in consumer demand.
- Batteries, gas and other network investments will deliver essential power system services to maintain grid security and stability.
- Rooftop solar and local batteries, connected to distribution networks, will generate consumers' own electricity, store it for when they need it, and supply the excess back to the grid.

Doing all this at once is complex. Across the electricity sector, people are working on the operational and engineering solutions needed to support our transition to a high-renewables power system.

All the while, the objective is a secure, reliable, affordable and low-emission electricity supply for Australian consumers.

1.2 Increasing electricity demand and consumption

The shift to renewable energy is the first part of the energy transition. Another is the great increase in demand for electricity, as consumers use it for transport, heating, cooling and cooking. Even more electricity will be needed as hydrogen production and other new energy industries emerge.

The increase in demand for NEM electricity will be partially offset by consumers' own efforts. Households, businesses and industry are investing in their own energy assets, and their technologies and behaviours are becoming more energy efficient.

This section sets out how:

- Future energy consumption from the NEM will rise by approximately 108% by 2050, largely from business and industry, as households increasingly meet their own electricity needs.
- Future daily demand profiles show how solar energy needs to be stored for use later in the day.

Terminology for measuring consumers' use of electricity

AEMO uses the industry terms 'demand' and 'consumption' to refer to how much electricity use will be needed in the NEM:

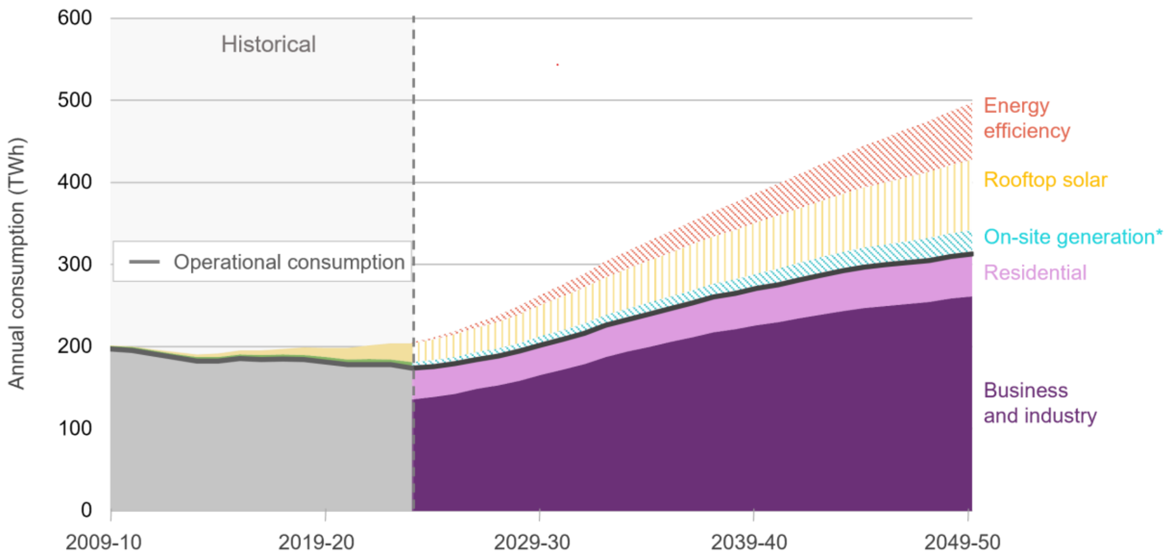
- **'Demand'** is the electricity needed **at a point in time**, expressed as 'kilowatts' (kW), megawatts (MW), gigawatts (GW) and terawatts (TW). Consumers may draw 21 GW of electricity from the grid at one time, and another 2 GW from their own 'behind-the-meter' resources. What the grid meets is 'operational demand', while the total 23 GW is the 'underlying demand'.
- '**Consumption**' is the total electricity used **over a period of time**, expressed as 'kilowatt hours' (kWh), megawatt hours (MWh), gigawatt hours (GWh) and terawatt hours (TWh). The underlying consumption across the NEM is about 200,000 GWh or 200 TWh. Allowing for 20 TWh supplied by consumer resources, the grid's annual operational consumption is currently about 180 TWh.

In this ISP, 'demand' means operational demand, and 'consumption' means operational consumption. These are what the NEM must deliver, reliably and affordably.

Future energy consumption

Overall, allowing for continued growth in energy efficiency, electricity consumption across the NEM is forecast to continue rising to over 410 terawatt hours (TWh) in 2049-50: see Figure 5. Growth in residential consumption is significantly offset by the uptake of rooftop solar and energy efficiency. Business consumption grows with the economy, its electrification, and the inclusion of hydrogen loads.

Figure 5 Electricity consumption, NEM (TWh, 2009-10 to 2049-50, *Step Change*)



Note: On-site generation (or "non-scheduled generation") is non-utility generation that includes on-the-ground PV and small wind and biomass, typically for industrial use.

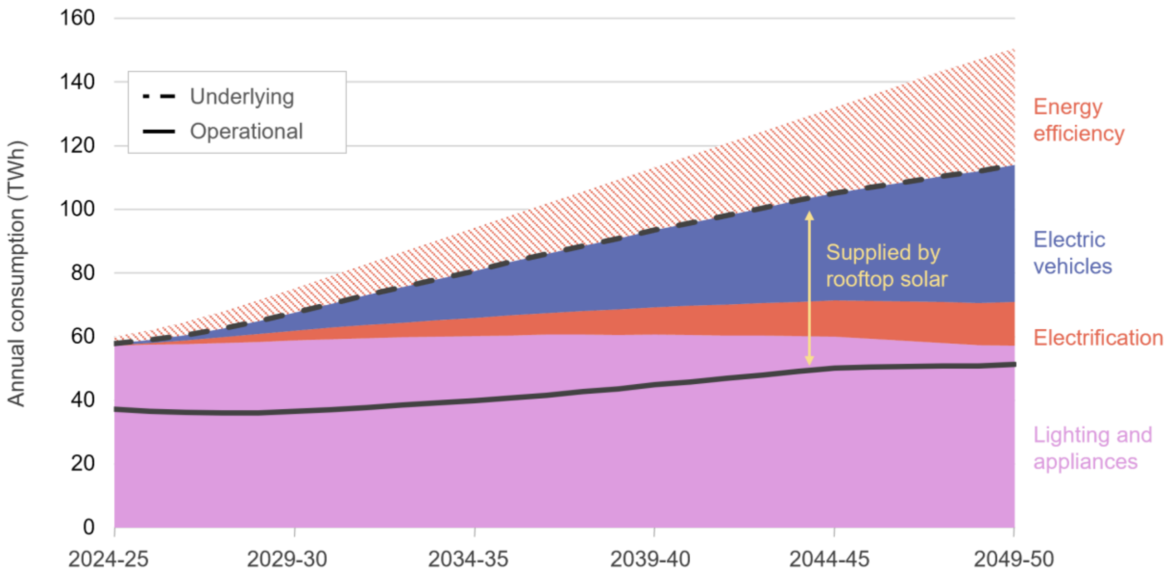
Residential electricity consumption steady on average

Taken as a whole, households are forecast to draw about as much from the grid across a year in 2050 as they do now. Their EVs and appliances will drive up underlying consumption, and be offset by their investments in rooftop solar and energy efficiency. Individual households will differ in how they rely on the grid. Many will continue to be without rooftop solar and draw electricity from the grid, while those with solar may export excess energy during the day and import from the grid overnight.

Figure 6 shows how electricity use for existing home lighting and appliances currently makes up almost all residential consumption. As households charge EVs and use more electricity for heating, cooling and cooking their total consumption increases to 150 TWh by 2050. However, uptake of energy efficient buildings, appliances and behaviour offsets this increase, resulting in underlying consumption of 115 TWh. Rooftop solar further reduces reliance on the grid to only 50 TWh across the year by 2050 – about the same as what it is today.

Households can draw electricity either direct from their rooftop solar, from the grid, from their household or community batteries, or even from EVs that are able to discharge their batteries. However, there will be big swings in demand across the day, as discussed below.

Figure 6 Residential electricity consumption, NEM (TWh, 2024-25 to 2049-50, *Step Change)*

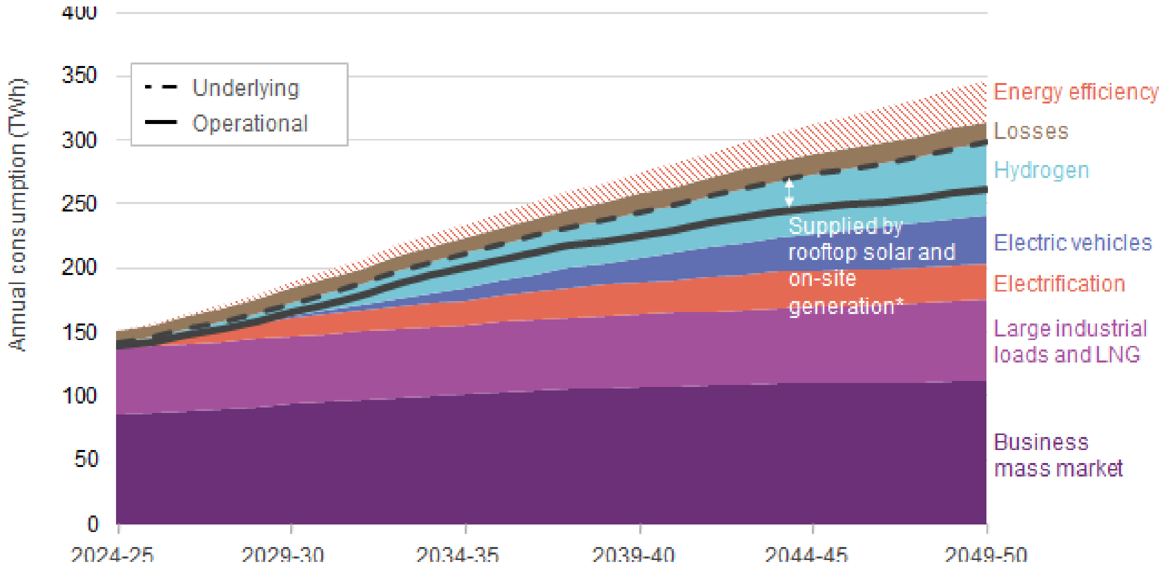


Business and industry electricity consumption to more than double

Business and industry total consumption is forecast to more than double from today's 145 TWh to almost 345 TWh in 2050: see Figure 7 over page. Economic growth is expected to drive a 45 TWh rise, the switch of transport and industrial processes to electricity would add another 65 TWh, and emerging hydrogen would add at least 55 TWh. However, these new industrial consumers may be more flexible in the timing of their electricity demand, shifting production to take advantage of lower costs when supply is in surplus.

Investment in energy efficient processes and buildings will offset this increase, bringing underlying consumption to 300 TWh. On-site generation will further ease demand on the grid to 260 TWh.

Figure 7 Business and industry electricity consumption, NEM (2024-25 to 2049-50, *Step Change*)



Note: On-site generation (or "non-scheduled generation") is non-utility generation that includes on-the-ground PV and small wind and biomass, typically for industrial use.

Future daily demand profiles

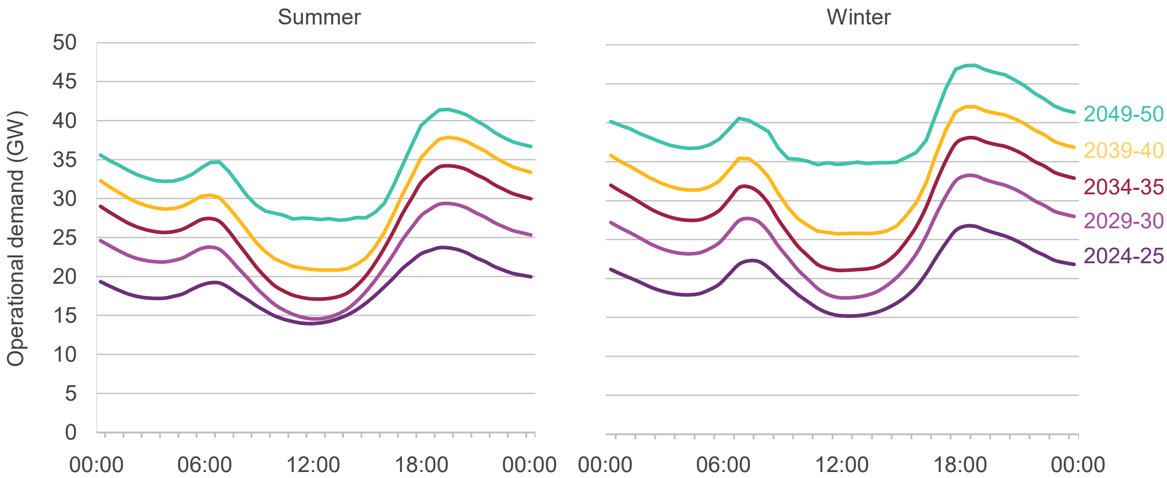
The five-yearly lines in Figure 8 below show the daily variations that the NEM must manage for consumers. Forecast electricity demand keeps a similar daily shape (or 'profile') through to 2050, but rises for all times of the day. In summer, the evening peak is forecast to rise over time, while midday operational demand stays lower due to rooftop solar. In winter, reduced solar output and more demand for energy means that operational demand is higher throughout the day, rising throughout the transition, requiring greater NEM capacity.

The ISP identifies the most efficient ways for the NEM to manage these midday lows and evening peaks. It takes into account how consumers help smooth out the demand profile by drawing on their own assets and by choosing what time of day they use electricity:

- **Residential and commercial batteries** can be installed to soak up surplus daytime solar for discharge later in the evening, and aggregated as virtual power plants (VPPs).
- **EVs** can contribute by being charged outside the morning and evening peaks, preferably through the peak solar daylight. Owners may also discharge their EV's stored energy back to the home, or to the broader grid when needed.
- **Smart home management systems** may similarly control hot water systems and other appliances to take advantage of cheaper daylight electricity and avoid the more expensive peaks.
- **Large industrial users, including hydrogen production**, may be set to take most advantage of surplus renewable generation when it is available, particularly during daylight hours.

Batteries, VPPs and EVs can reduce even more grid demand if their charging and especially discharging can be coordinated with the grid. This would reduce the need for more utility-scale investment: see Section 4.2.

Figure 8 Average operational demand by time of day and season, NEM (GW, 2024-25 to 2049-50, *Step Change*)



1.3 Significant and diverse benefits

The energy transition offers benefits that extend beyond reliable, affordable, low-emission electricity for the future. As a result of these investments, Australians are more likely to see:

- greater insulation from the international shocks that affect gas, petroleum and coal prices, and that put unwelcome pressure on the cost of living,
- reliable and affordable energy as increasingly coal-powered generation is replaced by renewables with lower fuel, maintenance and operation costs,
- almost 30,000 jobs over the next 20 years to build the new infrastructure and to maintain and operate the energy system,
- the energy sector's efforts to reduce emissions, targeting net zero by 2050, both to manage their own risks and to contribute to global efforts to reduce emissions,
- new economic opportunities for Australia – as both global trade and Australian policies press for low-emission products, Australia will have new export opportunities in low-emission, energy-intensive industries: steel and aluminium, data warehouse services, green energy (hydrogen and ammonia) and critical mineral processing, and
- support for Australia's existing regional and rural economies, by providing lower-cost electricity and further opportunities for economic expansion.

These potential benefits are both significant and attainable. While there is no guarantee that all benefits will flow in full, Australia is in a globally enviable position.

2 The transition is well underway

The energy transition is a once-in-a-century change to the way energy is generated, stored, moved, and used across the economy. Coal generators are retiring. The lowest-cost replacement is renewables, connected with transmission and distribution, firmed with storage and backed up by gas-powered generation. Forecasts show the NEM power system needs to almost triple its installed capacity in less than 30 years.

This section sets out how:

2.1 **The energy transition is well underway.** Major coal power stations continue to retire. Renewables delivered almost 40% of the NEM's total energy in 2023. Government policies for decarbonisation are in place and deepening, and consumers and business are investing in generation and storage.

2.2 **There are inherent tensions being managed**: today and tomorrow, the parts and the whole, people and populations, Australia and the world**.**

Section 3 then describes how AEMO has worked with consumers, the energy industry, governments and communities to set a clear plan for essential infrastructure to meet our future energy needs.

2.1 The energy transition is well underway

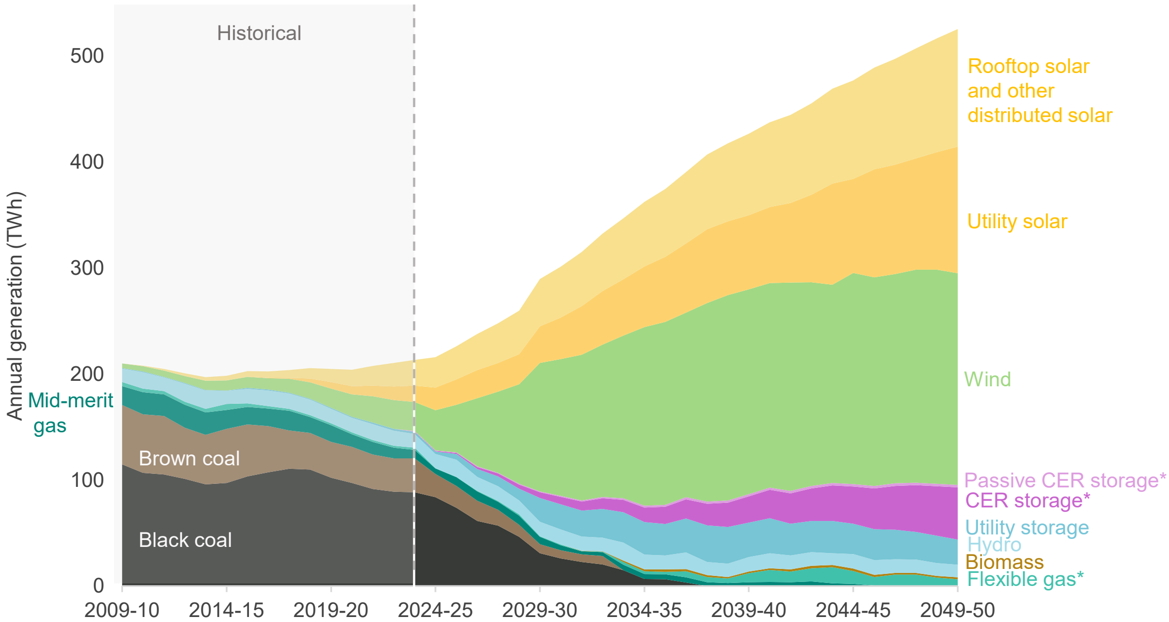
Australia is well underway in transforming its energy system. New investments in renewable generation and storage are accelerating, looking to keep ahead of coal closures and the big switch to electricity. Renewables accounted for almost 40% of the total electricity delivered through the NEM in 2023. Government policies for decarbonisation are accelerating, and network upgrades are underway. Consumers are influencing that transition as much as industry, becoming more familiar with its language and possibilities, and investing in their own new or replacement resources.

The NEM has already reached 72% renewable electricity

The level of renewable energy injected into the grid regularly sets new records. On 24 October 2023, 72.1% of total NEM generation came from renewable sources, a new record for a 30-minute period. At maximum available output from wind and solar generation, plus the actual dispatched output from other renewable sources, renewable potential represented 89.9% of the total NEM supply at that time (nearing the current record of 99.7% renewable potential observed on 1 October 2023).

Soon, AEMO will regularly face times when the power system is able to be supplied entirely by renewable energy, which will have implications for system security and strength. The NEM is among the first systems in the world facing the challenge of securely handling a high-renewables system. Figure 9 shows the past and forecast generation mix in the NEM, and indicates just how far through the transition we already are.

Figure 9 Generation mix, NEM (TWh, 2009-10 to 2049-50, *Step Change*)



Notes: Annual generation for 2023-24 has been estimated for the full financial year.
"Flexible gas" includes gas-powered generation and potential hydrogen capacity.
"CER storage" means consumer energy resources such as batteries and EVs.

Consumers are playing a major role

Many households and businesses are taking steps to shape their own energy futures. They are adopting innovative ways to reduce and manage their demand, investing in what the industry calls 'consumer energy resources' or CER (solar systems, batteries, EVs), and contributing to VPPs to bring them together. These innovations and resources – supported by distribution networks, coordination systems and markets – are playing a transformative role in the energy transition and will be indispensable in our future energy system. If they are well coordinated, they help deliver reliable and secure energy, offset the need for additional grid-scale investment, and reduce costs for consumers as well as energy sector emissions.

The first wave of consumer investment has seen the growth in new rooftop solar systems averaging 12% year on year over the past five years. Rooftop solar is now three times as common in Australia as backyard pools, and is capable of meeting 51.3% of underlying energy demand across the NEM in the middle of a sunny day. Rooftop systems contributed 13% of the NEM's total generation in the summer (Q1) of 2024, more than utility-scale solar (8.6%), wind power (11.8%), hydro (5.3%) and gas (4.1%)[3]. As the second wave gathers momentum, consumers are investing in all-electric homes with batteries and rechargeable EVs. Governments are encouraging these changes, with for example the Australian Capital Territory and Victoria phasing in bans of new residential connections to the gas system.

[3] AEMO. *Quarterly Energy Dynamics* Q1, April 2024, at https://www.aemo.com.au/energy-systems/major-publications/quarterly-energy-dynamics-qed.

Government policies for decarbonisation are accelerating

All NEM state and federal governments are pushing to decarbonise the economy, and most have accelerated and strengthened their targets in recent years[4]:

- **Australia's** commitment to reaching net zero emissions by 2050 has been in place since 2022. The federal *Climate Change Act 2022* set a 2030 emissions reduction target of 43% (from 2005 levels), supported by an 82% renewable energy target. Supporting those targets are the Powering Australia Plan, the Rewiring the Nation policy, the expansion of the Capacity Investment Scheme and the Renewable Energy Transformation Agreements, the Safeguard Mechanism, a method for calculating a value for emissions reductions in assessing energy projects, and the Future Made in Australia and Future Gas Strategy policies.
- **The Australian Capital Territory** achieved its target to source 100% renewable electricity from renewable generators in 2020, and has emissions reduction targets of 50-60% reduction by 2025 (from 1990 levels), 65-75% by 2030, 90-95% by 2040 and net zero by 2045.
- **New South Wales'** emissions reduction targets of 50% by 2030, 70% by 2035 and net zero by 2050 are supported by the Electricity Infrastructure Roadmap. The roadmap legislation requires the equivalent annual generation of at least 12 GW of new renewable generation, and at least 2 GW/16 GWh of long-duration storage by 2030, beyond 2019 levels.
- **Queensland** has expanded its renewable energy targets to 50% by 2030, 70% by 2032, and 80% by 2035, and legislated emissions reduction targets of 75% by 2035 and net zero by 2050. The Queensland Energy and Jobs Plan and SuperGrid Blueprint call for transmission and two large-scale pumped hydros for firming: Borumba Dam Pumped Hydro and Pioneer-Burdekin Pumped Hydro.
- **South Australia** has emissions reduction targets of 50% (from 2005 levels) by 2030 and net zero by 2050. The Hydrogen Jobs Plan includes a 250 megawatts (MW) electrolyser and a 200 MW hydrogen-capable generator, with budget commitments and supporting legislation in place.
- **Tasmania's** renewable targets of 150% of 2020 generation levels by 2030 and 200% by 2040 were set in 2020. In support, the Tasmanian Government is exploring the new hydro Battery of the Nation project.
- **Victoria's** near-term emissions reduction targets of 28-33% by 2025 (from 2005 levels) and 50% by 2030 were set in 2017. In May 2023, a new target of 75-80% by 2035 was set and the net zero target was brought forward to 2045. These targets are now supported by transmission, renewable generation and storage targets, Offshore Wind Targets of 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040, and a Gas Substitution Roadmap.

[4] The emission reduction and renewable energy targets of NEM jurisdictions have been a consideration in the National Electricity Objective from 21 November 2023, and in February 2024 the National Electricity Rules (NER) were amended to require that AEMO consider policies in the AEMC's *Targets Statement* when preparing the ISP. This is in addition to the standing requirement to consider current environmental or energy policies meeting specified criteria (NER 5.22.3(b)). AEMO has included consideration of relevant policies in the ISP, consistent with the NER requirements.

Network upgrades are underway

Network capacity was increased between Queensland, New South Wales and Victoria in 2023, and upgrades are also underway within regions, with the Eyre Peninsula expansion completed in 2023 and a reinforcement in far North Queensland nearing completion. Several capacity increases are well under way in committed and anticipated projects, with Project EnergyConnect to further connect South Australia with its eastern neighbours.

Heavy investment in utility-scale renewables

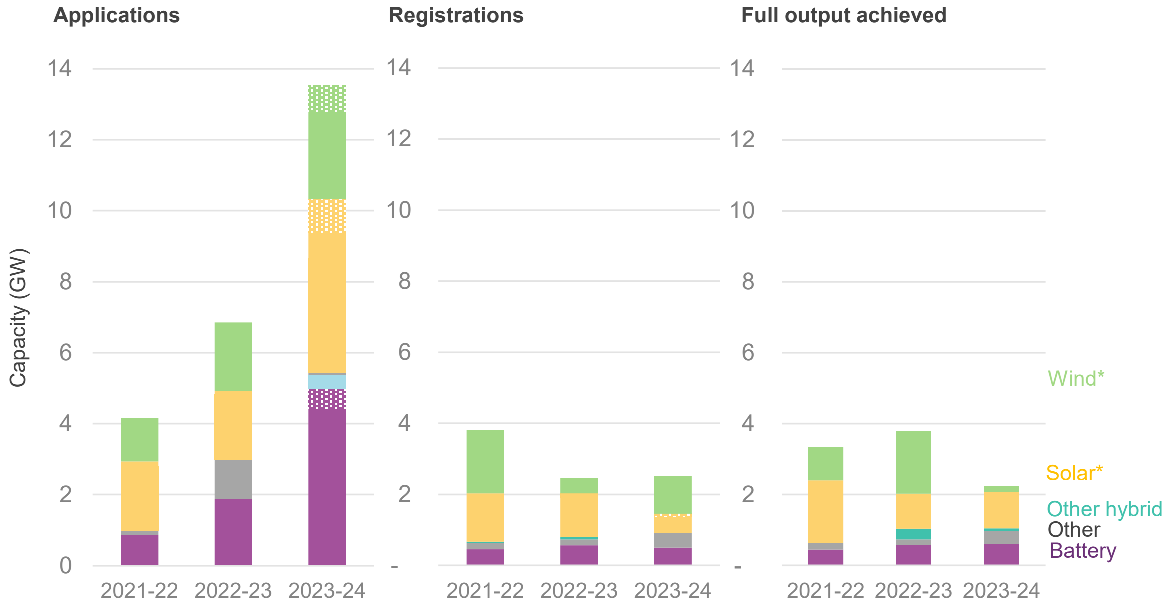
Developers have delivered a comprehensive portfolio of generation and storage projects, with a strong pipeline seeking connection to the NEM and achieving critical milestones on the way towards becoming operational (see Figure 10 below)[5]:

- 13.5 GW of generation and storage connection applications were approved in 2023-24, with batteries being 37%, solar accounting for 36%, wind being 24%, and pumped hydro at 3%.
- The significant increase in projects reaching connection application approval provides a strong pipeline of future projects, with nine out of 10 applications proceeding through to commissioning based on trends in recent years.
- 2.5 GW of generation and storage registrations were approved in 2023-24. Wind accounted for 42% of new capacity registered in 2023-24, with solar, batteries and gas accounting for 21%, 20% and 17% respectively.
- 2.2 GW of generation and storage projects achieved full output in 2023-24. About 45% were solar, 27% batteries, 17% gas, 8% wind, and 3% both wind and solar.

In the last couple of years, projects have been taking longer to reach commissioning stage due to a range of factors including changes in financial markets, supply chain constraints, construction contracting challenges, and environmental and planning approvals. Staged commissioning programs for larger projects are also being applied to progressively release capacity up to full output.

[5] Values in this list include some projections, as 2023-24 was not yet complete at time of publication.

Figure 10 Connection milestones, NEM (GW, 2021-22, 2022-23 and 2023-24)



Note: Wind and Solar include a small number of connections with a battery included in the connection. Patterned bars show projections, as 2023-24 was not yet complete at time of publication.

2.2 But there are inherent tensions

For this transition to succeed, four tensions must be managed that have always existed, but which are becoming more and more apparent. The way these tensions are managed will determine how quickly and how harmoniously the energy transition happens.

Today and tomorrow

The first tension is that lights must be kept on and the gas flowing while the new system is put in place. The NEM must operate safely and reliably today while being steadily but surely refitted for tomorrow. This is a highly complex technical challenge, but also a social and economic one.

Coal generators have been retiring earlier than initially announced, and a ‘just in time’ transition to replacement infrastructure risks reliable supply. The need for renewable energy, transmission, storage and backup gas generation is critical now and throughout the transition. Timing is critical, to make sure the new generation and firming capacity comes in ahead of coal retirements.

Yet rushing the transition is also risky. Market rules need to be in place and well understood, so that timely investments can be made. Global supply chains need to be negotiated so equipment is available to deliver the transition at reasonable cost. Policies need to ensure that Australia has a skilled workforce to draw on as the transition ramps up. Communities must be engaged so that social licence for these rules and investments is earned. These issues take time to resolve well.

A new orderly exit mechanism is being designed under the guidance of energy ministers to act as a backup while investment in clean technologies and transmission networks continue as fast as possible.

Parts and the whole

The second tension is about integrating the diverse range of technologies, small and large, that a multi-gigawatt clean energy system needs.

One aspect of this tension is in connecting generation or storage assets to the whole system. Australia's processes to register, connect and commission new resources are highly regarded by overseas operators, and the times needed are shortening, but AEMO acknowledges that these processes need to be further streamlined.

Another aspect is the shift from coal to renewables. Coal generators have been the 'electrical heartbeat' of the power system since before the NEM was formed. AEMO and other planning bodies are fast learning what innovations and standards are needed for a power system to run on high levels of renewables. This includes learning from and sharing with system operators and research institutions around the globe.

People and populations

The third tension is about the social licence needed to deliver secure and affordable electricity for all. Again, the tension lies in two places.

The first is where communities are asked to host infrastructure for Australia's energy future, and share the benefits with new industries across regional Australia and with households and businesses in our cities. While most Australian communities in city, regional and rural settings have long lived with electricity generation, transmission and distribution, communities facing them for the first time have legitimate questions and concerns.

Building social licence with communities is a real world, steady dialogue with communities to build understanding and trust, through sound processes, listening and responding. It takes into account the intrinsic commitments that communities have with each other (for example, the right for farmers to farm, rural communities to function harmoniously, and Aboriginal and Torres Strait Islander people to practice culture). Community acceptance of projects is fostered when organisations prioritise trust, and deliver promised benefits.

The second place where 'people and populations' meet is where households, businesses and communities have invested in their own energy resources. At times, rooftop solar offers so much electricity to the grid that action is needed to ensure power system security. However, if owners allow some coordination of their assets, including batteries and EVs, it will help keep them and the power system as a whole in balance. With the right incentives and systems, these assets can reduce the need for additional utility-scale investments, and materially reduce the cost of the energy transition.

Australia and the world

Australia is not the only country transforming its energy system, with the whole world competing for the same investment, equipment and engineering skills. Private investment is being attracted by public incentives: governments have allocated US$1.34 trillion to clean energy investments since 2020, and US$130 billion in the six months to June 2023[6].

This stimulus is led by the United States, where the *Inflation Reduction Act* is estimated to invest at least US$370 billion to attract private investment in renewable technology and manufacturing over a decade[7]. Japan's *Green Development Strategy* is intended to stimulate US$100 billion in private investment over 10 years[8], while South Korea's *New Deal* allocated US$60 billion to the energy transition[9]. Similarly, the European Union's *Green Deal Industrial Plan 2022* is supporting EU-located green technology, critical mineral supply and energy-efficient semiconductor chips, and Canada's *Budget 2023* allocates US$58 billion to clean energy[10]. To all of this must be added investment by China and India.

The enormous demand for green technologies will continue to influence costs, stretch and grow supply chains, and test delivery schedules. Managing these tensions will take the industry's collective strategic planning, and the disciplines to carry those plans through.

[6] International Energy Agency. 'Governments are continuing to push investment into clean energy amid the global energy crisis', June 2023, at https://www.iea.org/news/governments-are-continuing-to-push-investment-into-clean-energy-amid-the-global-energy-crisis.

[7] International Energy Agency. 'Inflation Reduction Act of 2022', April 2023, at https://www.iea.org/policies/16156-inflation-reduction-act-of-2022.

[8] Japanese Ministry of Economy, Trade, and Industry. *Overview of Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050 (Provisional translation),* March 2021, at https://www.mofa.go.jp/files/100153688.pdf.

[9] International Energy Agency. 'Korean New Deal', July 2021, at https://www.iea.org/policies/11514-korean-new-deal-digital-new-deal-green-new-deal-and-stronger-safety-net.

[10] Government of Canada. *Budget 2023: Chapter 3*, at https://www.budget.canada.ca/2023/report-rapport/chap3-en.html#a7.

3 Planning our electricity future

The ISP is an essential part of AEMO's work in managing the tensions inherent in the energy transition, and in adding to confidence for the investment needed.

It is a plan "*for the efficient development of the power system that achieves power system needs for a planning horizon of at least 20 years for the long-term interests of the consumers of electricity*"[11], taking relevant government energy policies into account.

In simpler terms, consistent with the updated National Electricity Objective, the ISP is a plan for secure, reliable and affordable power while reducing emissions, and AEMO extends the horizon to 2050 to recognise Australia's net zero emissions target.

To prepare the ISP, AEMO creates 'development paths' – combinations of the transmission, generation, storage and firming investments needed under different future scenarios. It analyses the costs and benefits of these paths using a framework set by the Australian Energy Regulator (AER), and chooses a plan that would best deliver secure, reliable and affordable electricity as the 'optimal development path'.

The ISP is the most comprehensive and robust analysis of the NEM's future power system needs. This section sets out how the ISP:

3.1 Is developed over two years in consultation with NEM jurisdictional planners and policy makers, energy consumers, asset owners and operators, and market bodies.

3.2 Prioritises reliable, secure and affordable electricity while meeting policy commitments, including the need to transition our economy to net zero.

3.3 Considers active government policies and power system elements in scenario-based planning using three plausible scenarios (its inputs) to optimise the generation, firming and transmission needs of the NEM (its output).

3.4 Uses Australia's most detailed integrated modelling for the whole NEM power system.

The 2024 ISP meets its regulated scope, and builds on previous versions to offer a comprehensive plan for the NEM's future. Australia's energy ministers have agreed for the 2026 ISP to expand to set a direction for the transformation of the energy system as a whole, with more detail on gas integration, energy demand forecasts, the withdrawal of coal-fired generation, system security and alignment with state planning and policies.

3.1 Preparing the ISP

AEMO develops the ISP every two years, through an inclusive industry collaboration that commences even before the previous ISP is completed. The 2024 ISP has considered over 1,000 potential development paths, and modelled their performance across three potential future

[11] NER 5.22.2.

scenarios. To do so, it has integrated Australia's most comprehensive set of power system models to plan for the optimal development path: an integrated system plan.

A two-year, inclusive engagement process

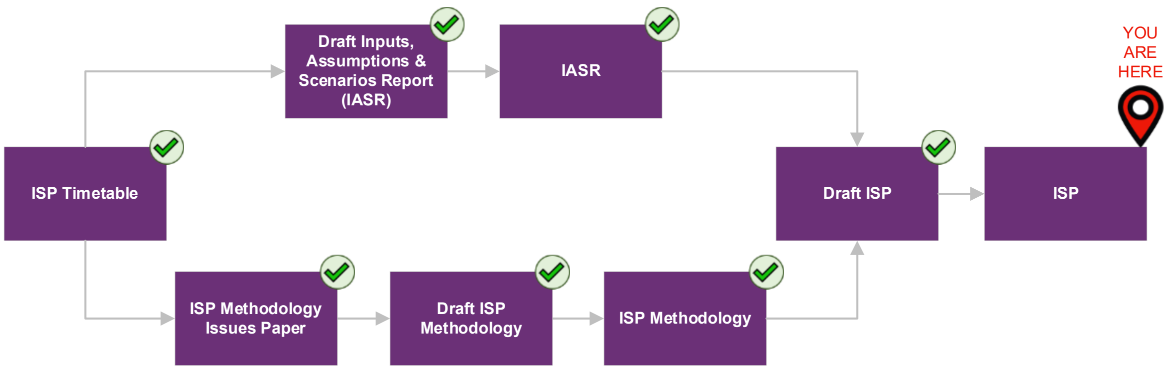
The 2024 ISP is the result of a two-year industry-wide journey with consumer and community representatives, governments, energy market authorities, investors and developers, network planners, industry bodies and research and technology institutions. This included regular engagement with the ISP Consumer Panel, and inputs from AEMO's Advisory Council on Social Licence.

In particular, the ISP adopts:

- The forecasts and insights provided in the 2023 *Electricity Statement of Opportunities* and the 2023 *Gas Statement of Opportunities*[12].
- The inputs published in the 2023 *Inputs, Assumptions and Scenarios Report* (IASR), with an addendum after the AER's review and in the 2023 *Transmission and Expansion Options Report* and announced updates since their publication.
- The cost benefit analysis and market modelling approaches set out in the *ISP Methodology*, updated in June 2023.

In formal consultations, AEMO has published 44 reports, hosted 2,037 attendances across 12 webinars and two face-to-face feedback sessions, and considered 220 written submissions. This testing of the ISP's inputs and approaches by energy experts and community members is essential for AEMO's energy planning. While more can always be done, AEMO is confident that this 2024 ISP represents the best effort possible by the energy sector and its stakeholders to set out a clear and actionable plan to meet the policy objectives for our energy future.

Figure 11 ISP consultations



[12] The ISP must have regard to these reports: NER 5.22.10(b).

3.2 The ISP supports the National Electricity Objective

The ISP must achieve power system needs and contribute to achieving the National Electricity Objective, which is:

> "to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to:
>
> a. price, quality, safety, reliability and security of supply of electricity; and
>
> b. the reliability, safety and security of the national electricity system; and
>
> c. the achievement of targets set by a participating jurisdiction for reducing …or that are likely to contribute to reducing Australia's greenhouse gas emissions."

This section considers each of these objectives. AEMO uses the term 'affordability' to refer to the 'price and quality'[13] elements of the National Electricity Objective, and to align with the 'affordability' objective featured in Australian and state energy policies.

Reliability and security as 'power system needs'

The NEM power system needs to be reliable and secure, operating within engineering limits and operating standards[14], as shown in Table 2.

Table 2 Power system needs considered in the ISP

Need	Operational requirements considered when developing the ISP	
Reliability	**Resource adequacy and capability**	Continuous real-time balancing of supply and demand. In addition, energy resources provide sufficient supply to match demand from consumers at least 99.998% of the time under the NEM Reliability Standard.
		Reserves exist to provide 'a buffer' – available to assist in meeting electricity demand in challenging conditions.
		Network capability is sufficient to transport energy to consumers.
Security	**Frequency and inertia**	Frequency control, minimum and secure levels of system inertia, and transient and oscillatory stability are maintained within operating and planning standards.
	Voltage management and system strength	Voltage control and fault levels are maintained within operating and planning standards and below equipment ratings.
	System restoration and flexibility	The right mix of flexible resources are available to maintain and restore the supply-demand balance across different timescales.

To be reliable, the NEM must match supply with demand from consumers while keeping power system equipment within its operating requirements. In addition, the NEM must be operated over the year so that there is enough supply to make sure demand is met at least 99.998% of the time. To meet both of these needs, reserves may be required to respond to demand peaks during periods of extreme heat or cold or to cover potentially long periods of dark and still 'renewable droughts' across the NEM.

[13] Electricity quality is also considered through ensuring ISP alignment with power system standards under the NER.

[14] NER 5.22.3(a), with the details set out in the NER for the reliability standard (3.9.3C(a)); system security principles (4.2.6), system standards (Schedules 5.1 and 5.1a), and applicable regulatory instruments (defined in NER Chapter 10).

To be secure, the system must continue to operate within defined technical limits despite highly variable demand and renewable supply, even if a major power system element (such as a generator or interconnector) is unexpectedly disconnected. If such an element fails, the system must be returned to secure operations as soon as practical, within 30 minutes.

Appendix 4 and Appendix 7 discuss more completely how system reliability and security are being provided through to 2050, although the issues are touched on throughout the ISP.

Affordability as 'long-term interests and net market benefits'

'Affordability' is considered in the ISP's purpose to serve 'the long-term interests of electricity consumers', taking into account the 'price, quality, safety, reliability and security' of supply[15]. This is measured by the 'net market benefits' that a development path may bring, which are in turn driven by 'low long-term system costs'. The lower those long-term costs are, all else being equal in an efficient market, the lower energy prices will be.

The benefits and costs considered in the ISP are set out in the 2023 *ISP Methodology*. Unless otherwise indicated, they are assessed for all utility-scale generation, firming and transmission infrastructure in the NEM, and include the value of greenhouse gas emissions reductions (VER): see Section 3.3 below.

AEMO notes, however, that lowering long-term system costs generally means investing in new assets, generally up front. This means short-term affordability is only protected if investments are repaid over long-term schedules that do not penalise current consumers. The ISP assumes that these payment schedules are adopted by investors, and reflected in wholesale energy markets.

Table 3 Classes of market benefits considered in the ISP cost-benefit analysis

Benefit	Realised by	Identified by
Operational costs	Low operating costs	Calculating plant maintenance, plant start-up and other operating costs.
	Reduced fuel costs	Co-optimising future generation, storage, and transmission build (and retirement) timings and calculating the fuel costs associated with this generation mix and future dispatch patterns.
	Reduced operational curtailment	Calculating the value to the customer of either voluntary curtailment or involuntary load shedding.
	Reduced network losses	Assessing additional generation costs effectively wasted due to network losses under each alternate development path across interconnectors.
Capital cost	Efficient investment timing	Investments being delivered in time for when they are needed, and deferred if they are not yet required.
	Optimal investment size	Total generation, storage, and transmission costs, compared to the case of no new transmission.
Reduced emissions	Valuation of reductions	Value of greenhouse gas emission reduction (VER) for years 2023 to 2050 as agreed by Australia's Energy Ministers and set out in the AER Guidance May 2024.

Note: AEMO does not consider ancillary service costs or competition benefits as part of the cost benefit analysis for the ISP because they are not generally material compared to other projects costs, as set out in the 2023 *ISP Methodology*. Where material, changes in ancillary service costs may be considered by transmission network service providers (TNSPs) as part of subsequent regulatory investment test for transmission (RIT-T) analysis on any actionable projects.

[15] A consideration in the National Electricity Objective: National Electricity Law (NEL) s 7(a).

Balancing affordability and reliability

The ISP is a plan to optimise investment, considering various futures and risks, in a way that achieves system security and reliability at the least long-term cost.

In preparing the ISP, AEMO may apply its professional judgement to reflect consumers' risk preferences[16]. Consumers may seek lower costs, but not at any level of risk. A major challenge for planners is to balance the risks of investment that is 'too early' or 'too late' in an uncertain future. Too early may mean over-investing in things that in the end are not needed. Too late, after waiting for certainty, may mean the system is less able to maintain reliable, secure and affordable power if unpredictable events occur.

In 2023, AEMO surveyed and met in person with residential consumers across the NEM, seeking to understand consumer risk preferences on infrastructure investment[17]. The research suggests that these consumers generally prefer some level of early investment if it will reduce the risk of later volatility in their bills, so long as it is not too much. However, some consumers were willing to pay more, and some were not willing or able to pay anything additional now.

Emissions reduction as an element in the National Electricity Objective

A recent addition of an emissions reduction element to the National Electricity Objective (NEO) in Australia's electricity law requires that AEMO plan the power system in a way that helps governments achieve targets that reduce greenhouse gas emissions, as well as being secure, reliable and cost-effective. AEMO has applied the amended NEO in its preparation of the 2024 ISP as follows[18]:

- Only scenarios that comply with Australian governments' emissions reduction policies have been applied (which meant removing the previous *Slow Change* scenario from the 2022 ISP).
- Policies and targets included in the Australian Energy Market Commission's (AEMC's) *Emissions Targets Statement* have been incorporated, including those which meet the National Electricity Rules (NER) requirements for public policies' inclusion in the ISP. Examples of polices and targets which are on their way to meeting rules requirements are Victoria's offshore wind targets, the Victorian Energy Storage Target, and New South Wales' updated emission reduction targets.
- AEMO has adopted the value of greenhouse gas emissions reduction (VER), agreed by the Australia's Energy Ministers, which rises from $70 per tonne of carbon dioxide equivalent (CO_2-e) abated in 2024[19]. These reductions are included as a class of market benefits under the NER.

[16] Consistent with the AER's Cost Benefit Analysis Guidelines, at https://www.aer.gov.au/industry/registers/resources/guidelines/guidelines-make-integrated-system-plan-actionable and AEMO's *ISP Methodology,* at https://aemo.com.au/en/consultations/current-and-closed-consultations/consultation-on-updates-to-the-isp-methodology.

[17] See Summary of consumer risk preferences project on the AEMO website, at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/draft-2024-isp-consultation/supporting-materials/summary-of-consumer-risk-preferences-project.pdf?la=en.

[18] For further information, see *Addendum to the 2023 Inputs Assumptions and Scenarios Report,* at https://www.aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2023/draft-2024-isp-consultation/supporting-materials/addendum-to-2023-inputs-assumptions-and-scenarios-report.pdf?la=en.

[19] The AER proposes an average between the spot price for an Australian Carbon Credit Unit, and an international measure aligned with IPCC Assessment Reports. See https://www.aer.gov.au/system/files/2024-03/AER%20-%20Valuing%20emissions%20reduction%20draft%20guidance%20-%20March%202024.pdf.

3.3 Inputs and outputs of the ISP's integrated modelling

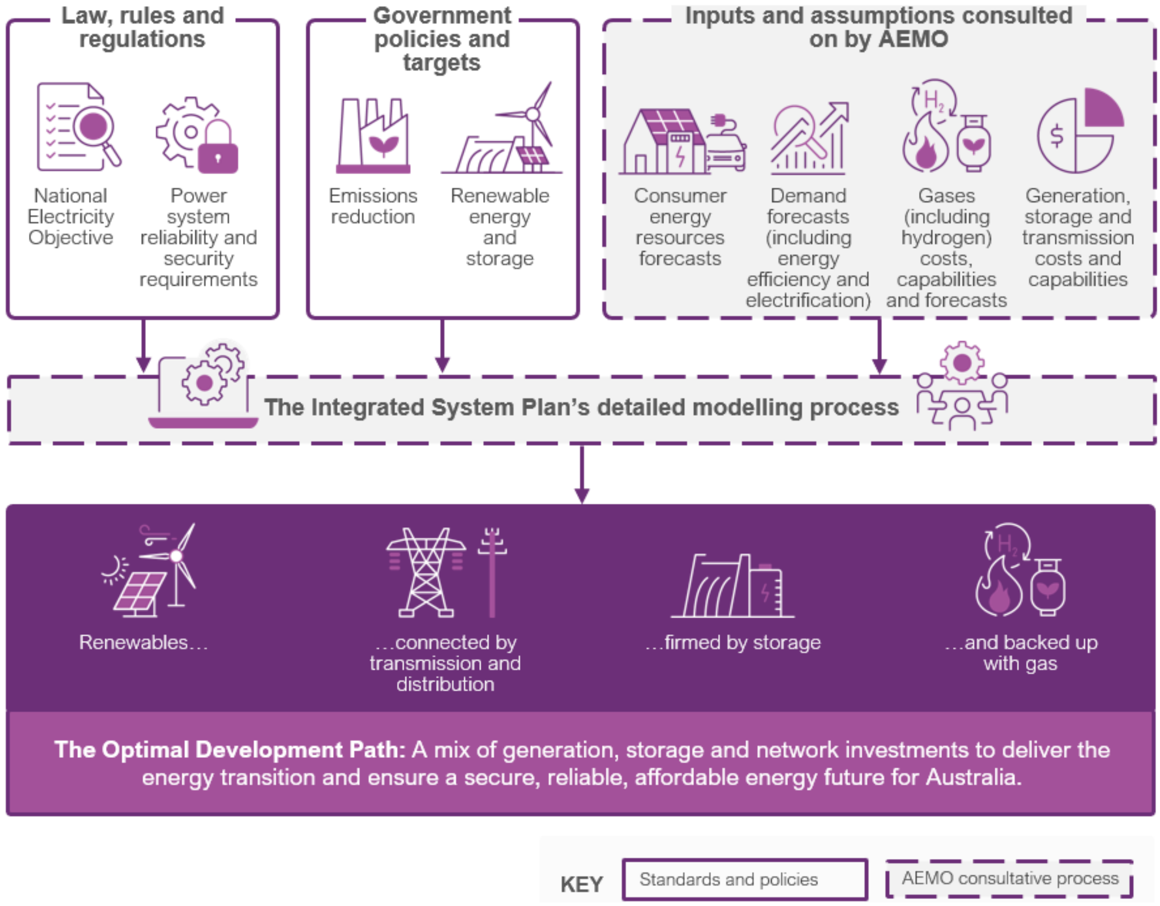
The ISP is a roadmap for the transition of the NEM power system, with a clear plan for both new and existing technologies. However, the NEM power system is not an isolated engineering system. It must operate in the real economy, supporting government policies and industry needs, and responding to infrastructure costs, workforce availability and community actions through the energy transition.

As shown in Figure 12, the regulated ISP methodology:

- captures the diverse market and policy inputs published in the *Inputs, Assumptions and Scenarios Report* (IASR) and summarised below,
- models all inputs through four integrated modelling components, and
- generates the optimal mix of generation, firming and transmission infrastructure, detailed in Part B below, to target secure, reliable and affordable electricity as Australia transitions to net zero.

Throughout this two-year process, AEMO consults extensively and transparently with industry, consumer and government representatives, to direct the modelling process towards secure, reliable and affordable power.

Figure 12 High level inputs and outputs of the *ISP Methodology*



ISP inputs: All current and relevant federal and state policies

Under the NER, the ISP may consider current Australian and state policies that reach a clear level of commitment (as defined in the NER), and must consider policies in the AEMC Targets Statement.[20] These include:

- **Emission reduction policies**, including the national target of 43% below 2005 levels by 2030 and net zero by 2050, and state targets that meet or exceed the national target, the federal Safeguard Mechanism and Capacity Investment Scheme.
- **Energy efficiency policies**, including building and construction codes, and specific rating, disclosure, efficiency, upgrade and peak demand reduction schemes.
- **Energy transition policies**, including the re-development of publicly owned coal-fired generation in Queensland into clean energy hubs (as defined in the Queensland Energy and Jobs Plan).
- **Renewable energy targets**, including the national target of 82% of national supply by 2030, and state targets that may be either in absolute terms (for example, the 12 GW required by NSW's *Electricity Infrastructure Investment Act 2020*) or proportional (for example, the Queensland target of 80% renewables by 2035 under the Queensland Energy and Jobs Plan).
- **Storage targets**, including Victorian targets building progressively to 6.3GW by 2035, and Queensland's commitment to the Borumba Pumped Hydro Energy Storage.
- **Offshore wind targets,** being at this stage only progressive targets building to 9 GW by 2040 under the Victorian Offshore Wind Policy.
- **Hydrogen policies**, supporting specific projects in New South Wales, Queensland and South Australia.
- **Transmission and REZ support policies (including landholder payment schemes)**, including New South Wales' Electricity Infrastructure Roadmap, Queensland's SuperGrid Infrastructure Blueprint, Victoria's coordinated development under the *National Electricity (Victoria) Act* and the landholder compensation schemes under those policies.

ISP inputs: NEM power system, consumer demand and supply technologies

Inputs have been published in the 2023 IASR (with an addendum after the Australian Energy Regulator's review), and the 2023 *Transmission and Expansion Options Report*. These include:

- **demand-side forecasts:** future trends in electricity consumption, energy efficiency savings, and the electrification of transport, heating, cooling and cooking,
- **technology capabilities and costs:** future trends and costs in existing and new transmission, generation and storage technologies, including the design and implementation of new REZs,

[20] The emission reduction and renewable energy targets of NEM jurisdictions have been a consideration in the National Electricity Objective from 21 November 2023, and in February 2024 the NER were amended to require that AEMO consider policies in the AEMC's *Targets Statement* when preparing the ISP. This is in addition to the standing requirement to consider current environmental or energy policies meeting specified criteria (NER 5.22.3(b)). AEMO has included consideration of relevant policies in the ISP, consistent with the NER requirements.

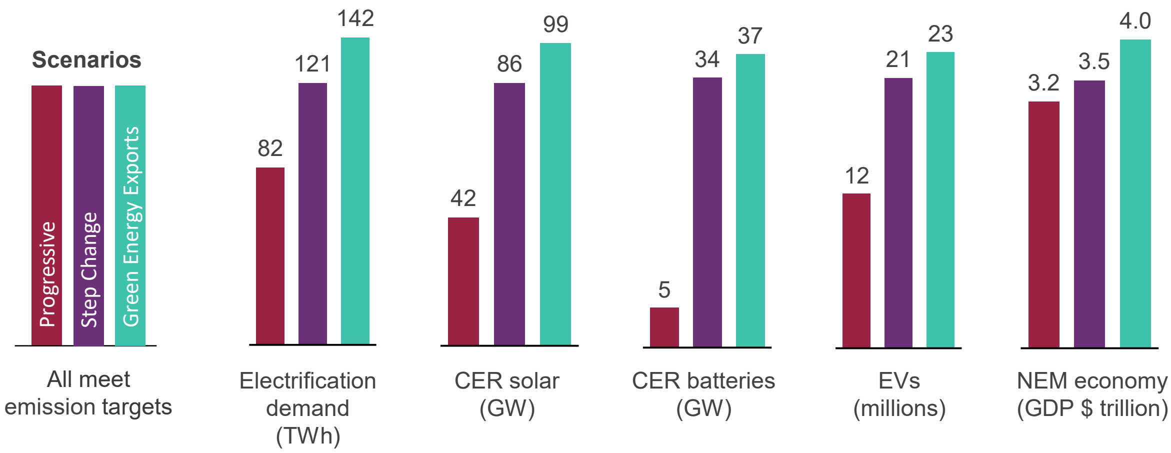
- **power system reliability and security** needs[21] that must be met as new technologies are integrated, and
- **coupled sector forecasts:** the interaction of the power system with other 'coupled' sectors such as transport, gas and hydrogen.

Three potential scenarios for the future

Through industry consultation, AEMO considered and published three scenarios in the 2023 IASR. Each acknowledges the retirement of coal-fired generation and aligns with government policy commitments:

- ***Step Change*** reflects a pace of energy transition that supports Australia's contribution to limit global temperature rise to less than 2°C, with CER contributing strongly to the transition.
- ***Progressive Change*** also reflects Australia's current policies and commitments to decarbonisation, but more challenging economic conditions and supply chain constraints mean slower investment in utility-scale assets and CER.
- ***Green Energy Exports*** reflects a very rapid decarbonisation rate to support Australia's contribution to limit global temperature rise to 1.5°C, including strong electrification and a strong green energy export economy.

Figure 13 Three scenarios of the future for ISP modelling



The choice of the ODP depends in part on the relative likelihood of these scenarios. To help determine the likelihoods, AEMO considered the insights of a 'Delphi Panel' of more than 30 participants, including industry experts, government representatives, network service provider representatives, generators and retailers, researchers, academics, and consumer advocates. The *Step Change* scenario received the most consistent level of support and was considered the most likely scenario by most participant groups. Support for *Progressive Change* was also relatively high, yet it was also more polarised, with more diversity of views between participant groups.

[21] See https://aemo.com.au/initiatives/major-programs/past-major-programs/future-power-system-security-program/power-system-requirements-paper.

Considering the Delphi Panel insights, AEMO assigned likelihoods of 43% for *Step Change*, 42% for *Progressive Change* and 15% for *Green Energy Exports*. The *Step Change* scenario is AEMO's 'most likely' scenario for this 2024 ISP, although the near-term transition is very similar in *Progressive Change*.

ISP outputs: optimised generation, storage and network investments

The optimal future generation, firming and transmission for the NEM form the ISP's optimal development path (ODP). The ODP aims to deliver reliable and affordable power to meet NEM needs for at least 20 years, fulfil the NEM's security and reliability requirements, meet government policy settings and manage risk through the energy transition.

The ODP describes:

- the total capacity of utility-scale wind and solar required,
- the transmission projects required and their optimal timing,
- the total firm dispatchable capacity required,
- additional power system security services to support that infrastructure, and
- the financial benefits to consumers from these investments.

These details are set out in Part B.

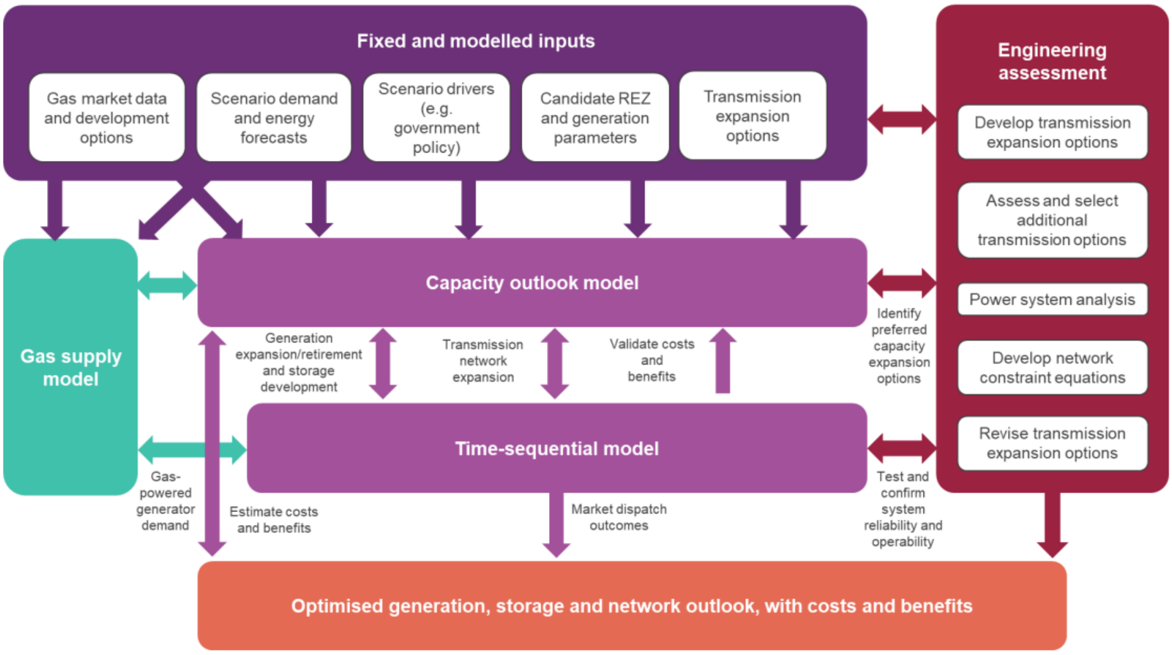
3.4 The ISP's integrated modelling in detail

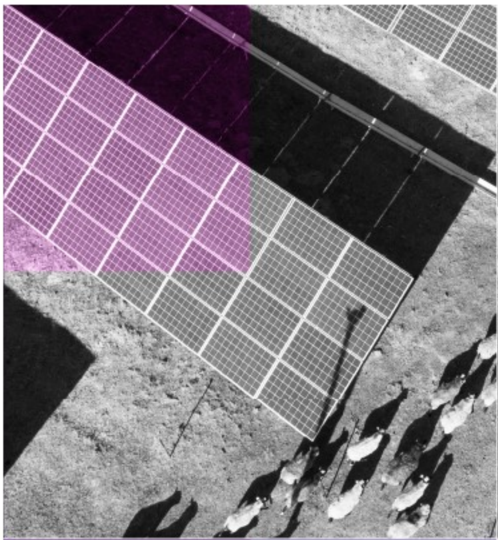
AEMO relies on a suite of models and analyses that covers generation and storage investments, as well as transmission projects. The components of this suite are shown in Figure 14 (over page):

- The **fixed and modelled inputs** are published in the IASR, and are influenced by **engineering assessments** of the NEM's capabilities.
- The **capacity outlook model** uses these inputs to develop options for generation, transmission and dispatch, in each of the ISP scenarios, aiming to minimise capital and operational costs over the long-term while achieving the ISP's objectives.
- The **time-sequential model** then optimises electricity dispatch for every hourly or half-hourly interval. It validates the outcomes of the capacity outlook model, and feeds information back into it.
- The **engineering assessment** tests these outcomes against the power system requirements (security, strength, inertia) and assesses marginal loss factors to inform new grid connections. These assessments feed back into the two models to continually refine outcomes.
- The **gas supply model** is used to test whether gas pipeline and field developments will meet the operational needs of gas generation.
- Finally, the **cost-benefit analyses** identify the net market benefits and potential 'regret' costs of each candidate development path, in each scenario, against each sensitivity analysis.

AEMO then applies its professional judgement to these outcomes to finalise the ODP.

Figure 14 Detailed ISP modelling methodology








PART B

An optimal development path for reliability and affordability

Part B: An optimal development path for reliability and affordability

Renewable energy connected by transmission and distribution, firmed with storage and backed up by gas-fired generation is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy.

In consultation with stakeholders, AEMO has comprehensively considered each of the consumer needs, government policies, potential issues and scenarios introduced in Part A.

The optimal size, place and timing for the NEM's future generation, firming and transmission form the ISP's optimal development path (ODP). The ODP aims to deliver reliable and affordable power to meet NEM needs for at least 20 years, fulfil the NEM's security and reliability requirements, meet government policy settings, and manage risk through a complex transformation.

Part B details how the NEM is forecast to develop in the *Step Change* scenario:

- **Section 4 – Renewable generation, focused in REZs.** The total capacity of utility-scale wind and solar is forecast to increase six-fold by 2050 – from 21 GW currently to 127 GW in *Step Change* – a doubling every decade. In addition, the capacity of rooftop solar and other distributed solar is forecast to rise from 21 GW to 86 GW.
- **Section 5 – Network investments in the ODP.** Transmission projects consistent with previous ISPs or as announced by a state government, including seven projects that are made actionable for the first time in this ISP.
- **Section 6 – Storage and services to support renewable generation.** 75 GW of firm dispatchable capacity is needed by 2050, as well as additional power system security services.
- **Section 7 – Rationale of the ODP**. The ODP and its benefits have been determined as required by the National Electricity Rules, following the *ISP Methodology.*

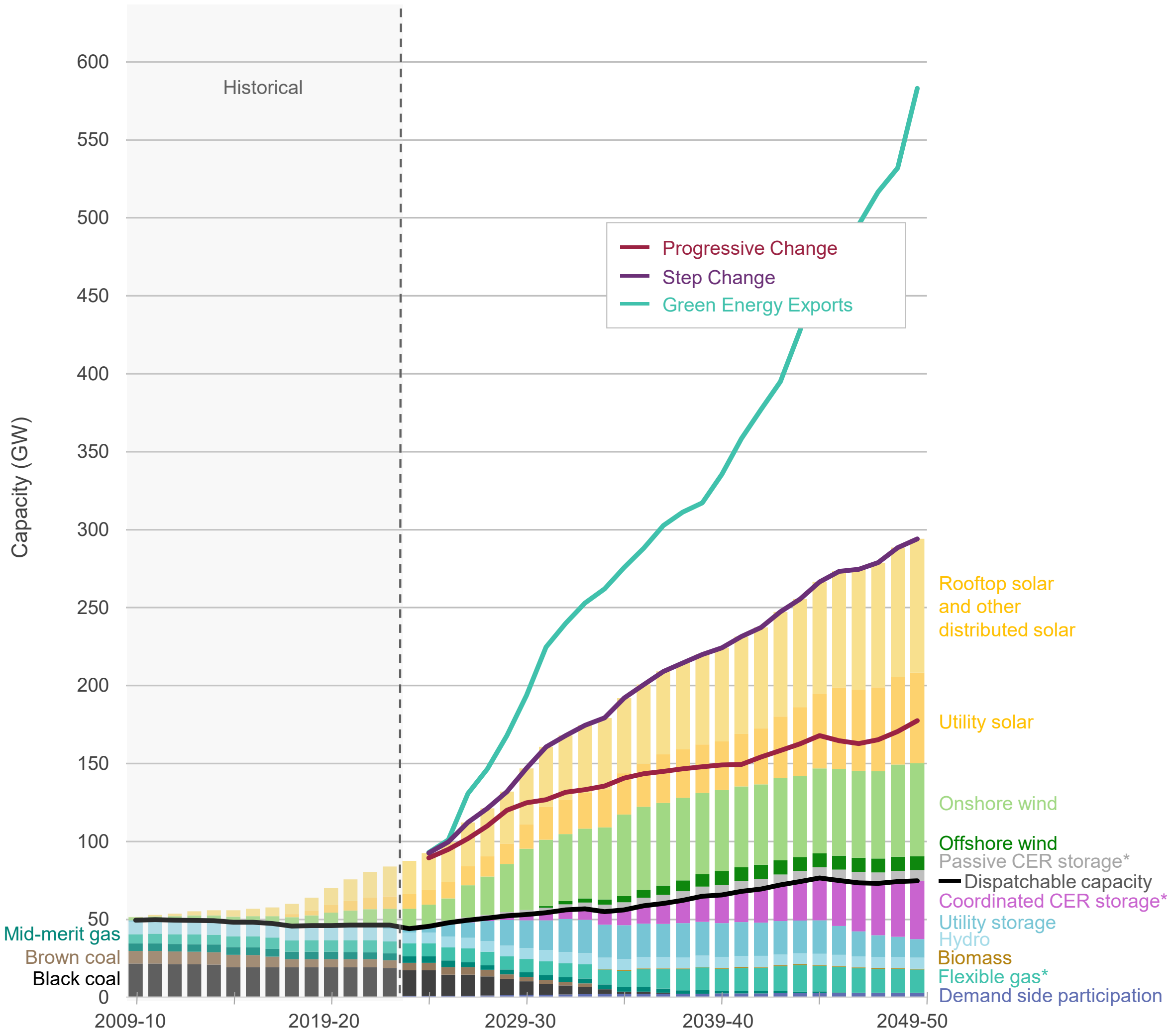
The ISP projects the optimal mix of generation and storage, including renewables such as solar and wind as well as firm capacity technologies like battery storage, pumped hydro and gas-fired generation. AEMO projects this mix based on capital and operating costs from GenCost, rather than using a levelised cost of electricity (LCOE) which is used by industry as a high-level guide.

The transmission projects in the ODP allow efficient investment in generation and storage, and add resilience. Their annualised cost through to 2050 is estimated to total $16 billion[22] and, after paying themselves back, they would avoid a further $18.5 billion in additional costs to consumers.

[22] This value includes transmission augmentation, and does not include the cost of commissioned, committed or anticipated projects, or distribution network upgrades.

Changing one element of the ODP is likely to render other elements, and the whole, less effective and more expensive.

Figure 15 Capacity, NEM (GW, 2009-10 to 2049-50)



Notes: "Flexible gas" includes gas-powered generation and potential hydrogen capacity.
"CER storage" means consumer energy resources such as batteries and electric vehicles.
Projections for "Rooftop solar and other distributed solar" and "CER storage" are forecast based on unit costs, consumer trends and assumptions about payments received to participate in the electricity market.

4 Transition to renewable generation

Renewable energy connected by transmission and distribution, firmed with storage and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy.

The NEM's transformation is well underway, promising material benefits but grappling with inherent tensions. Investment in both utility-scale and consumer-owned renewable generation is needed to meet growing demand for electricity as coal generation retires.

This section sets out how:

4.1 Coal is retiring, faster than announced.

4.2 Rooftop solar and other consumer-owned energy resources are forecast to grow five-fold.

4.3 Utility-scale solar and wind are forecast to grow six-fold.

4.4 REZs are being planned to house most of the utility-scale assets.

4.1 Coal is retiring, faster than announced

As discussed in Section 1.1, 10 coal-fired generators have retired over the last decade. Owners of all but one power station in the remaining fleet have announced retirements between now and 2051, with about half announcing retirements by 2035. This would continue the steady rate of retirement since the peak of installed capacity in 2012.

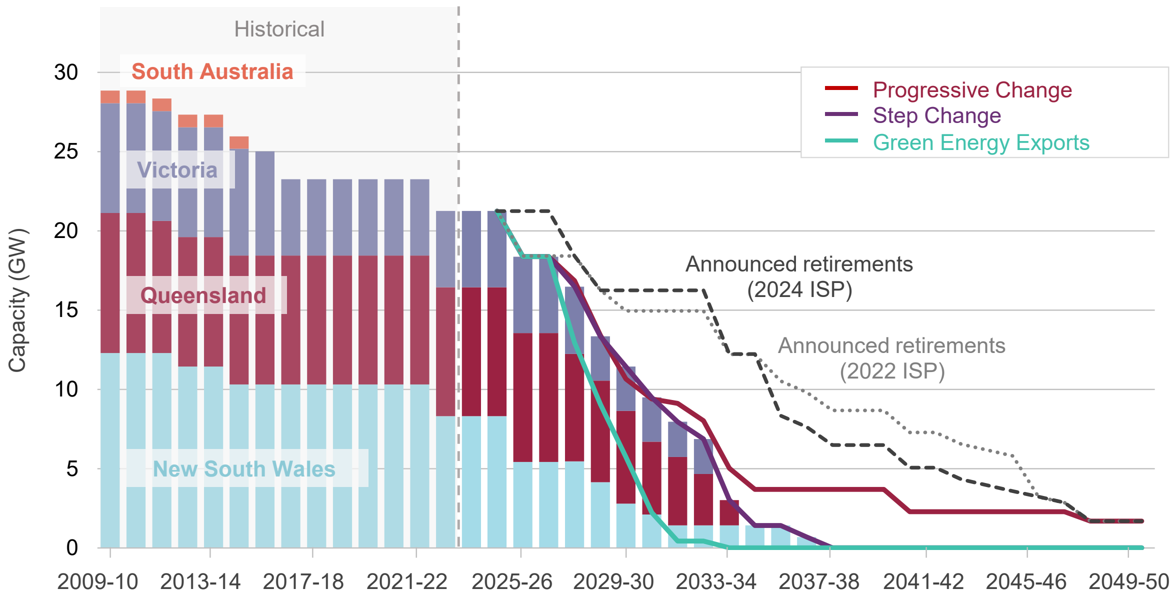
To meet government policy objectives, the ISP forecasts suggest that the remaining coal fleet will close two to three times faster than those announcements. In the *Step Change* scenario, about 90% of the NEM's coal fleet is forecast to retire by 2034-35, with all coal generators retired by 2037-38: see Figure 16 (over page).

However, coal retirements may occur even faster than these forecasts. Ownership has become less attractive, with higher operating costs, reduced fuel security, high maintenance costs and greater competition from renewable energy in the wholesale market.

Coal owners are only required to give three-and-a-half years' notice of a closure, which gives very little time for the NEM to react. Given the lead time to deliver new assets, replacement capacity is needed in advance to ensure reliability is not compromised for energy consumers. A new orderly exit mechanism is being designed under the guidance of energy ministers to act as a backup while investment in clean technologies and transmission networks continue as fast as possible.

The need for replacement capacity, and the ODP itself, are not affected by short-term postponements of coal power station retirements such as the recently announced extension of Eraring Power Station. If anything, that announcement delays the need for gas-fired generation and bolsters the case for the ODP's transmission investments to support additional storage, solar and wind capacity: see Appendix 6.

Figure 16 Coal capacity, NEM (GW, 2009-10 to 2049-50)



4.2 A forecast five times today's consumer energy resources

Many consumers are taking more direct responsibility for their energy needs, particularly as they rely more and more on electricity. Increasingly, they are investing in solar systems, batteries, EVs, and other energy management solutions. VPPs are starting to aggregate those assets into larger systems, trading energy between them and the grid, and maximising the system benefits that these resources can provide.

The 2023 IASR details how these valuable consumer resources are forecast to grow through to 2050, when they are expected to reach almost half the NEM's capacity and about a fifth of energy consumption (see Figures 2 and 5). The ISP's optimal development plan takes into account how:

- **Solar generation continues to rise.** Today, one-third of detached homes in the NEM have rooftop solar. By 2034 in the *Step Change* scenario, over half of the detached homes in the NEM would do so, rising to 79% in 2050, driven by ever-falling costs. At that time, forecast total rooftop solar capacity is 72 GW.
- **Residential and commercial batteries** are becoming more numerous as costs decline, with adoption forecast to grow strongly in the late 2020s and early 2030s. The *Step Change* scenario forecasts growth in capacity from today's 1 GW to an estimated 7 GW in 2029-30, then 34 GW in 2049-50.
- **EV ownership is also expected to surge** from the late 2020s, driven by falling costs, greater model choice and availability (assisted by new vehicle emission standards), and more charging infrastructure. By 2050, between 63% (*Progressive Change*) and 97% (*Step Change*) of all vehicles are expected to be battery EVs.

When rooftop solar growth is combined with growth in PV non-scheduled generation (PVNSG), total solar generation grows by four times between today and 2050.

As investment in CER continues to grow, CER have the potential to reduce the need for utility-scale solutions. An increasing proportion of rooftop solar, EVs, household and community batteries and even household hot water and pool pumps are expected to have the 'smarts' to help manage the import and export of electricity to the distribution grid. If consumer batteries are well coordinated, it would avoid up to $4.1 billion being spent on additional utility-scale storage in the NEM. Achieving these savings depends on a mix of financial incentives, technology and communication standards, customer preferences, and market or policy arrangements – and in turn increased engagement between consumers, retailers, networks and other market participants: see Section 8.2.

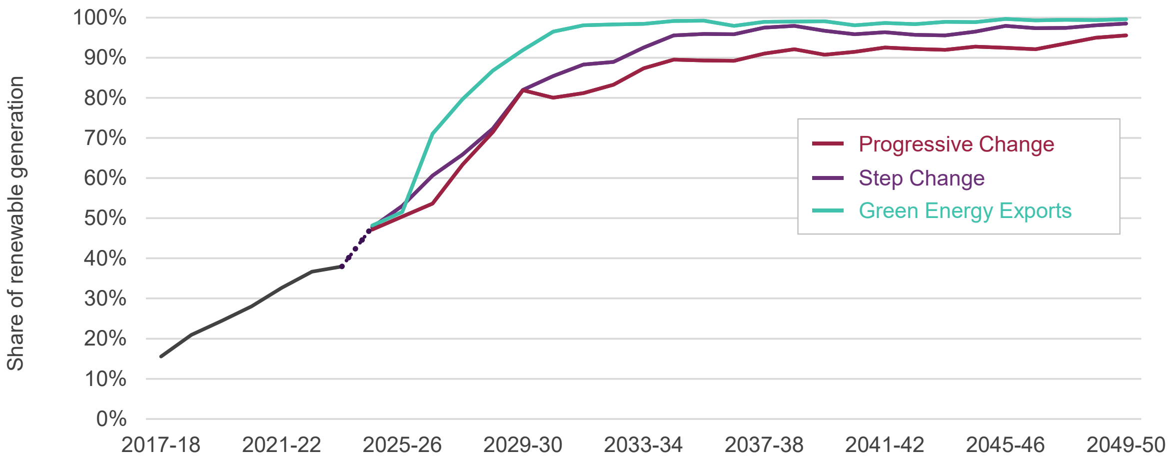
The potential of coordinated CER is demonstrated by Project EDGE[23], a recent industry pilot in which households and businesses engaged directly or through aggregators with the wholesale electricity market. With clear information and market incentives, the project delivered financial benefits to all participating parties.

4.3 Six times today's utility-scale wind and solar

With most coal forecast to withdraw by 2034-35, the race is on for new utility-scale generation both to replace that coal capacity and to provide for tomorrow's industry and transport. As a share of annual generation, renewable energy including hydro and biomass reached 32% in 2021-22.

In the *Step Change* scenario, renewables reach almost 70% of annual generation in 2027-28 and 99% by 2049-50: see Figure 17. By 2034-35, the NEM is forecast to need approximately 83 GW of utility-scale wind and solar, and 127 GW by 2049-50. This would be six times the current NEM capacity of 21 GW, with another 5 GW committed or anticipated to be operational before the end of 2024.

Figure 17 Share of generation from renewable sources, NEM (2017-18 to 2049-50)



[23] Project EDGE (Energy Demand and Generation Exchange); see https://arena.gov.au/assets/2023/10/AEMO-Project-EDGE-Final-Report.pdf.

This means that the current rate of investment in renewables would have to accelerate. In *Step Change* around 6 GW of new capacity is needed each year until 2029-30, easing back to over 3 GW per year through the 2030s. *Progressive Change* also calls for around 4 GW each year this decade, before easing to under 2 GW per year next decade.

Mix and spread of renewable generation

Renewable energy technologies complement each other, and transmission allows the NEM to take advantage of different weather conditions across eastern Australia. While conditions may be 'dark and still' in some places, it is highly unlikely to be so everywhere, so fewer utility-scale generation and storage assets are needed for secure and reliable supply across the NEM: see Section 6.5.

Early investment favours wind, with utility-scale solar catching up to a 40% share by 2050. Wind and solar are broadly complementary: wind generates energy overnight when solar cannot, and is typically stronger in the winter months. With strong rooftop solar in place, wind is forecast to account for 70% of new utility-scale variable generation through to 2030.

Offshore wind can drive further diversity in the generation mix. Offshore wind turbines may also contribute to Australia's energy mix. They capture stronger, more consistent wind than onshore turbines. However, onshore wind is lower cost, assuming it can be sited appropriately and connected efficiently to the grid. If not, and with policy support, offshore wind may be attractive.

Spilling or curtailing surplus renewable generation

As seen in Section 6 below, grid demand and consumption are forecast to become higher in winter than in summer. The NEM's generation capacity must be able to meet higher winter demand and ensure the surplus in summer can be stored while still serving traditional summer volatility.

However, building the network, storage and system services to use or store every last watt of power makes little financial sense. It would be more efficient to curtail generation when there are security constraints in the network, or spill generation when there is over-abundant renewable energy supply.

Approximately 20% of renewable generation is forecast to be spilled or curtailed in 2050. Further market reform is required to ensure incentives are in place for investors to develop an optimal level of capacity.

4.4 Renewable energy zones to efficiently connect renewables

Much of the new renewable generation would be built in REZs now being established in all NEM regions: see Figure 18 below in Section 5.1. They are selected for the quality of their renewable resource, and their proximity to consumers, existing transmission and available skilled workforces.

The REZs are a place-based way to build and coordinate electricity assets, with a more holistic approach to the needs of the energy transition and the aspirations of regional communities.

Efficient clusters of renewable energy development

If well planned and supported by appropriate social licence, REZs can:

- greatly reduce the overall cost and disruption of the energy transition, and deliver significant regional benefits,
- meet the needs of the power system, with better grid reliability and security, and the option to scale up to address the future needs of the power system,
- allow for more coordinated and effective community consultation,
- share the costs of transmission, connection and support infrastructure (such as weather observation stations) across multiple projects,
- promote regional expertise and employment over long periods to build and maintain generation and storage assets and the equipment needed to ensure power system security, and
- reduce the community, environmental and aesthetic impacts of state-wide development.

REZ candidates were initially developed for the 2018 ISP[24], and have been updated, refined and added to through both the ISP and state-based consultation processes: see Appendix 3. State energy infrastructure planners have engaged with relevant communities on both high-level and detailed REZ planning and development. The industry is conscious that these communities weigh both the economic and social benefits and the potential costs and risks of this investment: see Section 8.3.

REZ and network design to optimise capacities

The details for each of the 43 considered REZs in the NEM are set out in Appendix 3. These include an assessment of the REZ's solar and wind resource, forecast generation capacity, transmission implications, climate and event risks, and forecast curtailment and spill levels.

By state, the needs forecast in the *Step Change* scenario are:

- **New South Wales: 34 GW new utility-scale wind and solar by 2049-50.** Resource diversity will be opened by new networks, with an even mix of wind and solar across the state. Over 15 GW new generation capacity in Central-West Orana, 13 GW in New England, 3.2 GW in South West New South Wales, and 2.5 GW in Hunter-Central Coast by 2050. No offshore wind is yet forecast for New South Wales.
- **Queensland: 43 GW new utility-scale wind and solar by 2049-50**. The CopperString 2032 and Queensland SuperGrid upgrades allow new renewables in North Queensland (6 GW), Isaac (9 GW, mainly solar), Fitzroy (11 GW, mainly solar), Darling Downs (12 GW of solar and wind). REZs in the south of the state are forecast to make use of existing network capacity as coal retires.

[24] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/isp/2018/integrated-system-plan-2018_final.pdf.

- **South Australia: close to 10 GW new utility-scale wind and solar by 2049-50**. Almost 10 GW of new renewables are forecast for the region by 2050. Expansion of the Mid-North South Australia REZ is needed in the late 2020s to access mid-north wind and northern solar.
- **Tasmania: over 3.2 GW of new onshore wind by 2049-50**, with no offshore wind. Project Marinus and the Central Highlands REZ are established from 2029-30 onward.
- **Victoria: 23 GW new utility-scale wind and solar by 2049-50 including 9 GW offshore wind.** Increased network capacity from Victoria – New South Wales Interconnector West (VNI West) and Western Renewables Link (WRL) allows more wind in Western Victoria and solar in Murray River REZs. Offshore wind can access the network capacity vacated by retiring coal generation in the La Trobe Valley, and delays need for network upgrades in other REZs.

5 Actionable and other network investments

Renewable energy **connected by transmission** and distribution, firmed with storage and backed up by gas-powered generation is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy.

Section 4 detailed the renewable resources needed to meet consumer demand efficiently as coal generation retires, at the same time as industry and households switch to electricity from coal, petrol and gas fuels.

New transmission and modernised distribution networks are needed to connect these diverse low-cost resources to homes, businesses and industry in our towns and cities. The transmission network brings electricity where it is needed, when it is needed, and improves the power system's resilience. Modernised distribution networks then deliver that electricity to homes and businesses, and take back any surplus from consumers' own assets.

Transmission planners make the most of the existing network before considering new projects, for example by working with distribution planners to use capacity in the lower-voltage network, and by using real-time weather monitoring to maximise line use.

This section describes the transmission projects proposed by the ODP, covering:

- **5.1** An overview of the forecast transmission needs for the NEM, including a map and listing of the projects that will deliver those needs.
- **5.2** Listing of projects already committed or anticipated.
- **5.3** Details of projects that are identified as actionable in this ISP.
- **5.4** Potential future projects.

These transmission projects link the utility-scale generation assets to the distribution network, and to the ODP's storage and firming assets set out in Section 6.

This period of increased investment in transmission is the first of its kind in at least 25 years, and brings significant consumer and economic benefits: see Section 7.1. Delivery at this scale depends on earned social licence, a dependable supply chain and a skilled workforce. Not securing any one of these will materially risk the timely delivery of the ODP: see Section 8.3.

Appendix 5 sets out full details of the transmission projects, including their identified need as required by the NER.

5.1 Overview of transmission projects over the forecast period

As with the 2022 ISP, the 2024 ISP forecasts that close to 10,000 km of transmission will be needed by 2050 under the *Step Change* and *Progressive Change* scenarios. About 5,000 km of this transmission delivery is in the next decade, creating about 4,000 km of new transmission corridors and upgrading about 1,000 km of existing lines.

If Australia is to pursue the more transformational *Green Energy Exports*, then over twice as much transmission would be needed, delivered at a much faster pace.

The transmission projects that form part of the ODP are listed in Table 4, and set out visually in Figure 18 below. They are categorised as:

- **Five committed or anticipated projects** that are already underway. These make up about half of around 5,000 km of new transmission to be delivered in the next decade, and proponents advise they will be at full capacity before the end of 2029.
- **Twelve actionable projects**, five of which were previously actionable and remain so and are advancing, with seven more projects now progressed to actionable status. This will ensure the critical engagement associated with the initial investigation of these projects can start sooner. There is a clear need for earlier engagement with communities hosting infrastructure to allow for more coordinated and effective consultation.
  - Work on these should continue or commence as soon as possible under the ISP framework (actionable ISP projects) or the relevant state approvals framework. These projects will provide the other half of the transmission needed over the next decade, and the proponents have advised they could be delivered and at full capacity by early 2033.
- **A set of future ISP projects in each state**. Future ISP projects are forecast in the ISP to be an actionable ISP project in the future. Future projects will deliver net market benefits to consumers but are not needed until later in the horizon. AEMO may require proponents to undertake preparatory activities to enable more detailed consideration in the next ISP.

The actionable and future ISP projects on the ODP are selected by AEMO to meet power system needs and optimise market benefits to the NEM[25]. The optimal timings would give greater market certainty and enhanced power system resilience as coal retires, allow time for appropriate community co-design of project implementation, and allow flexibility in the procurement of expertise, materials and equipment. However, the actual projects and delivery dates depend on market development, the application of the RIT-T, supply-side issues, resourcing, and other factors that TNSPs must manage.

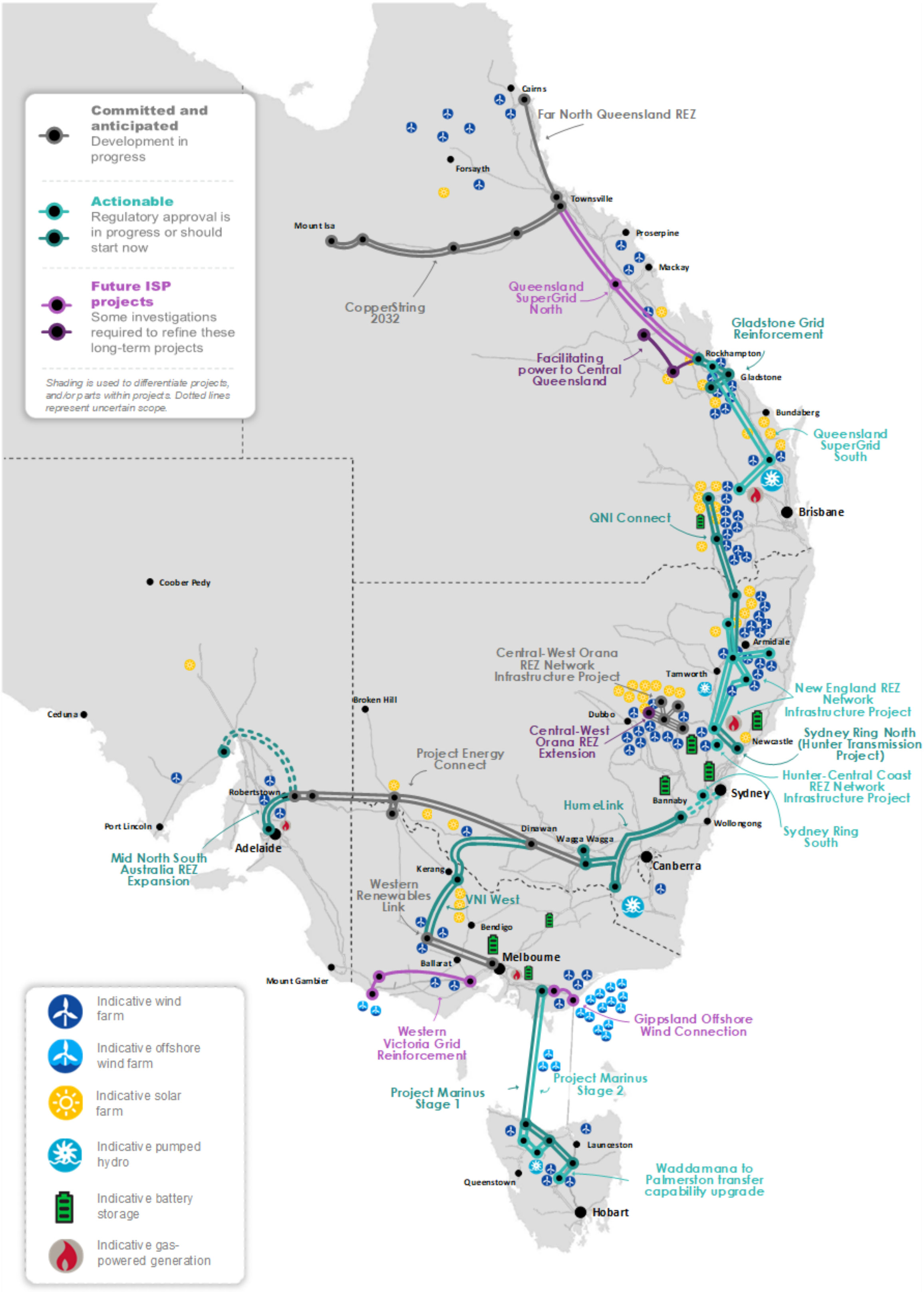
[25] The ISP must specify the identified need for each project (NER r 5.22.6(a)(6)(v)), with credible options able to be implemented in sufficient time to meet the identified need (r 5.15.2(a)).

Table 4 Network projects in the 2024 ISP optimal development path

Committed and anticipated ISP projects		In service timing advised by proponent	Full capacity timing advised by proponent[A]
Far North Queensland REZ		June 2024	June 2024
Project EnergyConnect		Stage 1: September 2024 Stage 2: May 2026	Stage 1: December 2024 Stage 2: July 2027
Western Renewables Link (uprated)[B]		July 2027	July 2027
Central West Orana REZ Network Infrastructure project		January 2028	August 2028
CopperString 2032		June 2029	June 2029
Already actionable projects *(confirmed in this ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent[A]**
HumeLink	ISP	Northern: July 2026 Southern: December 2026	Northern: July 2026 Southern: December 2026
Sydney Ring North (Hunter Transmission Project)	NSW[C]	December 2028	December 2028
New England REZ Network Infrastructure Project	NSW[C]	Part 1: June 2031 Part 2: June 2033	Part 1: June 2031 Part 2: June 2033
Victoria – New South Wales Interconnector West (VNI West)	ISP	December 2028	December 2029
Project Marinus[D]	ISP	Stage 1: June 2030 Stage 2: June 2032	Stage 1: December 2030 Stage 2: December 2032
Newly actionable projects *(as identified in this ISP)*	**Actionable framework**	**Earliest feasible in service timing**	**Earliest feasible full capacity timing[A]**
Hunter-Central Coast REZ Network Infrastructure Project	NSW[C]	December 2027	December 2027
Sydney Ring South	ISP	September 2028	September 2028
Gladstone Grid Reinforcement	QLD[E]	March 2029	March 2029
Mid North South Australia REZ Expansion	ISP	July 2029	July 2029
Waddamana to Palmerston transfer capability upgrade	ISP	July 2029	July 2029
Queensland SuperGrid South	QLD[E]	September 2031	September 2031
Queensland – New South Wales Interconnector (QNI Connect)	ISP	April 2032	March 2033
Future ISP projects			
New South Wales	Central West Orana REZ Expansion, Cooma-Monaro REZ Expansion.		
Queensland	Darling Downs REZ Expansion, Facilitating Power to Central Queensland, North Queensland Energy Hub Expansion, Queensland SuperGrid North[E].		
South Australia	Mid North South Australia REZ Extension.		
Tasmania	North West Tasmania REZ Expansion, Central Highlands REZ extension.		
Victoria	Western Victoria Grid Reinforcement, Eastern Victoria Grid Reinforcement, Gippsland Offshore Wind Connection.		

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. The scope of this project, which will unlock renewable energy resources, reduce network congestion, and improve utilisation of existing assets in western parts of Victoria, was updated as an outcome of the VNI West options analysis, resulting in a higher capacity and harnessing 1,460 MW of renewable capacity rather than the original design of 600 MW.
C. These projects will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.
D. Project Marinus is a single actionable ISP project without decision rules.
E. These projects will progress under the *Energy (Renewable Transformation and Jobs) Act 2024* (Qld) rather than the ISP framework.

Figure 18 Transmission projects in the optimal development path



This map shows indicative new generation and storage in 2040, and transmission projects that include new transmission lines, increase capacity by 500 MW or more, and are required in all scenarios by 2050.

Total transmission, by scenario

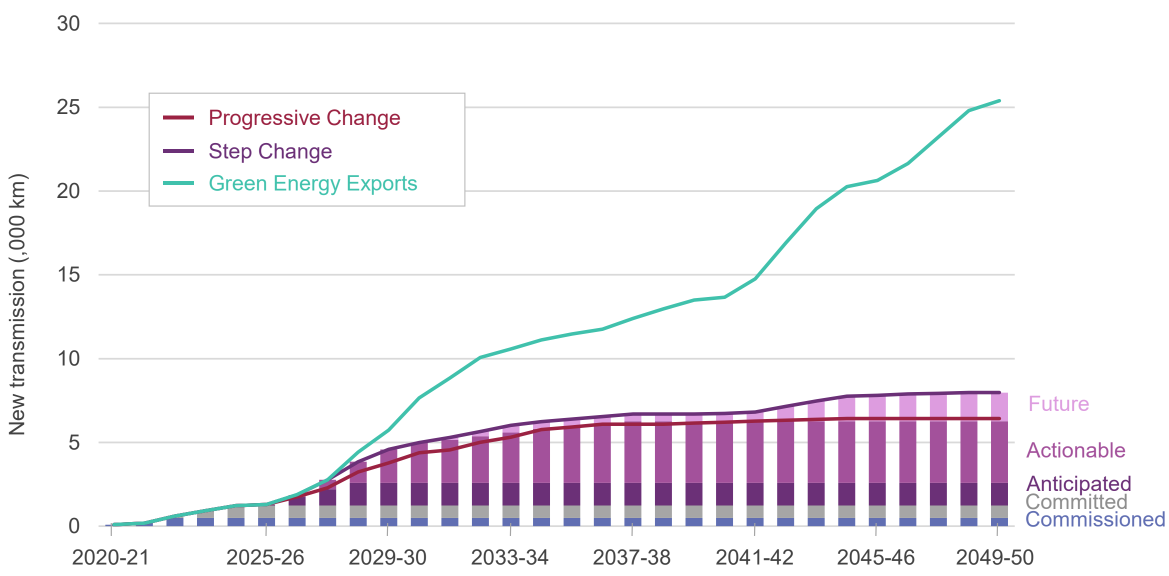
The *Step Change* and *Progressive Change* scenarios have similar needs for new transmission until the early 2040s, though delivered marginally slower in *Progressive Change*: see Figure 19.

Both *Step Change* and *Progressive Change* scenarios require around 5,000 km of transmission to be delivered over the next decade, about half of which is already underway as committed or anticipated projects. Around 10,000 km is needed by 2050. After the next decade, more capacity is expected from sources such as CER, storage and offshore wind that require less transmission for their connection. Future ISPs will continue to reassess the most cost-effective balance between transmission and the other system elements.

In *Green Energy Exports*, the NEM would support major new export industries: green energy exported as hydrogen or used to power low-emission heavy industry. This would require hydrogen electrolysers near existing export ports, served by associated transmission. The less likely *Green Energy Exports* would require 10,000 km of network in the next decade, and a total of 26,000 km through to 2050, with the additional capacity focused on areas useful for export such as ports.

The ODP contains largely the same major transmission projects as in the 2022 ISP, and the two ISPs before that. Projects have been refined to incorporate new information about potential routes, updated options and stakeholder feedback, but overall the plan remains broadly similar.

Figure 19 New transmission in least-cost development paths (km, 2020-21 to 2049-50)



5.2 Committed and anticipated projects

These projects already have regulatory approval and are highly likely to proceed. They are included in the modelling for all development paths, scenarios and sensitivities:

- **committed network projects** meet all five commitment criteria[26] (site acquisition, components ordered, planning approvals, finance completion and set construction timing), and
- **anticipated network projects** are in the process of meeting at least three of those criteria.

Table 5 Committed and anticipated network projects in the ODP

Status	Project	Description	Full capacity timing (advised by proponent)
Committed	**Far North Queensland REZ**	Uplift of an existing 132 kilovolts (kV) circuit into Woree to 275 kV.	June 2024, Powerlink
Committed	**Project EnergyConnect**	A new 330 kV double-circuit interconnector between South Australia and New South Wales, with a new 220 kV double-circuit line to Victoria.	Stage 1 December 2024 and Stage 2 July 2027[A], Transgrid, ElectraNet and AusNet Services
Anticipated	**Western Renewables Link (uprated)[B]**	A 500 kV double-circuit network upgrade to provide additional capacity to the Western Victoria REZ, including updated project scope to relocate a terminal station and increase the line capacity.	July 2027, AEMO Victoria Planning
Anticipated	**Central-West Orana REZ Network Infrastructure Project**	A network upgrade consisting of 500 kV and 330 kV circuits to provide additional capacity to the Central-West Orana REZ.	August 2028, EnergyCo
Anticipated	**CopperString 2032[C]**	An 840 km new double-circuit line to connect Queensland's North-West Minerals Province to the NEM near Townsville, as announced by the Queensland Government.	June 2029, Powerlink

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. The scope of this project, which will unlock renewable energy resources, reduce network congestion, and improve utilisation of existing assets in western parts of Victoria, was updated as an outcome of the VNI West options analysis, resulting in a higher capacity and harnessing 1,460 MW of renewable capacity rather than the original design of 600 MW.
C. CopperString 2032 will be built and owned by the Queensland Government, under the Queensland Energy and Jobs Plan commitment to public ownership of the state's transmission assets, and was not actioned through the ISP framework.

5.3 Actionable projects

Actionable projects are listed in Table 6, including delivery dates provided by project proponents. Appendix 5 provides detailed technical information on each project, including the identified need, progress and next steps, and optimal timing to optimise benefits for consumers consistent with the ISP modelling used to derive the ODP.

All actionable projects should progress as urgently as possible. Although Table 6 provides the project proponents' delivery dates, the optimal timing under the ODP may be earlier or later. Earlier

[26] In accordance with the AER's Cost Benefit Analysis Guidelines, at https://www.aer.gov.au/system/files/AER%20-%20Cost%20benefit%20analysis%20guidelines%20-%2025%20August%202020.pdf.

delivery would provide valuable insurance against early coal closures or if the development of generation and storage slows.

For projects actioned under the ISP framework, the proponent must assess the project under the regulatory investment test for transmission (RIT-T) as detailed below. For projects actioned under the ISP framework in this 2024 ISP, AEMO calls for nomination of non-network options and publication of Project Assessment Draft Reports (PADRs) by the dates set out in Table 6. For those actioned under state frameworks, the processes in that legislation apply.

Table 6 Actionable network projects in the optimal development path

Project	In service timing advised by proponent	Full capacity timing advised by proponent[A]	Brief description Cost estimates in $2023	Actionable framework *Non-network options date[B]* *PADR date[C]*
HumeLink[D]	Northern July 2026 Southern December 2026	Northern July 2026 Southern December 2026	A 500 kV transmission upgrade connecting Project EnergyConnect and the Snowy Mountains Hydroelectric Scheme to Bannaby. $4,892 million (-5% to +12%).	ISP
Hunter-Central Coast REZ Network Infrastructure Project	December 2027	December 2027	Substation upgrades[E] to supply generation from the Hunter and Central Coast to Sydney, Newcastle and Wollongong load centres. $59 million (±50%).	New South Wales[F]
Sydney Ring South	September 2028	September 2028	A switching station and modular power flow controllers to reinforce supply to Sydney, Newcastle and Wollongong load centres. $221 million (±50%).	ISP *18 September 2024* *30 June 2025*
Sydney Ring North *(Hunter Transmission Project)*	December 2028	December 2028	High capacity 500 kV transmission network to reinforce supply to Sydney, Newcastle and Wollongong load centres. $1,099 million (±50%).	New South Wales[F]
Gladstone Grid Reinforcement	March 2029	March 2029	Increase network capacity from Central Queensland into the Gladstone area to support the area's industry once Gladstone Power Station retires, and add capacity between Northern and Southern Queensland. $1.3 billion (±50%).	Queensland[G]

Project	In service timing advised by proponent	Full capacity timing advised by proponent[A]	Brief description Cost estimates in $2023	Actionable framework *Non-network options date[B]* *PADR date[C]*
Mid North South Australia REZ Expansion	July 2029	July 2029	New 275 kV and 132 kV transmission lines to connect renewable generation to Adelaide and to supply increasing industrial load. $389 million (±50%).	ISP *18 September 2024* *1 December 2025*
Waddamana to Palmerston transfer capability upgrade	July 2029	July 2029	New 220 kV transmission line[H] to connect renewable generation to Hobart, as well as mainland Australia. $201 million (±30%).	ISP *18 September 2024* *26 June 2025*
Victoria – New South Wales Interconnector West (VNI West)[I]	December 2028	December 2029	A new high capacity 500 kV double-circuit line to connect Western Renewables Link (from Bulgana) with Project EnergyConnect and HumeLink (at Dinawan) via a new substation near Kerang. $3.6 billion (±30%).	ISP
Project Marinus[J]	Stage 1 June 2030 Stage 2 June 2032	Stage 1 December 2030 Stage 2 December 2032	Two new high voltage direct current (HVDC) cables connecting Victoria and Tasmania, each with 750 MW of transfer capacity and associated alternating current (AC) transmission, to enable more efficient power sharing between these regions. HVAC network assets in Tasmania for REZs under the North West Transmission Developments project. Stage 1: $3.8 billion (±30%). Stage 2: $2.7 billion (±30%).	ISP
New England REZ Network Infrastructure project	Part 1 June 2031 Part 2 June 2033	Part 1 June 2031 Part 2 June 2033	Three separate projects to increase the transfer capability between central and northern New South Wales, enable more transfer capacity out of the Queensland New South Wales Interconnector, and expand the New England REZ. $3.7 billion (±50%). This cost estimate includes	New South Wales[F]

Project	In service timing advised by proponent	Full capacity timing advised by proponent[A]	Brief description Cost estimates in $2023	Actionable framework *Non-network options date[B]* *PADR date[C]*
			the three separate projects.	
Queensland SuperGrid South	September 2031	September 2031	Stage 2 of the Queensland SuperGrid, under the Queensland Energy and Jobs Plan, to greatly increase the transfer limit between Central and Southern Queensland and connect to the Borumba Pumped Hydro project. $3.3 billion (±50%).	Queensland[G]
Queensland – New South Wales Interconnector (QNI Connect)	April 2032	March 2033	Add capacity between southern Queensland and New England, following development of the New England REZ Network Infrastructure project. $2,518 million (±50%).	ISP *18 September 2024* *25 June 2026*

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. AEMO invites submission of non-network options for newly actionable ISP projects by this date.
C. AEMO requires publication of a PADR by the project proponent by this date.
D. 'Northern' is between Bannaby and Gugaa. 'Southern' is between Bannaby and Maragle, and Maragle and Gugaa.
E. Actual scope and cost of Hunter-Central Coast REZ will be determined through EnergyCo's procurement process.
F. These are actionable New South Wales projects. They will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework.
G. These are actionable Queensland projects. They will progress under the *Energy (Renewable Transformation and Jobs) Act 2024* (Qld) rather than the ISP framework.
H. This cost estimate covers only section of the scope which is not already covered by Project Marinus Stage 1. As the optimal timing of this project is before Project Marinus Stage 1, the 220 kV double circuit Palmerston to Sheffield line is expected to be built before Project Marinus Stage 1.
I. The scope of this project excludes Western Renewables Link uprate project.
J. Project Marinus includes MarinusLink and North West Transmission Developments (NWTD) projects. Stage 1 refers to Cable 1 and associated NWTD works, and Stage 2 refers to Cable 2 and associated NWTD works. Project Marinus is a single actionable ISP project without decision rules.

5.4 Future projects

Future ISP projects will deliver net market benefits to consumers, and are forecast to be actionable in the future. The projects and their timings are identified in Table 7 below and detailed in Appendix 5. The timings are indicative, as they will depend on which scenario unfolds in future.

If a project is intended to proceed under the ISP framework, a RIT-T is not required yet. Proponents may start planning and engaging with communities now, if appropriate, to ensure the projects optimise long-term benefits for consumers.

Table 7 Future ISP projects in the optimal development path

Project	Optimal timing *Step Change*	Earliest feasible full capacity timing	Brief description Cost estimate in $2023
New South Wales			
Central-West Orana REZ Extension	2036-37	2030-31	Expand Elong Elong substation to enable additional Central-West Orana REZ capacity following initial Network Infrastructure Project (Anticipated project). $243 million (±50%).
Cooma-Monaro REZ Expansion	2046-47	2030-31	Enable Cooma-Monaro REZ capacity. $512 million (±50%).
Queensland			
Facilitating Power to Central Queensland	2033-34	2030-31	Enable Northern Queensland and Isaac and Barcaldine REZ capacity, and transmission to Central Queensland. $173 million (±50%).
Darling Downs REZ Expansion	2034-35	2027-28	Enable Darling Downs REZ capacity. $28 million (±50%).
North Queensland Energy Hub Extension	2043-44	2030-31	Enable further capacity in North Queensland Clean Energy Hub REZ. $651 million (±30%).
Queensland SuperGrid North	Timing dependent on Queensland Government policy decisions	2032-33	Add transfer capacity between Central and North Queensland, and enable capacity in northern Queensland REZs. $4,184 million (±50%).
South Australia			
Mid-North REZ Extension	Option 1b: 2045-46 Option 1a: 2048-49	Option 1b: 2029-30 Option 1a: 2029-30	Enable capacity in Mid North, Yorke Peninsula, Leigh Creek, Roxby Downs, Eastern Eyre and Western Eyre Peninsula REZs to supply the Adelaide region. $70 million (±50%) for Option 1b. $350 million (±50%) for Option 1a.
Tasmania			
North West Tasmania REZ Expansion	2034-35	2029-30	Enable capacity in North West Tasmania REZ, connecting to Project Marinus Stage 1 and Hampshire Hills. $28 million (±30%).
Central Highlands REZ Extension	2042-43	2032-33	Extend Central Highlands REZ capacity. $274 million (±30%)
Victoria			
Western Victoria Grid Reinforcement	2033-34	2032-33	Enable capacity in South-West Victoria REZ. $1,140 million (±30%).
Eastern Victoria Grid Reinforcement	2035-36	2030-31	Add transfer capacity between Latrobe Valley and Melbourne to accommodate increased onshore and new offshore wind power generation. $297 million (±50%).
Gippsland Offshore Wind Connection	Consistent with offshore wind targets		VicGrid is coordinating shared transmission to support offshore wind energy in Victoria.

6 Storage and gas to firm renewables

Renewable energy connected by transmission and distribution, **firmed with storage and backed up by gas-powered generation** is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy.

As solar and wind are variable resources, different forms of storage and firming are needed across the NEM to smooth out the peaks and troughs in renewable generation.

Storage technologies (which include battery and pumped hydro systems) store electricity when supply is greater than demand, then release or 'dispatch' it when needed. The time between storage and dispatch is a time 'shift' in electricity supply.

Firming technologies include storage, hydro, gas and other fuelled generation. They help maintain grid stability and inertia, smooth out volatile frequencies, and balance out fast changes in supply and demand. Gas generation also provides back-up supply during long periods of 'dark and still' renewable droughts and times of extreme peak demand, particularly in winter.

These technologies play different yet overlapping roles. The ISP seeks the most efficient balance between them to meet its reliability, affordability and emission priorities. This is then balanced with transmission: the less transmission there is, the more firming capacity is needed, and vice versa.

Section 6 sets out how the optimal development path would provide:

6.1 **Storage of varied depths and technologies**, able to time-shift electricity supply for up to 4 hours, 12 hours, or longer.

6.2 **Storage for intra-day shifting**, including consumer-owned batteries, and shallow and medium utility-scale storage.

6.3 **Storage for seasonal shifting and renewable droughts**, including pumped hydro and hydro generation, with new potential technologies emerging.

6.4 **Flexible gas generation** to support storages during renewable droughts and cover rare peak demand spikes.

6.5 **Reliability and security in a renewable energy power system**, secured through the range of solutions to provide system services traditionally provided by coal.

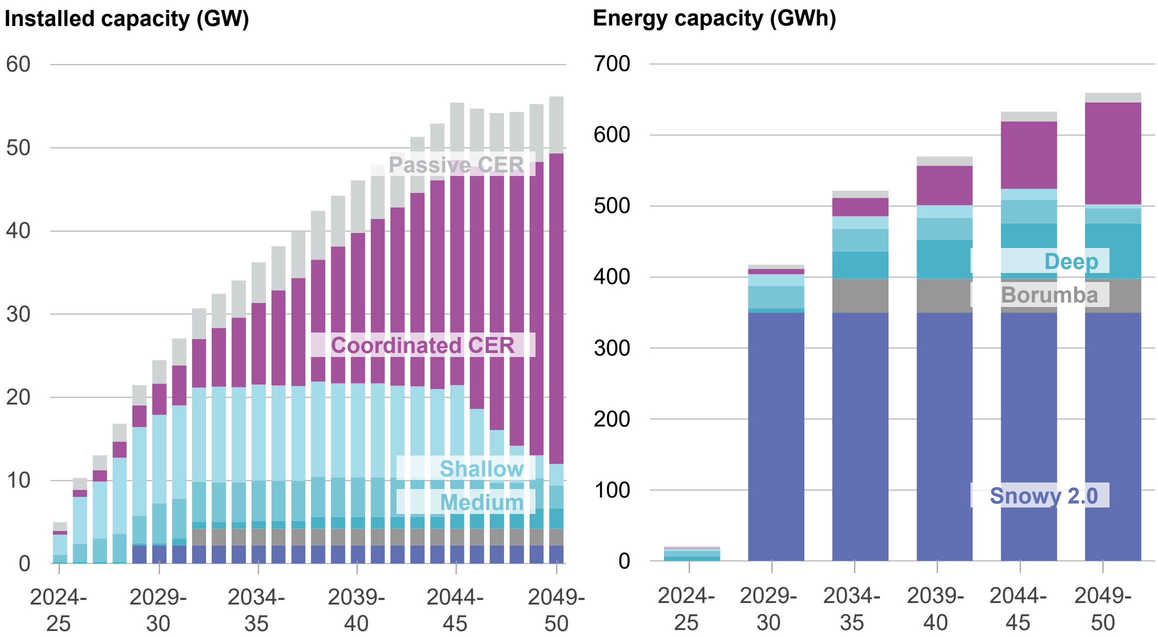
This section completes a description of the ISP's optimal development path. Section 7 then sets out why this path has been chosen as the lowest-cost way to securely and reliably supply electricity to homes and businesses as Australia transitions to a net zero economy.

6.1 Storage of varied depths and technologies

Different forms of storage are needed to firm both consumer-owned and utility-scale renewables at different times of the day and year. These vary according to their 'depth', that is, the length of time that electricity can be dispatched at maximum output before the stored energy is exhausted.

In total, the NEM is forecast to need 36 GW/522 GWh of storage capacity in 2034-35, rising to 56 GW/660 GWh of storage capacity in 2049-50.

Figure 20 Storage installed capacity and energy storage capacity, NEM (2024-25 to 2049-50, *Step Change*)



The broad categories used by AEMO are:

- **Consumer-owned storage** (or distributed or CER storage): behind-the-meter household, business or industrial batteries, including EVs that may be able to send electricity back into the grid. **Coordinated CER storage** is managed as part of a VPP, while **passive CER storage** is not. While the combined installed capacity of these batteries is large, they can only dispatch electricity for about two hours at full discharge, so their energy storage capacity is relatively small, and deeper, utility-scale storage is needed.
- **Shallow storage**: grid-connected storage to dispatch electricity for less than four hours, valued for both their system services and their energy value.
- **Medium storage**: to dispatch electricity for four to 12 hours. This may be battery or pumped hydro (or other emerging technologies in future) which can shift large quantities of electricity to meet evening or morning peaks. These solutions are increasingly needed to support renewable energy growth.

- **Deep storage:** strategic reserves that can dispatch electricity for more than 12 hours, to shift energy over weeks or months (seasonal shifting) or cover long periods of low sunlight and wind (renewable droughts), backed up by gas-powered generation. Borumba's anticipated 48 GWh capacity in Queensland would be larger than all coordinated CER storage combined, and Snowy 2.0 would provide 350 GWh.

6.2 Storage for intra-day shifting

Intra-day shifting can be achieved through both consumer-owned storage and shallow utility-scale storage, with the latter also focused on power system services.

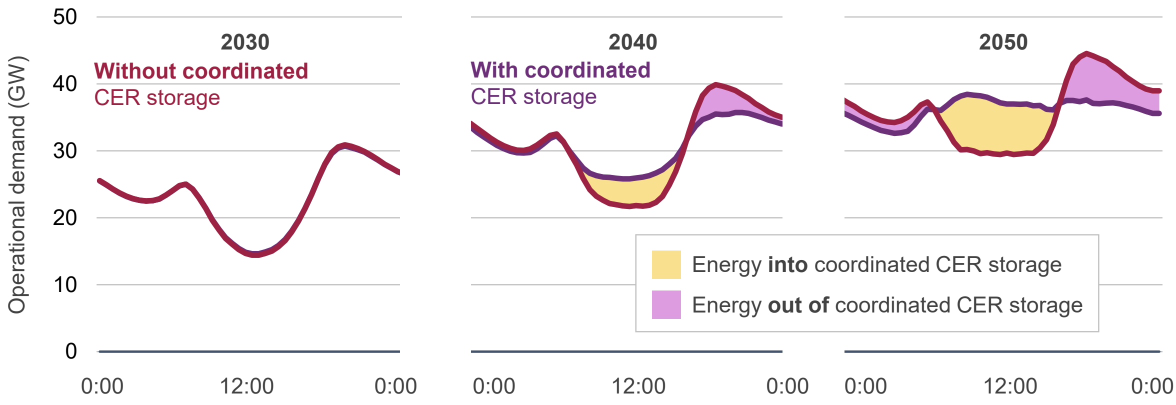
In total, approximately 17.9 GW of utility-scale storage is forecast to be needed by 2030, with an optimal mix of 2.4 GW as deep, 4.8 GW as medium and 10.7 GW as shallow storage: see Figure 20 above.

Growth in consumer energy resources

For the NEM as a whole, the three charts in Figure 21 below show the rising impact of coordinated consumer-owned solar and batteries on forecast hour-by-hour grid demand. With the assumption of coordination, they help smooth out the NEM operational demand curve considerably.

As the sun rises, rooftop solar starts to meet demand, and then generates excess supply (the yellow 'belly' of the 'duck'-shaped demand profile). That excess may be stored for later use during the evening peaks and into the night, or shared with local consumers to reduce the community's need from the grid at that time.

Figure 21 Impact of coordinated CER on average operational demand by time of day, NEM (GW, 2030 to 2050, *Step Change*)



Consumers may take advantage of financial incentives to add smart functionality and coordinate their batteries through VPPs, so that they can help balance supply and demand across the grid. The success of trials such as Project EDGE will help build consumer confidence to do so.

The capacity of these coordinated CER storages is forecast to rise from today's 0.2 GW to 3.7 GW in 2029-30, and then 37 GW in 2049-50 – by then making up 66% of the NEM's energy storage capacity. Without effective orchestration of consumer batteries, around $4.1 billion of additional grid-scale investment would be needed, increasing total power system costs to consumers: see Appendix A2.

Growth in utility-scale batteries

Many utility-scale batteries are already installed across the NEM, with a large pipeline being developed or seeking connection to the grid. These batteries are designed to dispatch electricity instantaneously, and so support grid security with frequency control ancillary services (FCAS) as well as storing excess electricity: see Section 6.5 below.

In future, the longer-duration role will also be served by pumped hydro storage, and potentially by emerging technologies like advanced compressed air energy storage, gravitational storage, flow batteries and concentrated solar thermal systems.

While batteries are relatively low cost to install, they also have a relatively short operational lifespan. Batteries installed through the 2020s are likely to need replacing in the 2040s. This explains the drop in shallow storage in that decade, in Figure 20 above. By then, deeper storage options may be needed to cover the more volatile winter season, while summer needs are met by the growth in solar. These solutions are forecast to include flexible gas generation capable of providing sustained support during renewable droughts.

6.3 Storage for seasonal shifting and renewable droughts

Deep storage, able to dispatch electricity for more than 12 hours continuously, can smooth out day-to-day variations in demand and renewable supply. The deepest storages available to the NEM are the existing deep-reservoir hydro assets, which can also mitigate renewable droughts and balance energy availability across seasons. New transmission such as HumeLink and Project Marinus gives the NEM better access to these assets.

A number of government programs support the development of new deep (or medium) storage, but at this stage only Snowy 2.0 (serving New South Wales and Victoria), Borumba and Kidston (both in Queensland) are committed or anticipated.

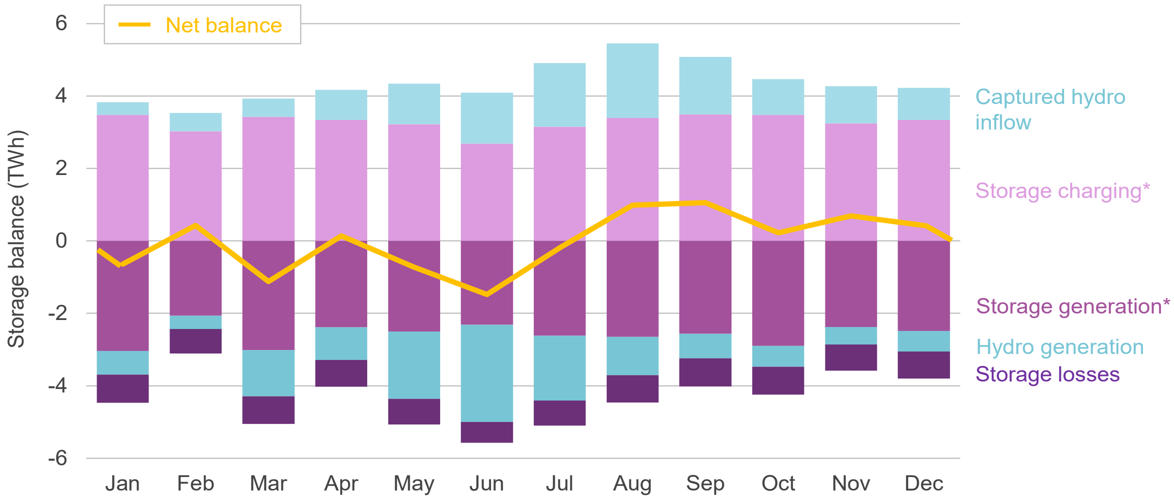
Queensland is also considering a deep Pioneer-Burdekin project, Hydro Tasmania is investigating a new pumped hydro Battery of the Nation initiative at Cethana, and New South Wales has legislated a 2 GW target for storage of at least 8 hours duration by 2030.

Figure 22 shows an ‘average’ future year to demonstrate the key role that traditional hydro and storage play across seasons. In summer, the NEM system is almost in balance across the months, with any used storage being replenished by solar. Into autumn, with typically more variable winds and decreasing sunlight, more energy starts to be drawn from hydro reservoirs. These will play their biggest role in winter, supported by gas, when heating demands are high, solar is reduced, and wind can be strong but intermittent. In June, storage and hydro generation would supply around 5 TWh of electricity across the NEM, drawing down water reservoirs to low levels. Through

August and into spring, snowmelt and higher rainfalls replenish those dams. Solar starts to generate again more than is consumed, bringing the system back into balance.

Forecasting both energy demand and weather can never be perfect. It is prudent to provide a buffer of deeper solutions to add resilience against known yet unpredictable risks. Market and policy settings will need to evolve to enable deep storage solutions with cost recovery mechanisms that are not limited to actual usage.

Figure 22 Storage and hydro energy balances, NEM (TWh, 2040, Step Change)



* Pumped hydro included as large-scale storage, not as hydro

6.4 Flexible gas for renewable droughts and peaking

Electricity from gas-powered generation is forecast to continue its important role in the NEM. After coal-fired generators retire, gas will be needed to support energy supply during periods of renewable drought (see Section 6.5) and of extreme peak demand (see below). Gas supply and potentially a hydrogen alternative also need consideration.

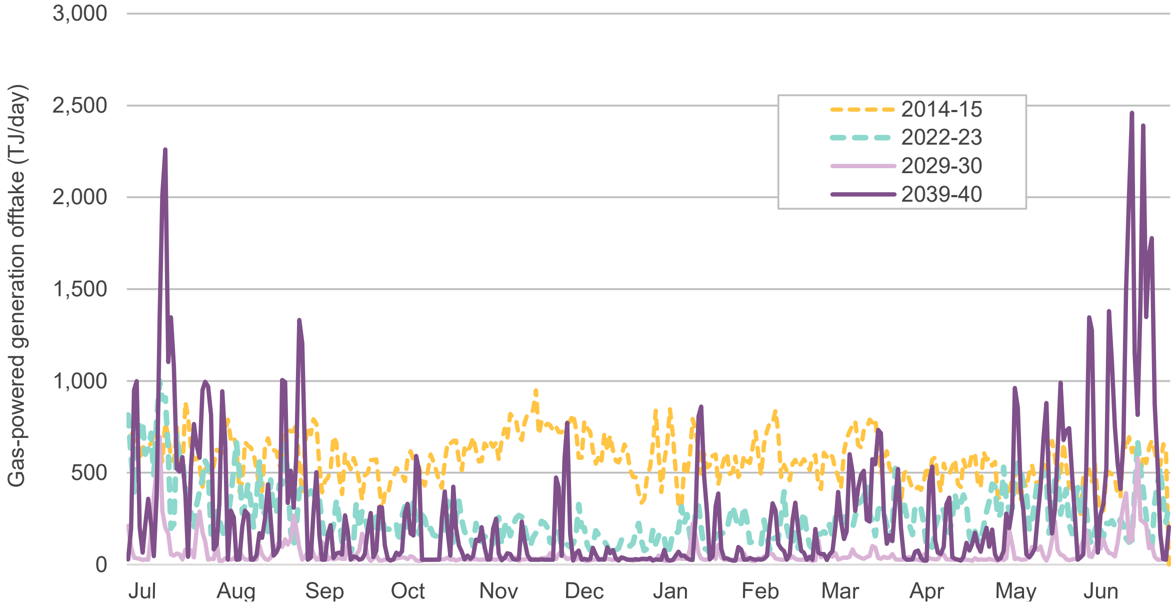
Growth in flexible gas generation

In total, the NEM is forecast to need 15 GW of gas-powered generation to ensure the NEM remains resilient under a range of power system and extreme weather events. Of the existing 11.5 GW capacity, about 9.3 GW is forecast or announced to retire, so that capacity would be replaced and another 3.5 GW added. This may be either as greenfield or brownfield development, but the gas generation must be flexible.

This gas generation is a strategic reserve for power system reliability and security, so is not forecast to run frequently. A typical gas generator may generate just 5% of its annual potential, but will be critical when it runs. Most of that will be needed to support some winter days of low renewable energy output, as discussed in Section 6.3 above.

This is a change in the role of gas-powered generation from more continuous 'mid-merit' gas to a strategic, back-up role. Figure 23 shows that change in role, from relatively stable supply in 2015 to the forecast winter peaks in 2040 and occasional use throughout the year. These peaks are forecast to test the limitations of the current gas supply network, and on-site storage or other solutions will be needed to address them during periods when delivery through the gas network is constrained.

Figure 23 Gas-powered generation offtake, NEM (TJ/day 2014-15 and 2039-40, *Step Change*)



Demand implications for gas network and secondary fuels

As more renewable generation enters the NEM, increasing the diversity of supply across the year and across the regions, an inherent tension will be necessary to manage which is that renewable energy yields are generally lower in winter, with shorter days affecting solar generators in particular. As a backup reserve to other electricity generation forms, including storage, gas generation is forecast to increasingly provide flexible operation at times when the supply-demand balance is tight. Gas for electricity generation is therefore expected to be needed most during winter, when gas demand for heating is also high. Its availability depends on gas supplies through the East Coast Gas System.

AEMO forecasts that if gas and electricity demands peak simultaneously, particularly during extreme conditions in winter affecting both electricity and gas demand, then there is a risk that gas supply to gas-powered generation may be curtailed by pipeline infrastructure constraints. Likewise, if electricity demand peaks when renewable energy availability is low, pipeline constraints may impact the capacity for gas generation to support other dispatchable reserves. During these conditions, secondary fuels (such as diesel or hydrogen) may be necessary to maintain reliable electricity supply, as well as other resources such as demand response and other storage resources.

For this reason, developing on-site secondary fuel storages, and the infrastructure to refill them as needed, will be an important consideration for future gas generation developments to support power system reliability even when delivery of gas from the network is limited. New generators should be sited with regard to potential gas network bottlenecks, the availability of secondary fuels including hydrogen, and proximity to electrical loads. Where the needed back-up generation exceeds the delivery capabilities of the East Coast Gas System, additional investments in on-site storage will be essential to provide fuel security.

Hydrogen as a potential alternative generation fuel

Hydrogen is one of several secondary fuels that could support power system reliability when gas pipeline infrastructure is constrained, and meet the need for growth of flexible gas generation. Policies in New South Wales, South Australia and Queensland are supporting investment in hydrogen-ready turbines. The 2024 ISP forecasts only a small contribution from this technology, as hydrogen is still a relatively expensive fuel to use at scale. If hydrogen becomes a cost-efficient fuel, or there is greater government support for hydrogen turbines, they will make a greater contribution.

6.5 Reliability and security in a system dominated by renewables

The challenge for the NEM power system is to be consistently reliable and secure: see Section 3.2. This becomes more challenging as the system approaches 100% renewable generation. Consumers should be confident that the NEM's mix of technologies will keep electricity supply secure and reliable during normal operation, extreme peak demand and renewable droughts.

System secure due to system services from batteries and other technologies

The heavy spinning turbines of coal, gas and hydro generators have multiple intrinsic benefits beyond their actual generation. For example:

- they spin at a rate that lines up with the electrical frequency of the power grid that they supply ('synchronous generation'),
- this, coupled with the physical spinning momentum, adds 'inertia' to help resist unwanted changes to the system frequency, and
- if a fault occurs somewhere in the system, the generators can add needed current to the system so that protections can operate until the fault can be isolated.

These 'system security services' help the power system stay stable and secure. As coal generators retire, the NEM will lose these services, and they will need to be replaced. System security services may be replicated by other technologies, for example grid batteries with advanced inverter technology, synchronous condensers[27], and gas and hydro generators that can operate in synchronous condenser mode. These solutions would produce synthetic responses to resist frequency changes, provide needed fault current, or strengthen local areas against challenging volatility and interactions: see Appendix 7[28].

[27] Synchronous condensers are synchronous machines, specially built to supply only reactive power.

[28] Note that the ISP modelling is an energy-only model and does not consider the co-optimisation of batteries for both their energy dispatch and system service roles. AEMO takes this conservative approach as it expects FCAS markets to remain of finite depth and quickly saturate as more battery projects connect.

Batteries also improve the utilisation of new and existing transmission lines. Several large-scale grid batteries[29] are contracted to provide system integrity protection services. Some of their capacity is held in reserve to inject power on short notice to help stabilise the lines and allowing the lines to operate at higher levels. This reserve can increase the capacity of congested grids, so that new renewable generation can be connected.

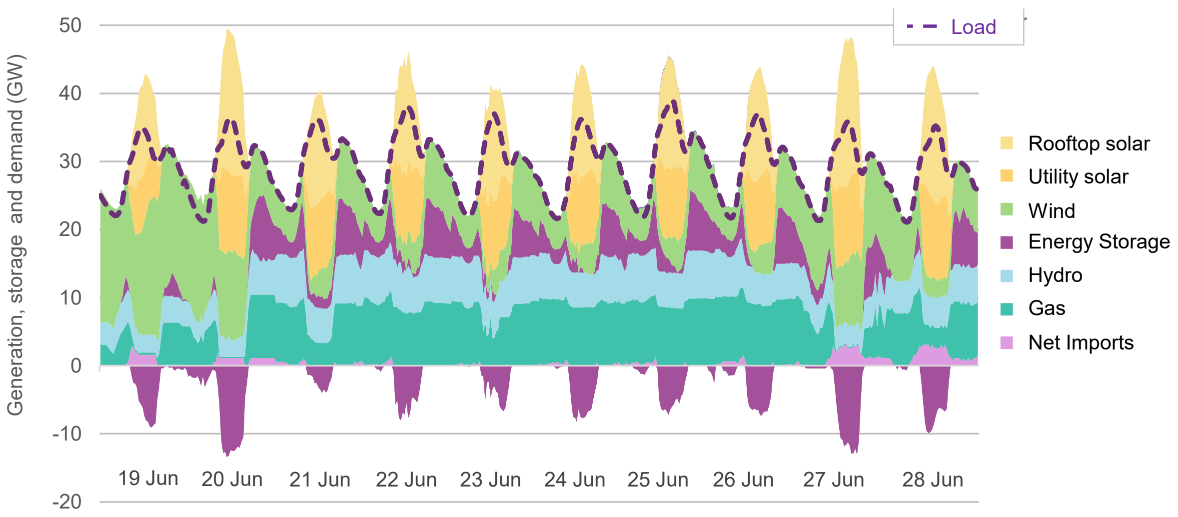
System reliable during peak demand and renewable 'droughts'

Peak demand is forecast to be met within the reliability standard throughout the entire forecast period, through combinations of renewable generation and storage, supported at times by gas-powered generators when required: see Section 6.4 above.

Renewable droughts are common, local events that typically last a few hours or a day or two, and are more likely in winter when there is less solar irradiation (energy) and shorter daylight hours. Assuming new transmission is delivered as planned, renewable resources can be shared across the NEM, so only renewable droughts that affect considerable portions of the NEM are a key concern.

Historical weather patterns suggest that longer 'dark and still' periods of up to three days covering a wide geographical area are rare, with low risk of a NEM-wide event. However, future weather may not replicate the past, especially with climate change, so there may be longer and more widespread renewable droughts. AEMO therefore tested the ODP to see whether it could meet the reliability standard through drought conditions across the southern regions of the NEM for eight days – a period at least twice as long and more severe than any since 2010, and possibly since 1980[30]. The test showed that the power system would remain reliable and secure (see Figure 24) but reliability risks would be elevated, particularly if major generator or transmission outages occur.

Figure 24 Operability through eight-day renewable drought, NEM except Queensland



[29] AEMO has contracted the Waratah Super Battery, Victorian Big Battery, Hornsdale Power Reserve and the Dalrymple Battery Energy Storage System in the System Integrity Protection Scheme (SIPS).

[30] AEMO's ISP modelling applies weather patterns from 2010-11 to 2019-20 to analyse the future operability of the power system. Wind records back to 1980 show similar average wind and a comparable spread of extremely high or low wind speed events.

7 Rationale for the ODP

Renewable energy connected by transmission and distribution, firmed with storage and backed up by gas-powered generation **is the lowest-cost way to supply electricity to homes and businesses as Australia transitions to a net zero economy**.

So far, Part B has laid out the major elements of the ISP's optimal development path: by 2050 it forecasts 127 GW of utility-scale renewables, 86 GW of rooftop solar and other distributed solar, 75 GW of firming technology, and new transmission and modernised distribution networks to connect these assets to consumers.

This section sets out how and why AEMO has determined the ODP, in accordance with the NER, the AER's Cost Benefit Analysis Guidelines, and the *ISP Methodology*. It considers:

7.1 The reliability and cost benefits of the ODP as a whole.

7.2 How the leading candidate development paths were developed and analysed following the *ISP Methodology*, and why the ODP was chosen, after testing the leading candidate development paths against changed assumptions.

7.3 Why the ODP delivers better outcomes to consumers than alternative approaches to the energy system.

Appendix 6 provides full details about the selection of the ODP.

7.1 Reliability, cost and broader benefits of the ODP

Investment in new generation, firming and transmission is essential to replace outgoing coal generation. The selected ODP ensures that the NEM continues to meet the reliability standard at the least forecast cost through Australia's energy transition. All of the transmission projects in the ODP are needed at some time.

In direct financial terms, the ODP's transmission projects would reduce costs for consumers by delivering benefits that would repay their investment costs, save consumers a further $18.5 billion in avoided costs, and deliver emissions reductions valued at $3.3 billion.

The development cost would be $16 billion[31] in net present value terms annualised to 2050, or 13% of the total $122 billion for all utility-scale generation, storage, firming and transmission infrastructure in the ODP (*Step Change* scenario to 2050)[32]. The equivalent upfront capital cost has a present value of $142 billion, as technical life remains after 2050 for long-lived assets.

[31] This value is the net present value of capital costs for transmission augmentation up to 2049-50 only.

[32] This value includes transmission augmentation, and utility-scale generation and storage capex, and does not include the cost of commissioned, committed or anticipated projects, consumer energy resources or distribution network upgrades.

In addition, the ODP investments would deliver a number of essential benefits:

- guide and provide investment certainty for $142 billion in essential capital investment, which will help sustain and grow Australia's $2 trillion annual economy and the social services on which its people depend, and create new economic and job opportunities, particularly in regional areas,
- connect emerging areas of renewable generation to regional industries and urban businesses and households, and firm up the variability of renewable energy with batteries, pumped hydro storage and gas-powered generation,
- support consumer investments in their own energy resources, which in turn would avoid $4.1 billion of additional utility-scale generation and storage,
- add energy self-reliance and insulation from global shocks to the price or supply of fossil fuels, and
- secure the flexibility to reduce emissions faster if needed.

The annualised capital cost of all utility-scale generation, storage, firming and transmission infrastructure in the ODP has a present value of $122 billion (*Step Change* scenario to 2050)[33]. The equivalent upfront capital cost has a present value of $142 billion (as some technical life remains after 2050 for the long-lived assets). Of that annualised cost, transmission projects amount to $16 billion[34] or 13% of the total.

Without these projects, consumers would pay more for electricity. The projects provide $38.2 billion in scenario-weighted gross benefits by avoiding $34.9 billion in costs, and by delivering emissions reduction valued at $3.3 billion (using Energy Ministers' value of greenhouse gas emissions reduction).

With these investments, the NEM will continue to contribute to the sustainable future of Australia's energy, economic, social and environmental systems, and support economic opportunities in new forms of energy exports, low-emission industrial production, and energy-intensive digital industries.

7.2 Identifying the optimal development path

AEMO has considered over 1,000 potential development paths of new transmission investments to support the generation, storage and CER developments needed, and whittled them down to a shortlist of 25 candidate development paths. These incorporate all the transmission and other investments needed, and include a 'counterfactual' that has no new major network projects beyond those already committed or anticipated.

To select the ODP from these candidate development paths, AEMO follows the steps provided by the AER's cost benefit analysis guidelines and detailed in the *ISP Methodology.* This section sets out that methodology in brief, with Appendix 6 setting out in detail the approach and findings of each step.

[33] This value includes transmission augmentation, and utility-scale generation and storage capex, and does not include the cost of commissioned, committed or anticipated projects, consumer energy resources or distribution network upgrades.

[34] This value is the net present value of capital costs for transmission augmentation up to 2049-50 only.

Identify and 'rank' the strongest candidate development paths

- **Determine the least-cost development path for each scenario.** These three candidate development paths would maximise net market benefits under their respective scenarios. They include a similar set of transmission projects. These projects deliver net market benefits in all scenarios, though their optimal timings (and so potential actionability) differ across the scenarios.
- **Determine a shortlist set of candidate development paths to assess.** The least-cost development path in the most likely *Step Change* scenario was the basis for other candidate development paths. To form a new candidate development path, projects were either pushed back to be delivered later, or brought forward to be delivered earlier, but no earlier than their earliest delivery date.
- **Assess and rank each candidate.** Two assessments were made to rank the candidate development paths. The first 'risk neutral' assessment was of net market benefits across the three scenarios. The second 'risk averse' assessment was of the regret costs, which are the benefits that are lost if projects are planned and delivered for one scenario, but another scenario plays out. These assessments take into account the likelihood of the scenarios occurring: see Section 3.3.

Several candidate development paths had a similar set of transmission projects, similar net market benefits, and similar 'regret' costs.

Test candidate development paths against sensitivities and consumer risk attitudes

AEMO then tests how the candidate development paths perform when key assumptions (or 'sensitivities') are changed, and considers consumer attitudes to risk. AEMO can use these additional tests to select the ODP, in its professional judgement.

The tested sensitivities were on more rapid decarbonisation, the level of new industry demand enabled by green energy (especially in South Australia and New South Wales), reduced energy efficiency measures, variable hydrogen demand, variable EV demand, alternatives to electrification, constrained supply chains and reduced social licence for infrastructure projects, the impact of major pumped hydro projects, lower orchestration of consumer energy resources, the impact of a delayed retirement date for Eraring Power Station as announced in May 2024, higher and lower discount rates, and higher cost uncertainties.

The analysis showed that the benefits changed materially with levels of deep storage assets and energy efficiency. However, the top-ranking candidate development paths still delivered high net market benefits (they were robust to the sensitivities), and there was minimal impact on their relative rankings. If anything, the sensitivities slightly favoured the candidate that maximised the net market benefits to consumers. This candidate also had very low regret costs. Given these findings, AEMO did not further consider consumer attitudes to risk in selecting the ODP.

7.3 Alternative approaches to the ODP

The ODP is a resilient, pragmatic path to the NEM's energy future that maximises net market benefits for consumers. The potential development paths included different balances between generation, storage and transmission, and were assessed against different levels of consumer-owned assets. Cost assessments have explored alternatives such as the undergrounding of transmission, replacing coal with gas and carbon capture and storage, and the impacts of large hydro developments.

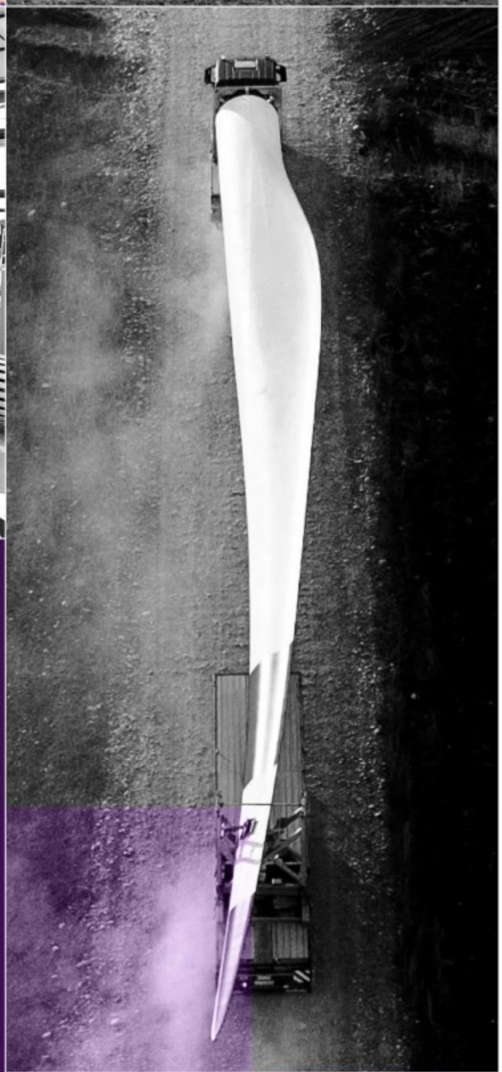
Alternative paths result in greater costs, in some cases substantially so. For example, regional landholders and communities have very reasonably raised underground cables as an alternative in visually sensitive areas. However, their costs range from four to 20 times higher than overhead lines, depending on their voltage, capacity, the use of tunnels and other design factors. Given the length of Australian transmission projects, the cost of undergrounding is often prohibitive and can only be considered in limited cases. It may be feasible for connecting a generation asset to the grid, if the distance is short and the cost can be incorporated into the business case of that asset. These issues will continue to be explored through The Energy Charter's 'Evaluating Transmission Undergrounding' initiative and the second New South Wales Government Inquiry into Transmission Undergrounding.

Similarly, investing in more gas-powered generation combined with carbon capture and storage depends on several site and technology assumptions for such a plant to be feasible. In any case, the ODP provides for the gas generation that is needed, and renewables are far cheaper for any additional need.

Future ISPs will continue to respond to material changes in technologies, costs and policies.







PART C

Delivering the optimal development path

Part C: Delivering the optimal development path

Seizing the opportunities of the energy transition is critical for our nation. Australia's wind and solar resources offer low-cost electricity as coal retires, and far exceed what we can use ourselves.

AEMO has identified the ODP as the most cost-effective path for maintaining reliable electricity supply as coal retires. If delivered, the ODP would meet electricity consumer needs for at least 25 years, fulfil the NEM's security and reliability requirements, meet government policy settings, and manage risk through a complex transformation.

Part C considers:

- **Section 8 – Risks to delivery of the ODP and to the energy transition.** Investment in infrastructure remains urgent. Market and policy settings have progressed and are supporting the transition and do not yet address all of the risks of coal retirement, with focus continuing on the social licence, workforce and supply chains needed for delivery of infrastructure.
- **Section 9 – Next steps to advance the ODP.** By 2050, the NEM must deliver a once-in-a-century transformation in the way electricity is generated and consumed in Australia. That transformation is essential for the Australian economy to enjoy affordable and reliable energy in the future, as well as achieve net zero emissions by 2050.

Identifying the ODP is only a very small contribution to Australia's energy future. It is what happens next that counts.

All industry organisations, including AEMO, must prioritise the important work of delivering a safe, reliable and affordable energy future for Australia.

8 Risks to the ODP and to the energy transition

AEMO has identified the ODP as the lowest-cost path to maintain reliable and secure electricity supply as coal retires and to deliver the power system needed for a net zero economy.

While significant progress is being made, AEMO is acutely aware of challenges and risks already being experienced and that may grow in the future. Risks to the reliability of the system are already becoming visible, and the NEM must be resilient to shocks such as unanticipated coal closures or outages, intense weather events or, conceivably, cyber attacks.

As well, the affordability of reliable supply is being tested by factors including market policies, project costs, supply chain interruptions or scarcities, cost pressures and investment uncertainty.

This section sets out how:

8.1 **Investment in infrastructure remains urgent** to keep the ODP to its schedule and the transition on track, and so reduce risks and maintain benefits to consumers.

8.2 **Market and policy settings have progressed and are supporting the transition, but continued focus is needed to address all of the risks arising from coal retirement.** The ODP relies on policy and market settings that promote competition and innovation, to deliver the efficient, reliable, lower emission electricity services contemplated by the National Electricity Objective.

8.3 **Social licence and supply chain issues continue to challenge delivery.** Planning for such a generational peak in infrastructure investments requires early engagement, and careful management of financial, supply chain and workforce resources. The transition is equally dependent on consumers and communities being engaged and empowered as part of the energy transition.

Positive action will be needed to ensure these risks are addressed.

8.1 Investment remains urgent to reduce risks

The need for planned investment remains urgent. The possibility of replacement generation not being available when coal power stations retire is real and growing, and a risk that must be avoided. Unplanned generator outages are increasing, as coal generator reliability is affected by reduced investment and high-impact weather events.

Any delay to the ODP will increase risks to the energy transition and its benefits. The sooner firmed renewables are connected, the more secure the transition will be. However, planned projects are not progressing as expected, due to the time needed for approval processes, investment decision uncertainty, cost pressures, social licence issues, supply chain issues and workforce shortages.

Federal and state policies in support of generation, storage and transmission recognise this urgency: see Section 2.1.

8.2 Risks that market and policy settings are not yet ready for coal's retirement

Four sets of risks require market settings to be in place if the NEM is to be ready for 100% renewables and for coal plant retirements:

- risk of insufficient infrastructure investment,
- risk of early retirements of coal-fired generators,
- risk that market and power system operations are not ready for 100% renewables, and
- risk that insufficient consumer energy resources are not adequately integrated into grid operations.

Market and policy settings must be in place to address these risks and keep the energy transition on track.

Risk of insufficient infrastructure investment

The energy transition depends on timely investment decisions, which are hampered by uncertainty. Delays and uncertainties in energy regulation and environmental and planning approvals increase the complexity faced by electricity infrastructure investors and add to the risk of project delay.

To help reduce that uncertainty, governments have initiatives such as the Capacity Investment Scheme and the Nationally Significant Transmission Project framework, Long-Term Energy Service Agreements in New South Wales, and state-based renewable energy and infrastructure targets. AEMO strongly supports further market reforms that will expedite investment and effectively balance timely investment with assessment rigour across all forms of infrastructure.

Even if there is greater market certainty, the level of investment in electricity infrastructure required by the ODP is high and remains high for approximately 15 years. As Australia is competing for global investment in the energy transition, the investment case must remain competitive. The need for investment, even with minimal uncertainty, does not guarantee that the investment will flow.

As well, the need for higher levels of flexible gas capacity and utilisation will challenge Australia's existing gas supply infrastructure. Further investment in gas infrastructure will be required to ensure energy reliability, potentially including additional supply, upgrades and expansions of existing pipelines, import terminals, increased storage, and alternative fuels such as hydrogen and other green gases, and other liquid fuels.

Risk of early coal retirements

Market and policy settings have progressed and are supporting the transition, but continued focus is needed to address all of the risks arising from coal retirement. While almost all owners of coal generators have announced their long-term retirement plans, they are only required to give three and a half years' notice of a closure. This leaves the NEM very little time to respond if coal closures are not carefully managed or if replacement investments are not planned and delivered.

Closures with short notice increase the risk of near-term reliability challenges and price shocks for consumers, and further accelerate the need for new generation. These risks are best mitigated through agreed closure timeframes and delivery of the planned investment in generation capacity.

Risk that markets and power system operations are not yet ready for 100% renewables

Renewable generation is being installed rapidly, but the NEM's energy markets, networks and operations must evolve to be ready for very high penetrations of renewable energy. Continued action is needed to make sure that system services, resource adequacy and operational capability are in place in time for coal retirements.

To that end, AEMO continues to work with governments, market bodies and industry on the technical requirements for a secure power system capable of operating at 100% renewables, and subsequent evolution of market frameworks and settings to deliver those requirements in both investment and operational timeframes, including through a system security transition plan.

Risk that CER are not adequately coordinated into grid operations

As mentioned above, many households and businesses are adopting innovative ways to reduce and manage their demand, investing in consumer energy resources, and contributing to VPPs. As more consumers do so and if they allow these resources to be well coordinated, they will help deliver more reliable and secure energy, at lower cost for all consumers, and contribute to lower emissions. In the ISP this is assumed to occur. Without effective coordination of consumer batteries, around $4.1 billion of additional grid-scale investment would be needed, increasing the costs that are reflected in consumer bills: see Appendix A6.

NEM policy, market, and system settings could secure this potential for CER, to ensure it can serve consumer energy needs without exacerbating any system security risks. The networks need to maintain safe operating margins; information needs to be shared across devices in a safe, consistent manner; and devices need to respond to market signals visibly and predictably.

Ultimately, consumers who own these systems will choose how they are used. They will need transparency and material benefits to ensure they support, with confidence, their systems being coordinated with the power system.

AEMO will continue working with industry, governments, market bodies and consumers for the benefits of CER orchestration to be realised.

8.3 Social licence and supply chain risks to delivery

The policy, market and operational settings noted above are largely in the hands of the energy industry. Even if they are in place, delivery of the ODP and the energy transition would not be guaranteed.

The energy industry must also work with communities throughout the NEM, and supply chain partners throughout the world, to ensure there is the social acceptance, equipment, materials and workforce needed to deliver the transition on time.

Risk that social licence for the energy transition is not being earned

Social licence – or the ability of governments, organisations and project developers to build and maintain trust and acceptance with those groups and communities most affected by the impacts, opportunities and challenges the energy transition affords – will be critical in enabling its success.

The ISP is clear in its call for urgent investment in the energy transition. Yet for the energy transition to succeed, community acceptance or social licence is needed in three areas:

- local community acceptance of new infrastructure development,
- owner acceptance for the 'orchestration' of their consumer energy resources (see above), and
- broad social acceptance of the energy transition itself.

Local communities are concerned with a range of community, social, cultural, environmental and economic values. Their acceptance will be affected by:

- their understanding and acceptance of the need for new infrastructure development, their roles within this, and feeling that their voices, preferences and concerns are being considered and acted on by project proponents,
- potential impacts on their sense of place and community, wellbeing, culture, ways of living, and connection to Country,
- potential impacts to local biodiversity, biosecurity, Indigenous heritage, sites of local and community significance, and the visual landscape, and
- potential impacts to their households, livelihoods and ability to carry out business, local economies, and the equitable distribution of associated benefits within and across communities.

Working collaboratively and gaining trust with regional and rural communities is essential to the success of the energy transition. The 2024 ISP highlights the need for significant renewable energy development, particularly within REZs, and for new transmission corridors. AEMO recognises that communities are being asked, for the most part, to host this new energy infrastructure for the benefit of all energy consumers, for industrial users in regional areas as much as city businesses and households.

Energy institutions, developers and communities are working hard to build the relationships of trust that underpin social licence. Their experience is being captured by the National Guidelines for Social Licence for Transmission, the Australian Energy Infrastructure Commissioner's review of community engagement practices, the Victorian Transmission Investment Framework (VTIF), and the New South Wales First Nations Guidelines for consultation and negotiation with local Aboriginal communities, among other initiatives.

These and like initiatives are critical to building the trust-based relationships needed for the energy transition. Developers and energy institutions must ensure that those being asked to host infrastructure are engaged early, consistently and respectfully; that voices and concerns are considered and responded to; that negative impacts are minimised wherever possible; and that potential opportunities and benefits are maximised and distributed fairly.

AEMO appreciates the input from the 2024 ISP Consumer Panel and Advisory Council on Social Licence in the development of the 2024 ISP, especially their input on a new sensitivity to explore social licence: see Appendix 8. AEMO and the Advisory Council on Social Licence have mutually agreed to evolve the council into a new format, to be known as the Community and Consumer Reference Group. AEMO will work with the reference group to better understand new and diverse perspectives, and to develop new analyses that account for levels of social acceptance for the ISP.

In this ISP, additional projects are now included as actionable in recognition of additional time and engagement associated with the initial investigation of these projects. There is a clear need for earlier engagement with communities hosting infrastructure to allow for more coordinated and effective consultation.

Risks in securing critical energy assets and workforce

The deep investments required in the ISP imply the need for thousands of critical energy assets – utility-scale generators and batteries, high voltage transmission lines and cables, synchronous condensers and transformers – and the people needed to install and operate them. This workforce is needed on top of that enabling the record-breaking investment in consumer energy resources.

In a global energy transformation, countries are competing for the same materials, technologies and expertise. The stimulus to renewable energy innovation and investment prompted by the *US Inflation Reduction Act* (IRA) has placed a global premium on these assets. Australia may benefit from outcomes of this investment, such as accelerated technology development, although it will increase competition for investment and skills.

This competition may exacerbate three existing risks.

- First, Australia may not be able to access reliable and cost-effective supply of these assets over the next 15 years, as global demand for them rises, and the global supply chain remains vulnerable. Some actionable ISP projects have already experienced schedule delays, and such slippages are likely to continue. A supply chain constraint was tested as a sensitivity for this 2024 ISP, finding that tight constraints may lead to renewable energy and emissions reduction targets being missed. Under the sensitivity analysis, the total renewable energy share would be only 68% by 2030, less than the 82% target, and NEM emissions would overshoot their 2024-2050 carbon budget by approximately 109 million tons (Mt) CO_2-e[35].
- The race to net zero may also push up some costs. Transmission cost estimates have increased approximately 30% in real terms over the past two years and future cost reductions are very unlikely[36]. Costs for wind and solar have increased over the past few years, largely due to

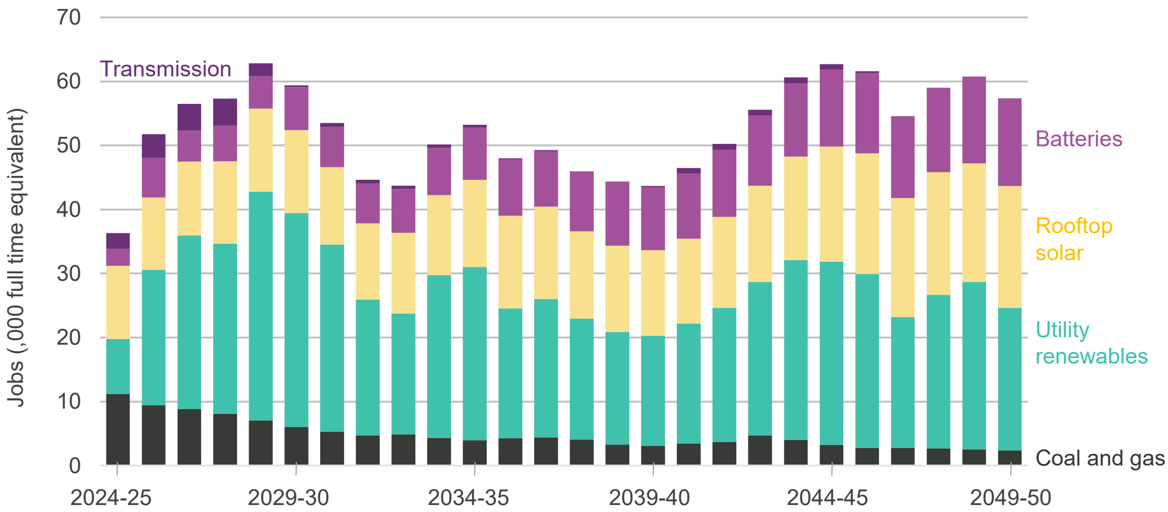
[35] The costs associated with the breach of these policies are not included in the sensitivity's net present value calculations.

[36] AEMO. 2023 *Transmission Expansion Options Report*, p 4, at https://www.aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.

pandemic-related supply chain issues, but they are forecast to continue their long-term decline with still further innovation.

- A further risk is that investment is not made in the training and immigration initiatives needed to secure a workforce for the energy transition. A large skilled workforce in Australia, across every discipline not just engineering, is needed for the enormous task ahead. The demand for skilled people directly employed to build and maintain energy infrastructure is forecast to increase from approximately 36,000 in 2025 to over 60,000 across the horizon to 2050[37], in the *Step Change* scenario. This growth will challenge engineering, procurement and construction (EPC) firms and regional communities, particularly if there are boom-and-bust cycles or if workers and contractors are engaged project-to-project. Governments are aware of these challenges in shaping new and existing labour force and skills policies[38].

Figure 25 Workforce needs for CER and utility infrastructure, NEM (2024-25 to 2049-50, *Step Change*)



Early investment will buttress the business case for infrastructure investment. As well, it will mitigate against supply chain risks in future, retain Australia's spot in global queues for essential equipment and materials, and ensure our ability to respond to future market and climate events.

[37] This forecast is an estimate based on 2024 ISP results, produced by the Institute for Sustainable Futures in collaboration with AEMO. Further detailed information and results will be provided in the supporting *Electricity Sector Workforce Projections* material to be published alongside the 2024 ISP in quarter three of 2024.

[38] See https://ministers.dewr.gov.au/oconnor/launch-towards-renewable-energy-superpower-report.

9 Next steps to advance the ODP

The NEM is delivering the energy transition: a once-in-a-century change in the way electricity is generated and consumed in Australia, since electricity generated from Latrobe Valley coal was carried to Melbourne by transmission in 1924. That transition is essential for the Australian economy to enjoy affordable and reliable energy, while achieving net zero emissions by 2050.

The energy transition and the ODP's delivery will require a concerted effort from industry, governments and communities – over the next decade in particular. That effort is being made in every necessary quarter, as the energy transition's momentum continues to build. The 2026 ISP will again report on that progress, and update priorities as the NEM continues to adjust to market and policy signals.

9.1 Advancing the ISP

The Energy and Climate Change Ministerial Council has requested that the 2026 ISP offer an even more comprehensive plan for Australia's energy future, with more detail on gas integration, energy demand forecasts, the withdrawal of coal-fired generation, system security and alignment with state planning and policies. AEMO is now commencing work on the 2026 ISP, starting with the analyses and consultations for the 2025 *Inputs, Assumptions and Scenarios Report*.

9.2 Advancing projects along the ODP

Through the Energy and Climate Change Ministerial Council, federal and state governments continue to put policies in place to secure the finance, assets and workforce required for the energy transition. These policies support both grid-scale and consumer investment in energy resources, including support for battery storage and VPPs which can help take full advantage of Australia's rapid adoption of rooftop solar.

Substantial generation, storage and transmission projects are underway across the NEM, in keeping with previous ISPs. Additional projects will progress as the ODP and energy transition gain momentum, and it will be important communities are engaged in transition.

- **A further 16 GW in household and business energy systems – individual distributed battery and solar systems** – is expected to be installed by 2030, at a rate of 3 GW per year.
- **Utility-scale development of generation and storage continues at pace**, with more than 8 GW of solar, wind, batteries and other generation and storage in the pipeline.
- **About 2,500 km of new and upgraded transmission lines** are currently being delivered in five projects across the NEM, to be at full capacity before the end of 2029. These include the CopperString and Far North Queensland REZ transmission link, the Western Renewables Link in

Victoria, the Central-West Orana REZ Network Infrastructure Project in New South Wales, and Project EnergyConnect linking New South Wales and South Australia.

- **Five transmission projects** from the 2022 ISP are already progressing as actionable, now joined by another seven, which are in early stages of commencing and are targeting delivery by early 2033. This will ensure the critical engagement associated with the initial investigation of these projects can start sooner. There is a clear need for earlier engagement with communities hosting infrastructure to allow for more coordinated and effective consultation.
- **Eleven of the proposed 43 REZs across the NEM** are underway, with significant planning, community consultation, and community benefit and employment efforts. These are led by the Western Victoria, Far North Queensland and the Central-West Orana REZ in New South Wales.

Although the ISP cannot forecast exactly where and how the generation, storage and transmission of the future will emerge, the ODP is clear that urgent investment and delivery across the sector is needed to ensure secure, reliable, affordable, low-emission electricity through the NEM.

* * *

The ISP's proposed investment in the NEM will provide opportunities for Australia's industries and regions, while reducing local emissions in line with government policies. The transmission elements would repay their investment costs, save consumers a further $18.5 billion in avoided costs, and deliver emission reductions valued at $3.3 billion.

AEMO will continue to work collaboratively with all industry, governments, networks, consumer representatives and other stakeholders to address risks and deliver the energy transition.

AEMO again sincerely thanks all those who have contributed to this ISP, and looks forward to engaging with all NEM participants towards the 2026 ISP.

List of tables and figures

Tables

Figures

Glossary

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

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

Term	Acronym	Explanation
Demand	-	The amount of electrical power consumed at a point in time. This quantity is typically expressed in megawatts (MW) or its multiples. Various definitions for demand, depending on where it is measured. For example, underlying demand means demand supplied by both CER and the electricity grid.
Demand-side participation	DSP	The capability of consumers to reduce their demand during periods of high wholesale electricity prices or when reliability issues emerge. This can occur through voluntarily reducing demand, or generating electricity.
Development path	DP	A set of projects (actionable projects, future projects and ISP development opportunities) in an ISP that together address power system needs.
Dispatchable capacity	-	The total amount of generation that can be turned on or off, without being dependent on the weather. Dispatchable capacity is required to provide firming during periods of low variable renewable energy output in the NEM.
Distributed solar/ distributed PV	-	Solar photovoltaic (PV) generation assets that are not centrally controlled by AEMO dispatch. Examples include residential and business rooftop PV as well as larger commercial or industrial "non-scheduled" PV systems.
Firming	-	Grid-connected assets that can provide dispatchable capacity when variable renewable energy generation is limited by weather, for example storage (pumped-hydro and batteries) and gas-powered generation.
Future ISP project	-	A transmission project (or non-network option) that addresses an identified need in the ISP, that is part of the ODP, and is forecast to be actionable in the future.
Identified need	-	The objective a TNSP seeks to achieve by investing in the network in accordance with the NER or an ISP. In the context of the ISP, the identified need is the reason an investment in the network is required, and may be met by either a network or a non-network option.
ISP development opportunity	-	A development identified in the ISP that does not relate to a transmission project (or non-network option) and may include generation, storage, demand-side participation, or other developments such as distribution network projects.
Net market benefits	-	The present value of total market benefits associated with a project (or a group of projects), less its total cost, calculated in accordance with the AER's Cost Benefit Analysis Guidelines.
Non-network option	-	A means by which an identified need can be fully or partly addressed, that is not a network option. A network option means a solution such as transmission lines or substations which are undertaken by a Network Service Provider using regulated expenditure.
Optimal development path	ODP	The development path identified in the ISP as optimal and robust to future states of the world. The ODP contains actionable projects, future ISP projects and ISP development opportunities, and optimises costs and benefits of various options across a range of future ISP scenarios.
Regulatory Investment Test for Transmission	RIT-T	The RIT-T is a cost benefit analysis test that TNSPs must apply to prescribed regulated investments in their network. The purpose of the RIT-T is to identify the credible network or non-network options to address the identified network need that maximise net market benefits to the NEM. RIT-Ts are required for some but not all transmission investments.
Reliable (power system)	-	The ability of the power system to supply adequate power to satisfy consumer demand, allowing for credible generation and transmission network contingencies.
Renewable energy	-	For the purposes of the ISP, the following technologies are referred to under the grouping of renewable energy: "solar, wind, biomass, hydro, and hydrogen turbines". Variable renewable energy is a subset of this group, explained below.
Renewable energy zone	REZ	An area identified in the ISP as high-quality resource areas where clusters of large-scale renewable energy projects can be developed using economies of scale.
Renewable drought	-	A prolonged period of very low levels of variable renewable output, typically associated with dark and still conditions that limit production from both solar and wind generators.

Term	Acronym	Explanation
Scenario	-	A possible future of how the NEM may develop to meet a set of conditions that influence consumer demand, economic activity, decarbonisation, and other parameters. For the 2024 ISP, AEMO has considered three scenarios: *Progressive Change*, *Step Change* and *Green Energy Exports*.
Secure (power system)	-	The system is secure if it is operating within defined technical limits and is able to be returned to within those limits after a major power system element is disconnected (such as a generator or a major transmission network element).
Sensitivity analysis	-	Analysis undertaken to determine how modelling outcomes change if an input assumption (or a collection of related input assumptions) is changed.
Spilled energy	-	Energy from variable renewable energy resources that could be generated but is unable to be delivered. Transmission curtailment results in spilled energy when generation is constrained due to operational limits, and economic spill occurs when generation reduces output due to market price.
Transmission network service provider	TNSP	A business responsible for owning, controlling or operating a transmission network.
Utility-scale or utility		For the purposes of the ISP, 'utility-scale' and 'utility' refers to technologies connected to the high-voltage power system rather than behind the meter at a business or residence.
Value of greenhouse gas emissions reduction	VER	The VER estimates the value (dollar per tonne) of avoided greenhouse gas emissions. The VER is calculated consistent with the method agreed to by Australia's Energy Ministers in February 2024.
Virtual power plant	VPP	An aggregation of resources coordinated to deliver services for power system operations and electricity markets. For the ISP, VPPs enable coordinated control of CER, including batteries and electric vehicles.
Variable renewable energy	VRE	Renewable resources whose generation output can vary greatly in short time periods due to changing weather conditions, such as solar and wind.

Supporting documents

All documents comprising or supporting the 2024 ISP are available on AEMO's website[39].

Appendices to the 2024 *Integrated System Plan*

- Appendix 1 – Stakeholder Engagement
- Appendix 2 – Generation and Storage Opportunities
- Appendix 3 – Renewable Energy Zones
- Appendix 4 – System Operability
- Appendix 5 – Network Investments
- Appendix 6 – Cost Benefit Analysis
- Appendix 7 – System Security
- Appendix 8 – Social Licence

Supporting documents

- 2024 ISP Consultation Summary Report
- 2024 *Integrated System Plan* – overview
- 2024 ISP infographic
- 2024 ISP chart data
- 2024 ISP generation and storage outlook
- 2024 ISP Inputs and Assumptions workbook, including the latest input data used for the 2024 ISP modelling *[To be published in July 2024]*
- 2024 ISP traces
- 2024 ISP REZ boundaries – GIS data
- Summary of consumer risk preferences project
  - Attachment 1 Deloitte report consumer risk preferences
  - Attachment 2 Antenna report consumer risk preferences
- Electricity Sector Workforce Projections *[To be published within quarter three of 2024]*

Regulatory publications

- *Notice of consultation – Non network options for Sydney Ring South*
- *Notice of consultation – Non-network options for Mid North South Australia REZ Expansion*
- *Notice of consultation – Non-network options for Waddamana to Palmerston transfer capability upgrade*
- *Notice of consultation – Non-network options for QNI Connect*

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