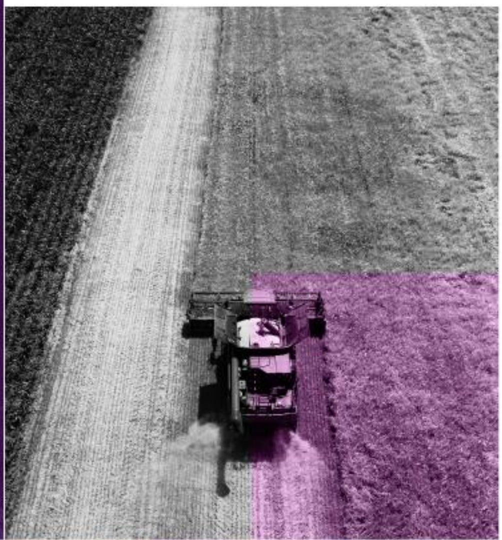
AEMO

AUSTRALIAN ENERGY MARKET OPERATOR

Draft 2024
Integrated System Plan

For the National Electricity Market

A roadmap for the energy transition



Important notice

Purpose

AEMO publishes the Draft 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 30 October 2023 unless otherwise indicated.

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Version control

Version	Release date	Changes
1.0	15/12/2023	Initial release.
1.1	15/01/2024	Updates to Figures 5, 6 and 7 (amend apportionment of losses), Figures 9 (add in mid-merit gas) and Figure 19 (correct Snowy 2.0 depth). Corrections to text associated with Figures 5,6, 7 and 19 to reflect figure edits. Minor typographical corrections including reference to the initial year for Victorian offshore wind targets.

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

I am pleased to present AEMO's Draft 2024 Integrated System Plan (ISP) for your review and comment.

The plan is a roadmap for the energy transition in the National Electricity Market (NEM) over at least the next 20 years, in line with government policies to reach a net zero economy by 2050.

The plan outlines the lowest-cost pathway of essential generation, storage and transmission infrastructure to meet consumers' energy needs for secure, reliable and affordable energy, and to achieve net zero emissions targets.

AEMO's message is clear and consistent: urgent action is needed to deliver benefits for consumers as the NEM moves away from its traditional dependency on coal-fired generation. Release of this draft comes at a time of ongoing and significant change in the way Australia's electricity supply is generated, transferred and consumed.

Australia's ageing coal-fired power stations are closing down. Renewable energy connected by transmission, firmed with storage and backed up by gas is the lowest cost way to supply electricity to homes and businesses through Australia's energy transition.

Together, as a nation, we are facing important decisions that shape the way our power system will operate in the coming decades. Twenty five years ago Australia took a bold step forward in creating the National Electricity Market to maximise benefits to consumers from existing infrastructure. Today, Australian consumers urgently need new infrastructure to ensure reliable and affordable electricity supply going forward.

AEMO prepares the ISP every two years in collaboration with its stakeholders, including energy companies, consumer organisations, and agricultural and First Nations communities. AEMO acknowledges First Nations peoples' connection to land and water for more than 60,000 years, and the opportunity to mutually benefit from Australia's energy transition.

The 2023 Inputs, Assumptions and Scenarios Report forms a core input to this draft plan. The analysis that underpins the Draft 2024 ISP takes into account many factors, including developments in government policies, technology and investment settings. For example, since the 2022 ISP was published, the Commonwealth has released its Rewiring the Nation policy, and its Capacity Investment Scheme and the National Energy Transformation Partnership to support the large volume of energy-transition investment required. The plan's actionable projects also consider state and territory government scheme frameworks.

A recent change to the national electricity law requires that AEMO plans the power system in a way that helps achieve government targets that reduce greenhouse gas emissions, while being secure, reliable and cost-effective. This has been incorporated into the Draft 2024 ISP.

Australians' own investments in domestic rooftop solar systems are a valuable resource, and this draft plan highlights how they can make a significant contribution to the NEM.

Community support is critical to enable timely and cost-effective investments in the power system. Gaining the trust of regional and rural communities is essential to avoid the risk of essential infrastructure not being built before coal-fired generators close.

I would like to thank everyone who has been involved in the preparation of this draft ISP, and look forward to your feedback.

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 renewable energy.

With coal retiring, renewable energy connected with transmission, firmed with storage and backed up by gas-powered generation is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition 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 in the National Electricity Market (NEM) supplied from renewable sources.

The energy transition, well underway, is by far the biggest transformation of the NEM since it was formed 25 years ago. As well as the shift from coal to firmed renewables, it will treble capacity to meet future demand, and enable a two-way flow of electricity across the grid.

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 to meet future energy needs.

Previous iterations of the ISP set an ambitious pace for investment. Projects now need to be delivered, as planned. About 90% of the NEM's coal fleet is forecast to retire before 2035 in AEMO's most likely future scenario, and the entire fleet before 2040.

This Draft 2024 ISP is a milestone on an industry-wide journey to prepare the ISP. It reflects consultations with consumer and community representatives, governments, energy market authorities, investors and developers, network planners, industry bodies and science and technology institutions.

The Draft 2024 ISP is a robust plan that calls for urgent investment in generation, firming and transmission that targets secure, reliable and affordable electricity through the energy transition, with its transmission elements delivering $17 billion in net market benefits to consumers.

- The energy transition is already well underway, breaking renewable generation records while managing inherent tensions. 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, which would deliver significant net market benefits for consumers and economic opportunities in Australia's regions (Part B).
- The transition is urgent, and faces significant risks if market and policy settings, social licence and supply chain issues are not quickly addressed (Part C).

AEMO welcomes feedback on this Draft 2024 ISP by 16 February 2024. Stakeholder feedback will inform the final 2024 ISP due for release by 28 June 2024.

An essential transition is well underway

The ISP is a roadmap through an energy transition that is already well underway, breaking renewable generation records while managing inherent tensions.

Australia's energy 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. 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, but 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 energy delivered through the NEM in the first half of 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 2023 (12.1%) 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. 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 now pursuing a Hydrogen Jobs Plan, and Tasmania has long had strong renewable energy targets. Victoria has set its Transmission Investment Framework and Renewable Energy and Storage Targets and is now including offshore wind towards its renewable energy targets, with explicit offshore wind development targets as well.

It 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. NEM regions are forecast to need over 70,000 people in jobs to build and maintain the new infrastructure over the next 20 years. Australia may also develop new opportunities for lower-emission exports 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 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

AEMO takes all these matters into account. The ISP modelling approach integrates four separate 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 system's reliability and security needs and supports government emissions reduction policies[1] in the long-term interests of 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 18 'candidate' development paths, which included the option of generation development with no additional transmission at all.

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, and
- *Green Energy Exports*, which sees very strong industrial decarbonisation and low-emission energy exports.

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

After extensive consultation, AEMO has 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). Others considered 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. 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 is retiring, faster than announced

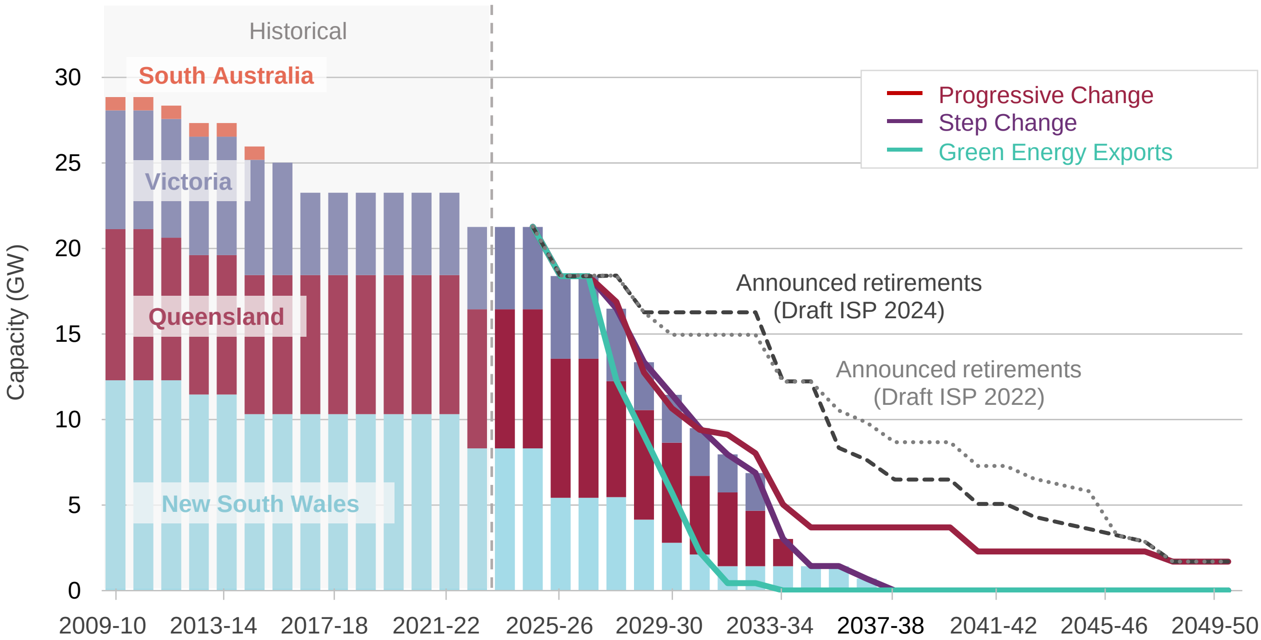
Ten large coal-fired generators have closed since Munmorah ceased operations in 2012, the latest being Liddell this year. Retirements have been announced for all but one of the remaining fleet, with about half by 2035 and the rest by 2051, continuing the steady rate of retirement since 2012: see Figure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

[1] In November 2023 a new emissions reduction element came into force in the National Electricity Objective (NEO) of the National Electricity Law. AEMO has chosen to apply the amended NEO in its preparation of the Draft 2024 ISP, by using only scenarios that comply with Australian governments' emissions reduction policies and by considering policies and targets in the Australian Energy Market Commission's *Emissions Targets Statement,* including those which are on their way to meeting (but have not yet met) the National Electricity Rules requirements for public policies' inclusion in the ISP.

However, the ISP forecasts that the remaining coal fleet will close two to three times faster than those announcements. In the most likely *Step Change* 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.

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. Replacement capacity must be put in place well in advance.

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

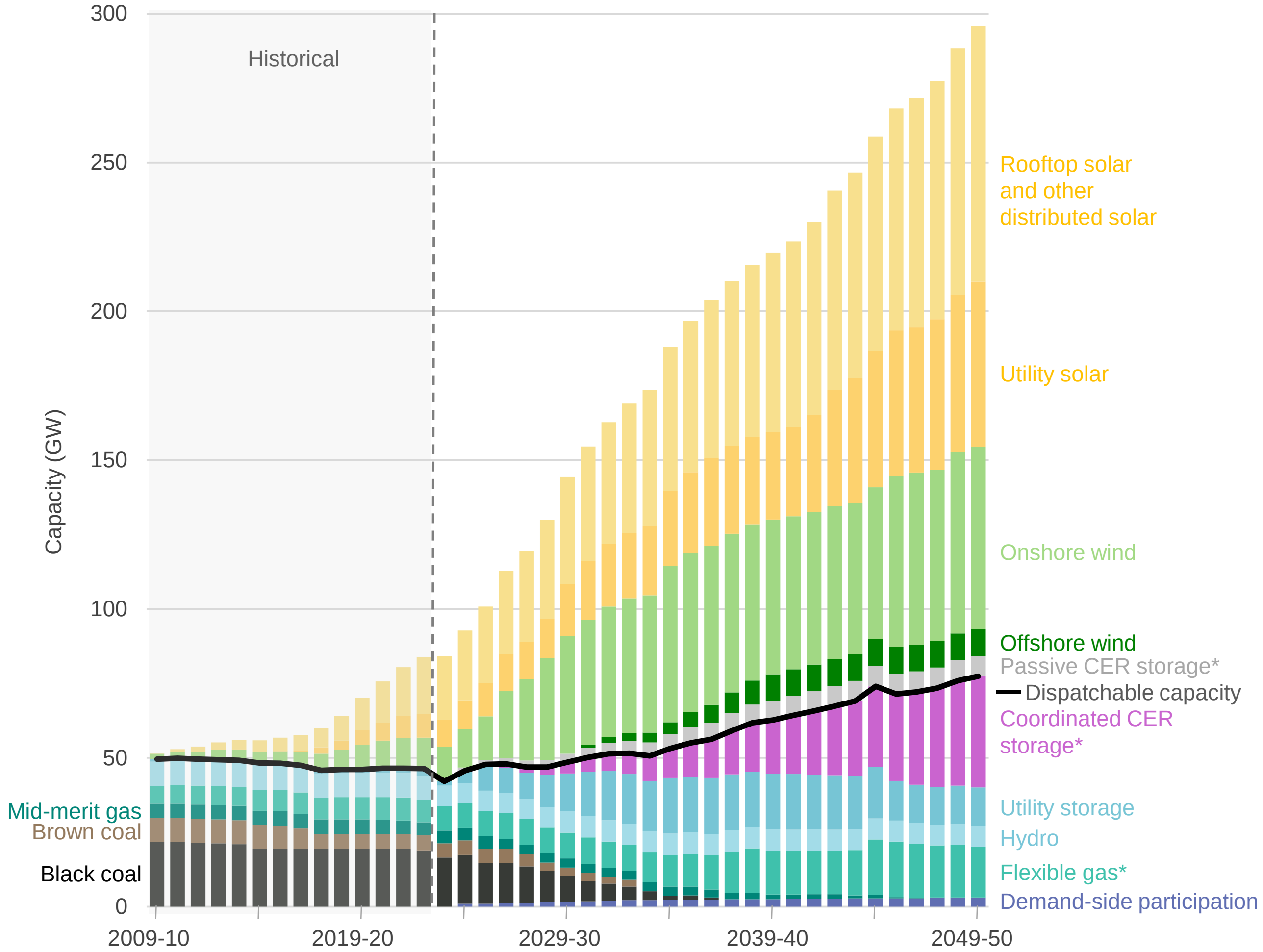


Generation and storage investments in the optimal development path

With coal retiring, renewable energy connected with transmission, firmed with storage and backed up by gas-powered generation is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition 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.

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



Notes: Flexible gas includes gas-powered generation, and potential hydrogen and biomass capacity.
"CER storage" are consumer energy resources such as batteries and electric vehicles.

AEMO has selected an optimal development path that sets out the capacity of new generation, firming, storage and transmission needed in the NEM through to 2050. Under forecasts for the *Step Change* scenario, the ODP calls for investment that would:

- **Triple grid-scale variable renewable energy by 2030, and increase it seven-fold by 2050**. About 6 GW of capacity would need to be added every year, compared to the current rate of almost 4 GW. Wind would dominate installations through to 2030, complementing installations of rooftop solar systems, and by 2050 grid-scale solar capacity would be 55 GW and wind 70 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 utility-scale batteries, pumped hydro and other hydro, coordinated consumer energy resources as "virtual power plants" (VPPs), and gas-powered generation.

This includes 50 GW / 654 gigawatt hours (GWh) of dispatchable storage, as well as 16 GW of flexible gas.

- **Support a four-fold increase in rooftop solar capacity** reaching 72 GW by 2050, and facilitating the use of consumer-owned batteries and VPPs to deliver 27 GW of flexible demand response for the NEM.
- **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*.

The resulting NEM capacity through to 2050 is shown in Figure 2 on the previous page.

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 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.

Close to 10,000 km of transmission would be needed by 2050 under the *Step Change* and *Progressive Change* scenarios. 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 ODP contains largely the same major 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 two future projects have now progressed to actionable status as planned. There is a clear need for urgent delivery of all actionable transmission projects.

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

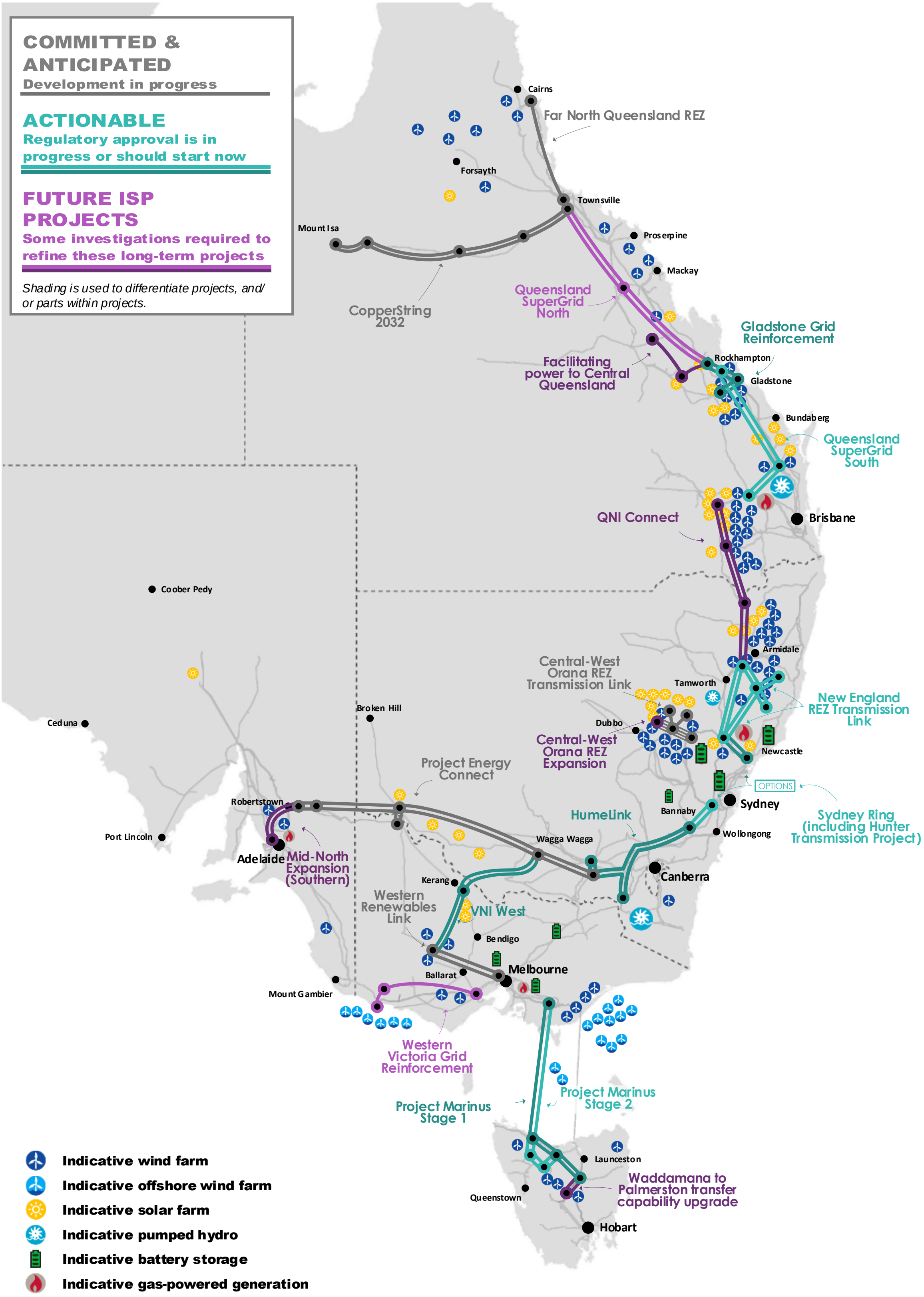
- **committed and anticipated transmission** projects already underway,
- **actionable projects**, for which work should continue and/or commence urgently, and
- **future ISP projects**, which may include the need for the transmission network service providers (TNSPs) to undertake preparatory activities.

Table 1 Network projects in the Draft 2024 ISP optimal development path

Committed and anticipated ISP projects		In service timing advised by proponent	Full capacity timing advised by proponent
Far North Queensland REZ		April 2024	April 2024
Project EnergyConnect[A]		Stage 1 April 2024 Stage 2 December 2024	Stage 1 July 2024 Stage 2 July 2026
Western Renewables Link		July 2027	July 2027
Central West Orana REZ Transmission Link		January 2028	August 2028
CopperString 2032[B]		June 2029	June 2029
Already actionable projects *(confirmed in this Draft ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent**
HumeLink[C]	ISP	Northern Circuit July 2026 Southern Circuit December 2026	Northern Circuit July 2026 Southern Circuit December 2026
Sydney Ring *(Hunter Transmission Project and investigation of southern network options)*	NSW[D]	December 2027	December 2027
New England REZ Transmission Link	NSW[D]	September 2028	September 2028
Victoria – New South Wales Interconnector West (VNI West)	ISP	December 2028	December 2029
Project Marinus[E]	ISP	Stage 1 June 2030 Stage 2 June 2032	Stage 1 December 2030 Stage 2 December 2032
Newly actionable projects *(as identified in this Draft ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent**
Gladstone Grid Reinforcement[F]	QLD[G]	September 2029	September 2029
Queensland SuperGrid South[F]	QLD[G]	June 2031	June 2031
Future ISP projects			
Interconnectors	Queensland – New South Wales Interconnector (QNI Connect)		
New South Wales	Central West Orana REZ Expansion, Hunter-Central Coast REZ Expansion, Cooma-Monaro REZ Expansion.		
Queensland	Darling Downs REZ Expansion, Facilitating Power to Central Queensland, North Queensland Energy Hub Uplift, Queensland SuperGrid North.		
South Australia	Mid North REZ Expansion.		
Tasmania	Waddamana to Palmerston transfer capability upgrade, North West Tasmania REZ Expansion.		
Victoria	Western Victoria Grid Reinforcement, Eastern Victoria Grid Reinforcement.		

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. CopperString 2032 will be built and owned by the Queensland Government, continuing the commitment made through the Queensland Energy and Jobs Plan that all the state's transmission assets will be 100% publicly owned. This project was not actioned through the ISP framework.
C. 'Northern Circuit' is between Bannaby and Gugaa. 'Southern Circuit' is between Bannaby and Maragle, and Maragle and Gugaa. Transgrid has advised the Southern Circuit has been programmed to December 2026 for optimal delivery.
D. These are actionable New South Wales projects. They will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework. New England REZ Transmission Link includes additional scope compared to 2022 ISP, with the proponent date only applying to the original scope.
E. Project Marinus includes MarinusLink and North West Transmission Developments (NWTD) projects. Project proponent dates represent modelling dates and are under negotiation. 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.
F. Project proponent dates are subject to further refinement.
G. These are actionable Queensland projects. They may progress under the *Energy (Renewable Transformation and Jobs) Bill* 2023 (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 1,000 MW or more, and are required in all scenarios by 2050.

Benefits of the optimal development path

The selected ODP sets out the capacity of new generation, firming, storage and transmission needed in the NEM through to 2050. It would:

- guide the capital investment needed for essential electricity infrastructure to sustain and grow Australia's $2 trillion annual economy
- avoid $17 billion in additional costs to consumers (in present value terms) if no transmission was included in this capital investment
- connect emerging areas of renewable generation to regional industries and to urban businesses and households
- firm variable renewable energy with batteries, hydro and gas-powered powered generation, and
- create new economic and job opportunities, particularly in regional areas.

The annualised capital cost of all generation, storage, firming and transmission infrastructure in the ODP has a present value of $121 billion (*Step Change* scenario to 2050)[2]. The equivalent upfront capital cost has a present value of $138 billion (as some technical life remains after 2050 for the long-lived assets). Of the annualised cost, transmission projects amount to $16.4 billion[3] or 13.5% of the total. They would pay themselves back and deliver the additional $17 billion net market benefit noted above.

Risks to delivery of the ODP and to the energy transition

AEMO has identified the ODP as the most effective path to maintain reliable 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 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 plants 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.

[2] This value does not include the cost of commissioned, committed or anticipated projects.

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

Risk of uncertainty for infrastructure investment

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

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, which would leave the NEM very little time to respond. 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. More action is needed to make sure that system services, resource adequacy and operational capability are in place in time for coal retirements.

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.

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

Consumer-owned assets offer significant system benefits and offset the need for grid-scale investment. These benefits would be foregone unless two steps are taken. First, that consumer-owned assets are grouped together and coordinated as virtual power plants (VPPs) to respond to market or network signals. Then, that the VPPs are appropriately integrated into the NEM to help support power system reliability and security. Owners would need to see the benefits of both actions, and trust the energy sector to deliver them. 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. NEM affordability and reliablity is essential for community acceptance on each of these dimensions.

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 its Advisory Council on Social Licence to better understand new and diverse perspectives, to develop new analyses that account for levels of social acceptance for the ISP.

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

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 40,000 people in 2023 to a peak of over 70,000 by 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.

AEMO will continue to work with all industry organisations to ensure a secure, reliable, affordable energy future for Australia.

Invitation for submissions on the Draft ISP

Drawing on extensive consultation over the past 18 months, the Draft 2024 ISP provides a roadmap for the transition of the NEM power system, with a clear plan for essential infrastructure to meet future energy needs, balancing consumer risks and benefits in their long-term interests.

All stakeholders are invited to provide a written submission on the Draft 2024 ISP, which should be sent in PDF format to **ISP@aemo.com.au** by 6pm (AEST) on Friday, 16 February 2024.

The consultation questions are:

1. Does the proposed optimal development path help to deliver reliable, secure and affordable electricity through the NEM, and reduce Australia's greenhouse gas emissions? If yes, what gives you that confidence? If not, what should be considered further, and why?
2. Does the proposed timing and treatment of actionable projects support a reliable, secure and affordable NEM? If yes, what gives you that confidence? If not, what should be considered further, and why?
3. Does the Draft 2024 ISP accurately reflect consumers' risk preferences? If yes, how so? If not, how else could consumers' risk preferences be included and what risks do you think are important to consider?
4. Do you have advice about how social licence can be further considered in the ISP, or advice on how to quantify the potential impact of social licence through social licence sensitivity analysis?
5. Do you have any feedback on the *Addendum to the 2023 Inputs Assumptions and Scenarios Report*?

AEMO thanks all stakeholders for their advice and input so far, and looks forward to continuing to consult with consumers, industry and other stakeholders to finalise the 2024 ISP.

Key changes from the 2022 ISP

The Draft 2024 ISP sets out how AEMO has identified the optimal development path (ODP) for the NEM. The ISP is adjusted as economic, physical and policy environments change. AEMO notes the following key differences between the 2022 ISP and this Draft 2024 ISP.

Changes to the overall framing of the ODP

- **None** – AEMO continues to find that renewable energy connected with transmission, firmed with storage and backed up by gas-powered generation is the lowest cost way to supply reliable electricity to homes and businesses throughout Australia's transition to net zero.

Updates to inputs, assumptions and scenarios used to analyse the ODP

- **Stronger emissions reduction policies now apply**, with Australia's Paris Agreement commitment increased to 43% emissions reduction by 2030 and the complementary Powering Australia Plan for an 82% share of renewable generation by 2030.
- **AEMO's refined scenario set reflects significant expansions in commitments to net zero**. AEMO's *Step Change*, *Progressive Change* and *Green Energy Exports* scenarios all align with the updated commitments. *Step Change* is considered 'most likely' and features an energy transition pace to less than 2°C and compatible with 1.5°C outcomes depending on the actions taken across other sectors.
- **Consumer energy resources are forecasted to be taken up even faster than before**, with 18 GW more rooftop solar by 2050 under *Step Change* compared to the 2022 ISP.
- **Higher costs for transmission, generation and storage** have been observed in recent years due to supply chain issues and workforce shortages, including around 30% increases for transmission projects. AEMO expects that transmission project costs will continue to increase beyond the rate of inflation as the sector adapts to market pressures and to account for environmental and land costs.

Further analysis to inform the ODP

- **Sensitivity analysis considering the impact of low social licence** on the development opportunities and transmission network developments considered in the ISP.
- **Analysis considering the impact of gas system capacity limitations** on the operation of gas-fired generation during peak periods.
- **Investigation of consumer risk preferences** through in-person focus groups and an online survey, finding that in general consumers are open to some prudent infrastructure investment now to manage the risk of future price shocks – although this needs to be weighed carefully against any near-term bill impact.

Changes to the speed or scale of the ODP

- **The entire coal fleet in the NEM is retired by 2038 in *Step Change*** in this Draft 2024 ISP, five years earlier than in the 2022 ISP.
- **Earlier need for renewable energy** with a need for 6 GW of new renewable energy per year under *Step Change* in the coming decade, compared to 4 GW in the 2022 ISP (and a current

rate of almost 4 GW[4]). This is to replace the coal generation capacity that is exiting faster and to meet the higher demand forecast compared to the 2022 ISP.

- **Increased need for dispatchable supply and a shift towards consumer-owned storage.** The Draft 2024 ISP increases backup gas-powered generation capacity to 16 GW by 2050, up from 10 GW in the 2022 ISP. The forecast need for medium-depth storage has reduced by 5 GW due to increased wind generation and increased storage capacity from consumer energy resources.
- **The 2023 *Progressive Change* scenario acknowledges more rapid change due to new policies, and is now considered almost as likely as *Step Change*.** However, the near-term need for projects across the NEM is common to both scenarios, with only two actionable projects required slightly later in *Progressive Change* than *Step Change*.

Changes to investment in the ODP

- **Net market benefits of transmission investment have reduced by 37 percent**, from $27.7 billion in the 2022 ISP to $17.45 billion. Factors include increased transmission costs, generator and storage costs, updated energy policies, commitment to transmission projects whose benefits are now assumed and not included in the total, and lower gas prices.
- **The need for new transmission network is broadly the same over the coming decade**. Beyond the next decade, the ODP sees slightly less transmission build than the 2022 ISP, due to higher transmission costs, the optimisation of project options, and more generation from sources that need less transmission.
- **More offshore wind in Victoria** and **more pumped hydro (and supporting transmission) in Queensland** in line with State policies.
- **Transmission projects have progressed across the NEM:**
  - **Some planned projects have been completed** and are now operational, including Queensland – New South Wales Interconnector Minor upgrade (QNI Minor), Victoria – New South Wales Interconnector Minor upgrade (VNI Minor) and Eyre Peninsula Link.
  - **Newly committed or anticipated transmission projects,** such as CopperString 2032 and increased capacity planned for the Central West Orana REZ Transmission Link.
  - **Future ISP projects have become actionable projects**, as expected. In Queensland, SuperGrid South (formerly Central to Southern Queensland) and Gladstone Grid Reinforcement have become actionable. In New South Wales, the New England REZ Extension and further augmentation is now included as stages in the New England REZ Transmission Link project.

[4] This is generation which commenced operating at its full capacity.

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, firmed with storage and backed up by gas-powered generation (GPG) 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 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 will best meet the NEM's needs. Part C explores the risks currently faced by the energy transition, and the consultation needed on the Draft ISP.

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, firmed by 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

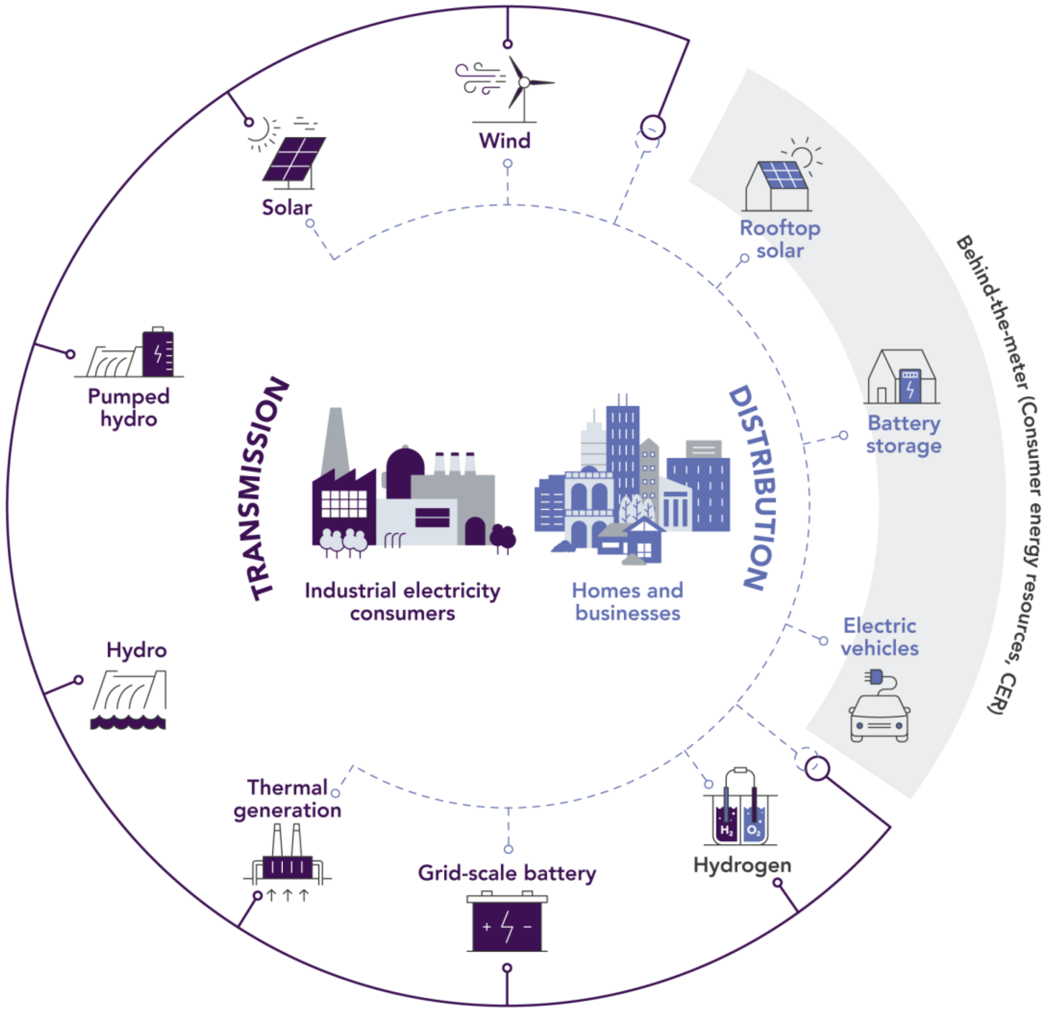
We rely on a complex power system

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, firmed by 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 modernized 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 priority is secure, reliable and affordable 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 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:

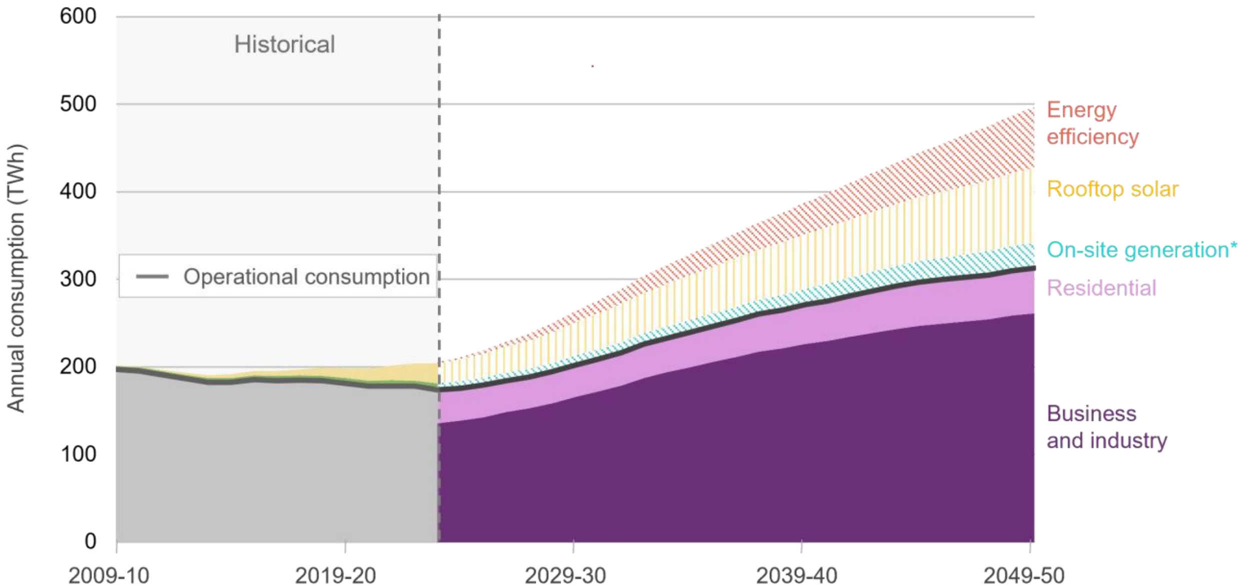
- **'Demand'** is the electricity needed **at a point in time**, expressed as 'kilowatts' (kW), megawatts (MW), gigawatts (GW) and terawatts (TW). Consumers may draw 21 GW of electricity from the grid at one time, and another 2 GW from their own 'behind-the-meter' resources. What the grid meets is 'operational 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 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.

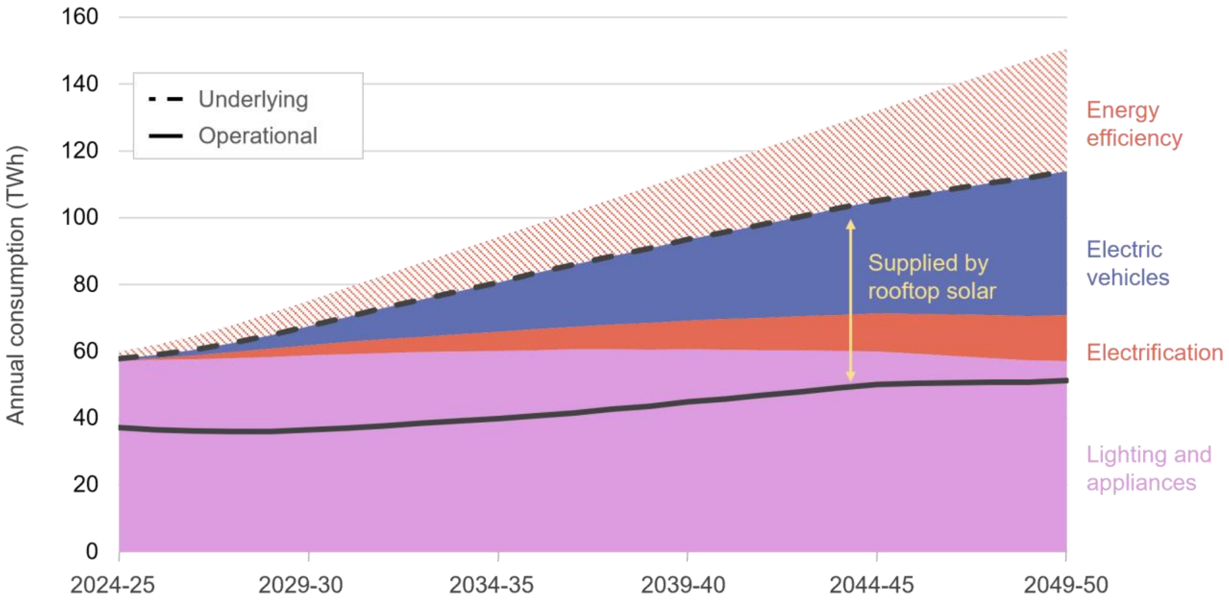
Residential consumption to stay flat

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)*

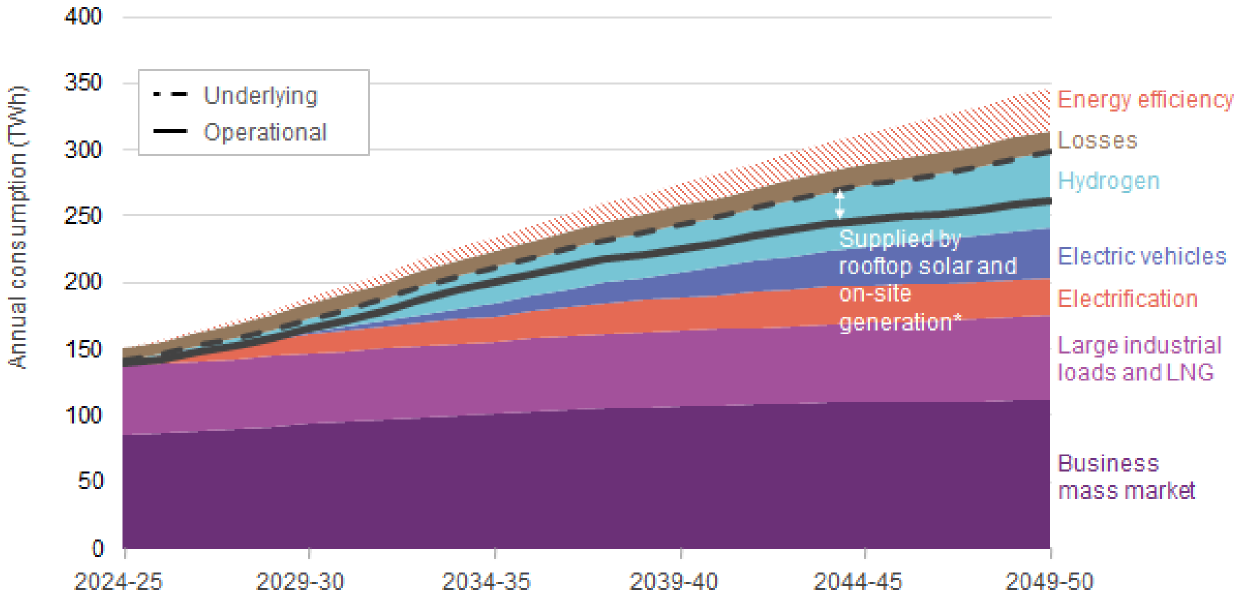


Business and industry consumption to almost double

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 advantages 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 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.

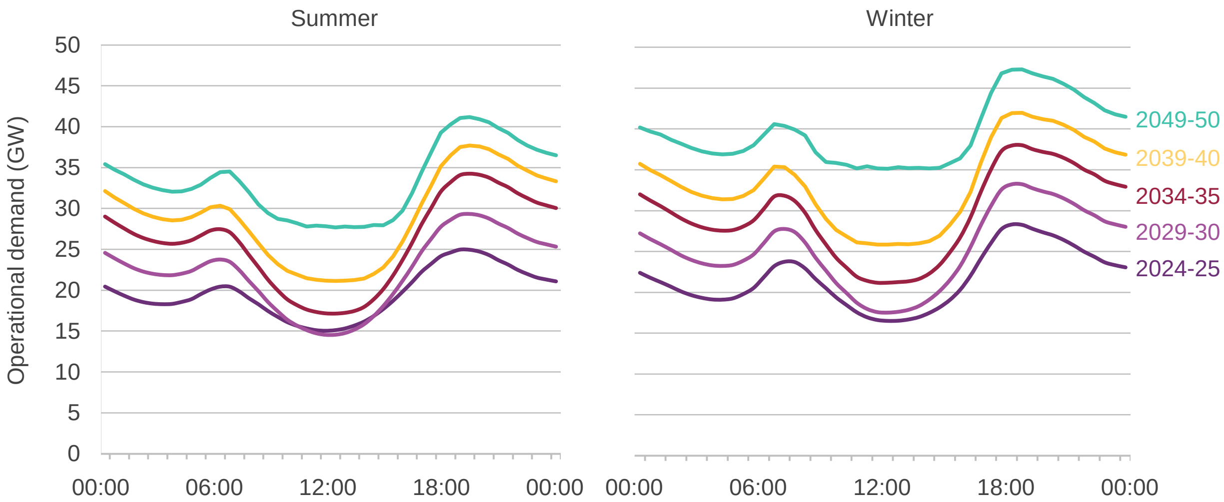
The ISP identifies the most efficient ways for the NEM to manage these midday lows and evening peaks. Consumers can also help smooth out the demand profile by drawing on their own assets and by choosing what time of day they use electricity.

- **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 integrated 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 this investment, 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 expensive and unreliable coal-powered generation is replaced by renewables with far lower fuel, maintenance and operation costs,
- around 30,000 new jobs over the next 20 years to build the new infrastructure and to maintain and operate the energy system,
- a vast new economic opportunity for Australia – as the global economy seeks to reduce emissions, 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 opportunities are both strong 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, firmed by 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 transition is well underway.** Major coal plants continue to retire. Renewables delivered almost 40% of the NEM's total energy in the first half of 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 transition is well underway

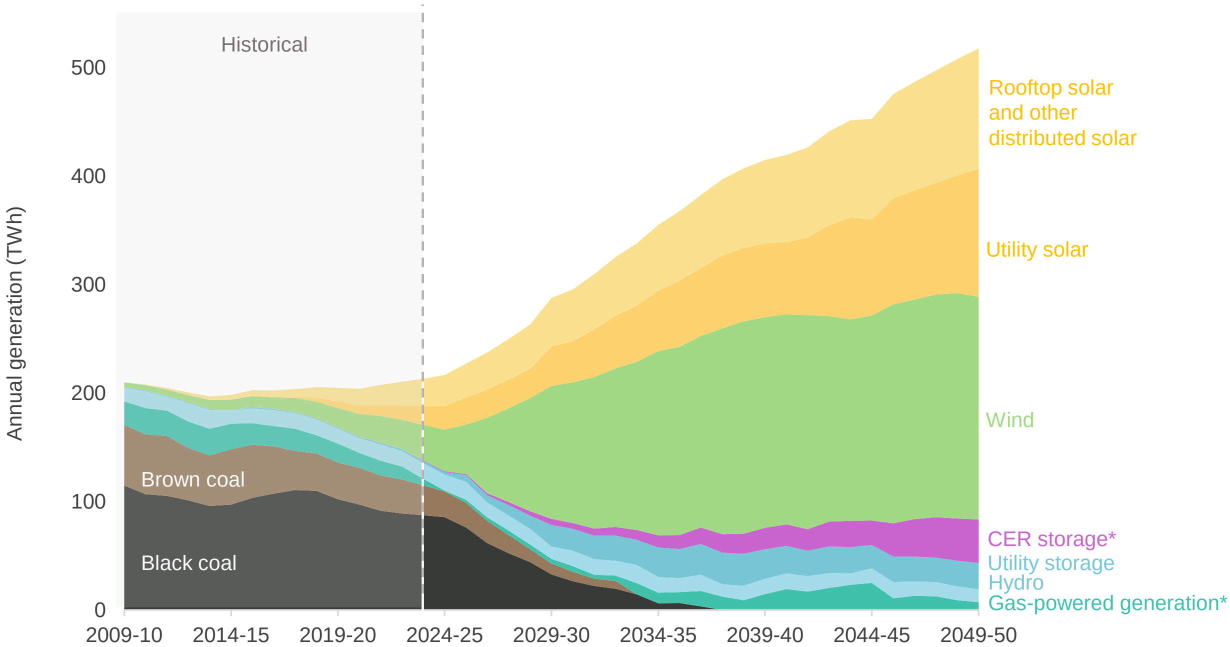
Australia is well underway in transforming its energy system. New investments in renewable generation and storage are accelerating, looking to keep ahead of coal closures and the big switch to electricity. Renewables accounted for almost 40% of the total energy delivered through the NEM in the first half of 2023. Government policies for decarbonisation are accelerating, network upgrades are underway, and consumers are investing heavily in their own resources.

The NEM has already reached 72% renewable

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 (over page) 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.
The forecasted gas-powered generation includes some potential hydrogen and biomass capacity.
"CER storage" are consumer energy resources such as batteries and electric vehicles.

Consumers are investing in their own resources

The growth in new rooftop solar systems has averaged 12% year on year over the past five years, reaching 3.1 million systems in 2023. Rooftop solar is now three times as common in Australia as backyard pools, and is capable of meeting 48% of underlying energy demand across the NEM in the middle of a sunny day. Rooftop systems contributed 12.1% of the NEM's total generation in the summer (Q1) of 2023, more than utility-scale solar (7.5%), wind power (11.6%), hydro (6.1%) and gas (4.6%)[5].

This is the first wave of consumer investment in their own energy transition. All-electric homes with batteries and rechargeable electric vehicles are gaining popularity. Early adopters are taking control of both their energy costs and their emissions footprint. Governments are encouraging these changes, with the ACT and Victoria phasing in bans of new residential connections to the gas system.

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[6].

[5] AEMO. Quarterly Energy Dynamics Report Q1, April 2023. At https://www.aemo.com.au/energy-systems/major-publications/quarterly-energy-dynamics-qed.

[6] The emission reduction or renewable energy targets of any NEM participating jurisdiction have been a consideration in the National Electricity Objective from 21 November 2023. AEMO has included these policies if either their legislation or their funding arrangements are likely to be in place by the June 2024 publication of the 2024 ISP: see *Addendum to the 2023 Inputs, Assumptions and Scenario Report* at https://aemo.com.au/energy-systems/major-publications/integrated-system-plan-isp/2024-integrated-system-plan-isp/current-inputs-assumptions-and-scenarios.

- **Australia's** commitment to reaching net zero emissions by 2050 has been in place since 2015. The Federal Government increased the interim 2030 reduction to 43% (from 2005 levels), supported by an 82% renewable energy target under the Powering Australia Plan and the Rewiring the Nation policy, with the recent Capacity Investment Scheme expansion and Renewable Energy Transformation Agreements supporting those targets.
- **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 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. 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 targets of 50% reduction (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 generationand storage targets, and Offshore Wind Targets of 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040.

Network upgrades are underway

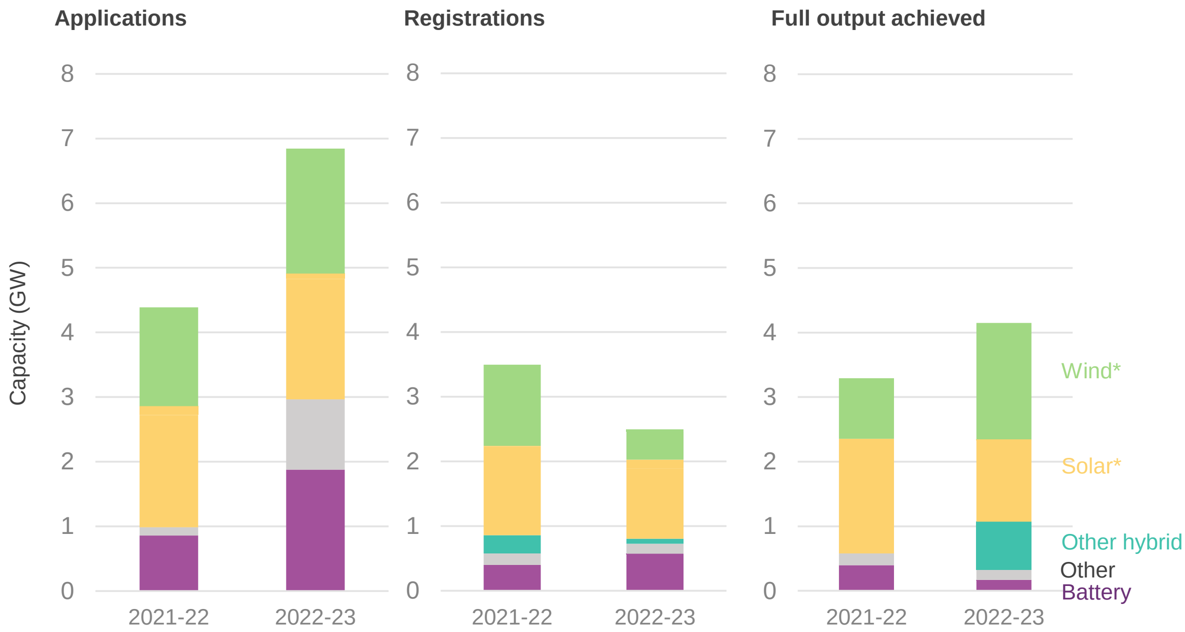
Network capacity was increased between Queensland, New South Wales and Victoria in 2023, and upgrades are also underway within regions, with the Eyre Peninsula expansion completed in 2023 and a reinforcement in far North Queensland nearing completion. Several capacity increases are well under way in committed and anticipated projects, with Project EnergyConnect on track 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):

- 6.9 GW of generation and storage connection applications were approved in 2022-23, with GPG being 15%, and wind, solar and batteries about a third each of the remainder.
- 2.5 GW of generation and storage registrations were approved in 2022-23. Solar accounted for 40% of new plant registered in 2022-23, with both wind and battery accounting for 20% each. Of the 12 GW of projects in pre-registration phase, 6.8 GW of new generation have signed a connection agreement with the local network service provider and are ready for construction. This could increase the number of projects registering to the NEM in the coming years.
- 4.1 GW of generation and storage projects achieved full output in 2022-23. About 43% were wind, 30% solar, 20% both wind and solar, with the remainder being batteries and GPG.

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



Note: Wind and Solar include a small number of connections with a battery included in the connection.

2.3 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

For the transition to succeed, lights must be kept on and the gas flowing while the new system is put in place. This is a highly complex technical challenge, but also a social and economic one.

Coal generators are retiring earlier than initially announced, and a 'just in time' transition to replacement infrastructure would risk reliable supply. The need for renewable energy, transmission, storage and backup gas generation is critical now and throughout the transition. The critical thing is timing, 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 that 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.

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.

The first 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 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 to and 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 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[7].

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[8]. Japan's *Green Development Strategy* is intended to stimulate US$100 billion in private investment over 10 years[9], while South Korea's *New Deal* allocated US$60 billion to the energy transition[10]. 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[11]. To all of which 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.

[7] 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.

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

[9] 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.

[10] 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.

[11] 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*"[12], taking relevant government energy policies into account.

In simpler terms, the ISP is a plan for secure, reliable and affordable power, and AEMO extends the horizon to 2050 to recognise Australia's net zero emissions target.

To develop 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, and chooses a plan that best delivers 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. It is rigorously prepared in collaboration with NEM jurisdictional planners and policy-makers, energy consumers, asset owners and operators, and market bodies, with this Draft ISP open to public comment before being finalised in June 2024.

This section sets out how the ISP:

3.1 Considers the whole NEM power system,

3.2 Prioritises reliable, secure and affordable electricity while meeting policy commitments, and

3.3 Is rigorously developed in consultation with the entire energy industry.

3.1 A plan that considers the whole NEM power system

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, responding to government policies, infrastructure costs, workforce availability and community responses to the energy transition.

In particular, the ISP considers:

- government energy and environmental policies, including emission reduction and renewable energy targets, and policies for REZs and electricity infrastructure[13],

[12] National Electricity Rules (NER) 5.22.2.

[13] NER 5.22.3(b) provides requirements for public policies' inclusion in the ISP. In November 2023 a new emissions reduction element came into force in the National Electricity Objective (NEO) of the National Electricity Law. AEMO has chosen to apply the amended NEO in its preparation of the Draft 2024 ISP, by using only scenarios that comply with Australian governments' emissions reduction policies and by considering policies and targets in the Australian Energy Market Commission's *Emissions Targets Statement,* including those which are on their way to meeting (but have not yet met) the National Electricity Rules requirements for public policies' inclusion in the ISP.

- future trends in electricity consumption, net of CER, energy efficiency savings, and the electrification of transport, heating, cooling and cooking,
- future trends and costs in existing and new transmission, generation and storage technologies, including the design and implementation of new REZs,
- power system reliability and security needs[14] that must be met as new technologies are integrated, and
- the interaction of the power system with other 'coupled' sectors such as transport, gas and hydrogen.

3.2 The reliability, security, affordability and emissions reduction needs

The objectives of the ISP align with the National Electricity Objectives, which are to promote efficient electricity services for the long-term interests of consumers. This takes in three sets of considerations: reliability and security, price and quality (affordability), and the need to reduce Australia's greenhouse gas emissions. These three objectives are discussed below, and balancing reliability and affordability is a matter of judgment.

Reliability and security as 'power system needs'

The NEM power system needs to be reliable and secure, operating within engineering limits and operating standards[15], 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 that demand is met at least 99.998% of the

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

[15] 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).

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, as well as flexible generation that can respond to regular large swings in demand.

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 System Operability and Appendix 7 System Security discuss most completely how system reliability and security are being provided through to 2050, though 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[16]. 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 and captured in Table 3 below. Unless otherwise indicated, these benefits are assessed for all utility-scale generation, firming and transmission infrastructure in the NEM.

AEMO notes, however, that lowering long-term system costs generally means investing in new assets, generally up front. That 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.

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 RIT-T analysis on any actionable projects.

[16] 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[17]. 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. 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.

Further details see: Summary of consumer risk preferences project.

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 Draft 2024 ISP as follows:

- Only scenarios that comply with Australian governments' emissions reduction policies have been applied (which meant removing the previous *Slow Change* scenario).
- Policies and targets included in the Australian Energy Market Commission's *Emissions Targets Statement* have been incorporated, including those which are on their way to meeting (but have not yet met) the National Electricity Rules 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 may also include a value of emissions reduction in future analysis, potentially for the final 2024 ISP, once a value is determined by an appropriate market institution or government body.

For further information, see *Addendum to the 2023 Inputs Assumptions and Scenarios Report*.

[17] 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.

3.3 Preparing the ISP

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

This Draft ISP is a milestone on an industry-wide journey that started in July 2022 and will only finish when the final ISP is published by 28 June 2024.

Over that time AEMO has engaged and will continue to engage openly with consumer and community representatives, governments, energy market authorities, investors and developers, network planners, industry bodies and science and technology institutions. This includes regular engagement with the ISP Consumer Panel, and seeking input on consideration of social licence from AEMO's Advisory Council on Social Licence. In particular:

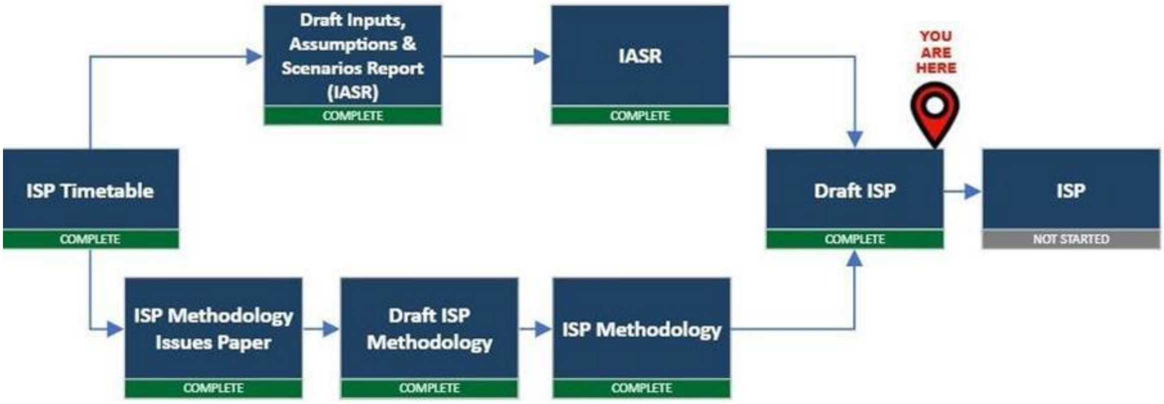
- The ISP considers the forecasts and insights provided in the 2023 *Electricity Statement of Opportunities* and the 2023 *Gas Statement of Opportunities*[18].
- Inputs have been progressively published in the draft and final 2023 *Inputs, Assumptions and Scenarios Report* (the IASR, with an addendum after the Australian Energy Regulator's review), and the draft and final 2023 *Transmission and Expansion Options Report*.
- The methodology for determining the ISP's optimal development path is governed by the National Electricity Rules and the Regulator's *Cost Benefit Analysis Guidelines*, and follows steps set out in the *2023 ISP Methodology.*

In formal consultations, AEMO has published 43 reports, hosted 1,418 attendances across 10 webinars and considered 117 written submissions, and will continue this effort through formal consultation on this Draft 2024 ISP, which will inform development of the final 2024 ISP.

AEMO considers that the development path most likely to succeed is the one which has been transparently and comprehensively tested by as many energy and community experts as possible. While more can always be done, AEMO is confident that this Draft 2024 ISP represents the best effort possible by the energy sector and its stakeholders to set out a clear and actionable plan for our energy future.

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

Figure 11 ISP consultations

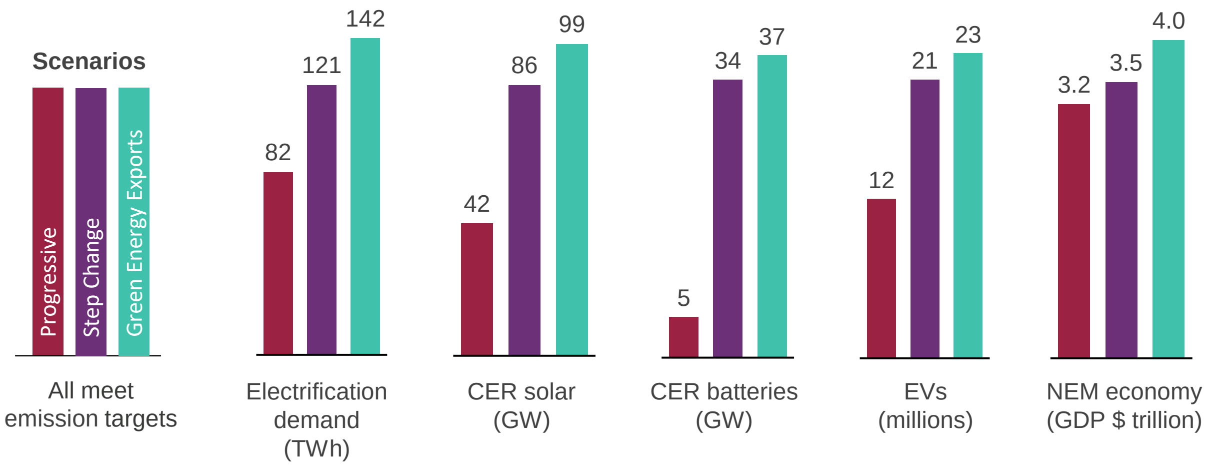


Three potential scenarios for the future

Through industry consultation, AEMO considered and published three scenarios in the 2023 IASR*:* see Figure 12. Each acknowledges the retirement of coal-fired generation through the 2030s 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 consumer energy resources (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 12 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.

Considering the Delphi Panel insights, AEMO has 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 Draft 2024 ISP, although the near-term transition is very similar in *Progressive Change*.

Integrated modelling to identify the ODP

The methodology for determining the ODP is set at a high level in the National Electricity Rules and provided in detail in AEMO's *ISP Methodology*[19].

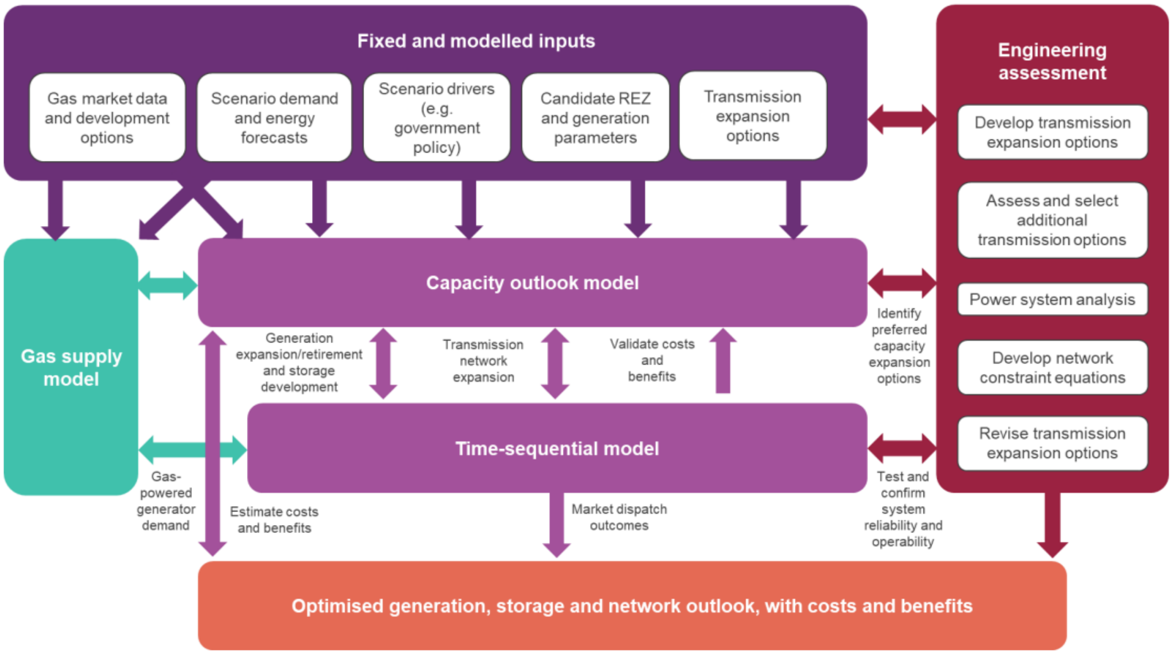
AEMO relies on a suite of models and analyses that covers generation and storage investments, as well as transmission projects. The components of this suite is shown in Figure 13 (over page):

- The **fixed and modelled inputs** are published in the *Inputs, Assumptions and Scenarios Report*, 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.

[19] At https://aemo.com.au/en/consultations/current-and-closed-consultations/consultation-on-updates-to-the-isp-methodology.

Figure 13 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, firmed with storage and backed up by gas-fired generation is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition 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 increases seven-fold by 2050 – from 19 GW currently to 126 GW in Step Change – a doubling every decade. In addition, the capacity of rooftop solar and other distributed solar rises from 19 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 two projects that are made actionable for the first time in this ISP.
- **Section 6 – Storage and services to support renewable generation.** 74 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.*

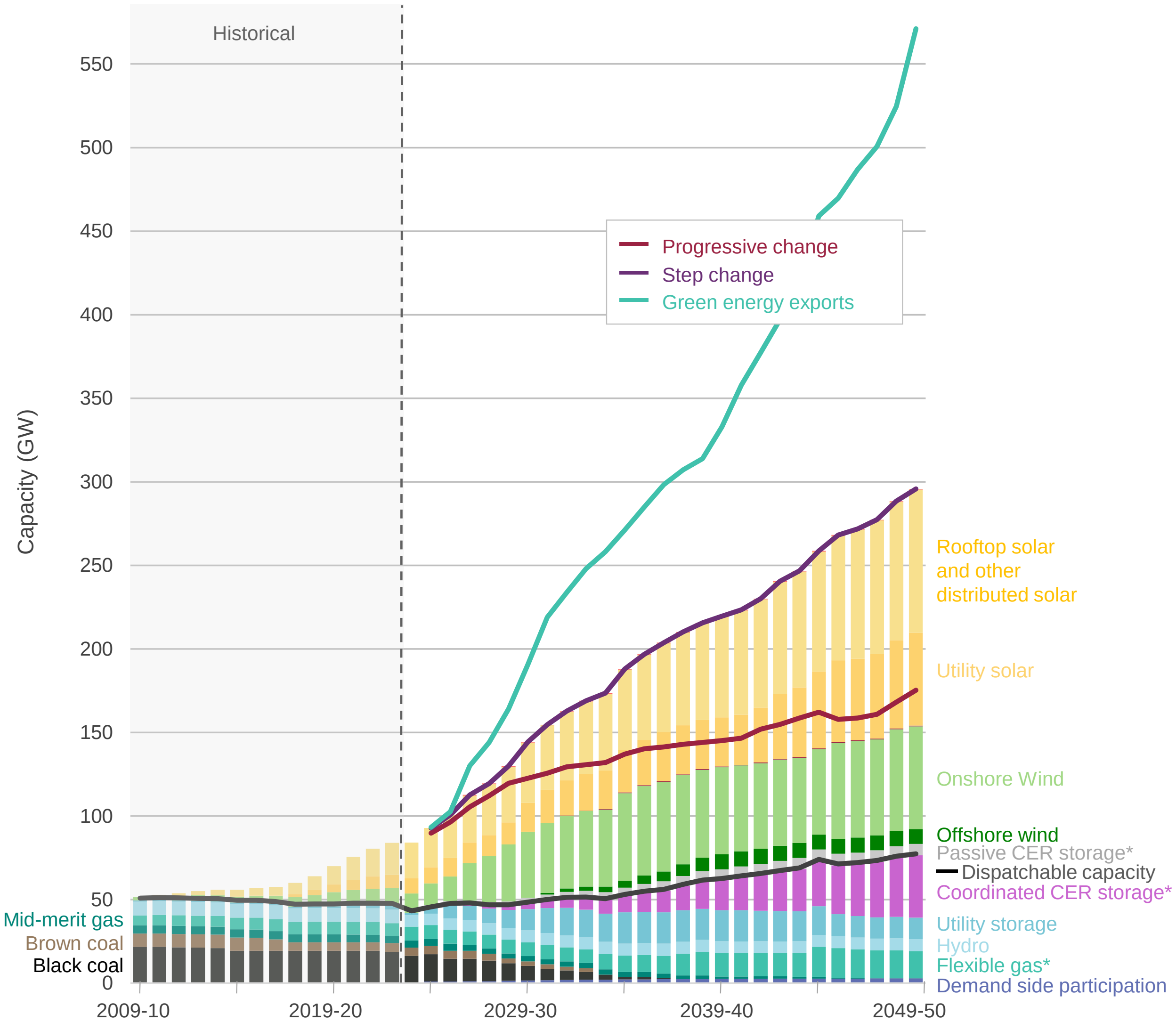
The ISP projects the optimal mix of generation and storage, including renewables such as solar and wind as well as firm capacity technologies like battery storage, pumped hydro and gas-fired generation. AEMO projects this mix based on capital and operating costs from GenCost, rather than using a levelised 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 $16.4 billion[20] and, after paying themselves back, they would avoid $17 billion in additional costs to consumers.

Changing one element of the ODP is likely to render other elements, and the whole, less effective and more expensive. AEMO has also considered alternative solutions to the NEM's requirements.

[20] This value does not include the cost of commissioned, committed or anticipated projects.

Figure 14 Capacity, NEM (GW, 2009-10 to 2049-50)



Note: Flexible gas includes gas-powered generation as well as potential hydrogen and biomass capacity.
"CER storage" are consumer energy resources such as batteries and electric vehicles.

4 Transition to renewable generation

Renewable energy connected by transmission, firmed with storage and backed up by gas is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition 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 four-fold.

4.3 Utility-scale solar and wind are forecast to grow seven-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, ten coal-fired generators have retired over the last decade. Owners of all but one plant of 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.

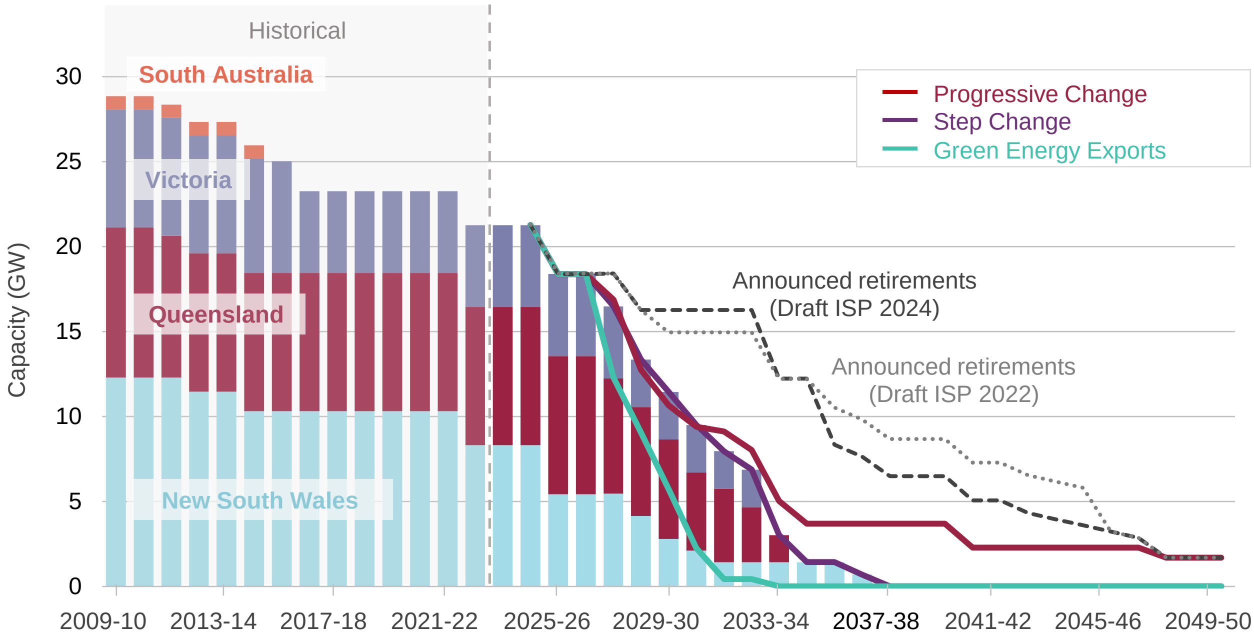
The ISP forecasts suggest that the remaining coal fleet will close two to three times faster than those announcements. About 90% of the NEM's coal fleet is forecast to retire by 2034-35, with all coal generators retired by 2037-38 in the *Step Change* scenario: see Figure 15 (over page).

However, coal retirements may occur earlier than even this forecast, as they have in the past. Ownership has become less attractive, with higher operating costs, reduced fuel security, and high maintenance costs as well as increasing competition by lower-cost renewable energy in the wholesale market.

Coal owners are only required to give three-and-a-half years' notice of a closure, which is very little time in which the NEM has to respond. Given the lead time to deliver new assets, replacement capacity must be put in place well in advance.

Government policies and corporate strategies are driving the needed changes. The ISP informs how those investments can be made efficiently to maintain a reliable and secure power system.

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



4.2 Four 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. Virtual power plants (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.

- **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, and 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, 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.

Any growth in CER reduces the need for utility-scale solutions, especially if the assets can be coordinated or 'orchestrated' to complement and support the grid most efficiently. 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. How this works will depend on a mix of financial incentives, technology and communication standards, customer preferences, and market or policy arrangements. This will require increased engagement between consumers, retailers, networks and other market participants: see Section 8.2.

The potential of coordinated CER is demonstrated by Project EDGE[21], 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 Seven times today's utility-scale wind and solar

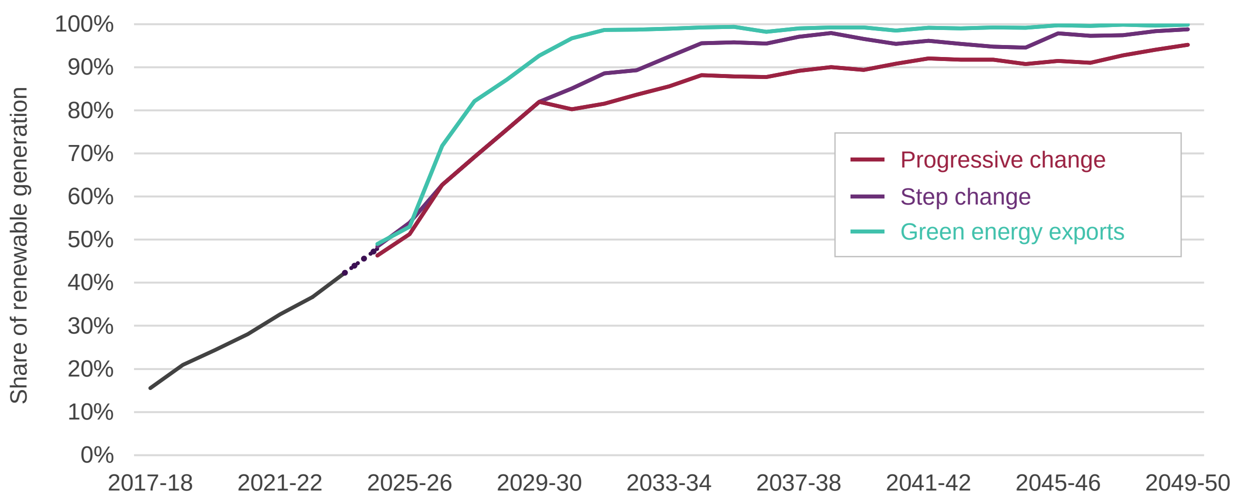
With most coal forecast to withdraw by 2034-35, the race is on for new utility-scale generation both to replace that coal capacity and then provide for tomorrow's industry and transport.

As a share of annual generation, renewable energy including hydro and biomass reached 32% in 2021-22. In *Step Change*, this is forecast to reach almost 70% in 2027-28, 82% in 2029-30, and 99% by 2049-50: see Figure 16.

By 2034-35, the NEM is forecast to need approximately 82 GW of utility-scale wind and solar, and 126 GW by 2049-50. This would be seven times the current NEM capacity of 19 GW, with another 5 GW committed or anticipated to be operational before the end of 2024.

This means that the current rate of investment in renewables has 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.

Figure 16 Share of generation from renewable sources, NEM (2017-18 to 2049-50)



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

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 grid-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 77% 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.

However, building the network, storage and system services to use or store every last watt of energy 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 17 below. They are selected for the quality of their renewable resource, and their proximity to consumers and existing transmission.

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[22], 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 are forecast to be:

- **Tasmania: over 3.7 GW of onshore wind by 2049-50**, with no offshore wind. Project Marinus and the Central Highlands REZ are established from 2029-30 onward.
- **Victoria: 22 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 Gippsland areas.
- **South Australia: 9 GW new utility-scale wind and solar by 2049-50**. Over 9 GW of new renewables are forecasted for the region by 2050. Expansion of the Mid-North South Australia REZ is needed in the mid-2040s to access mid-north wind and northern solar.
- **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 14 GW new generation capacity in Central-West Orana, 12 GW in New England, 4 GW in South West New South Wales, and 2.4 GW in Hunter-Central Coast by 2050. No offshore wind is yet forecast for New South Wales.
- **Queensland**. **46 GW new utility-scale wind and solar by 2049-50**. The CopperString 2032 and Queensland SuperGrid upgrades allow new renewables in North Queensland (7.7 GW wind), Isaac (9 GW, mainly solar), Fitzroy (11 GW, mainly solar), Darling Downs (15 GW each of solar and wind). REZs in the south of the state are forecast to make use of existing network capacity as coal retires.

[22] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/isp/2018/integrated-system-plan-2018_final.pdf?la=en&hash=40A09040B912C8DE0298FDF4D2C02C6C.

5 Actionable and other network investments

Renewable energy **connected by transmission**, firmed with storage and backed up by gas is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition 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.

This section describes the transmission projects in 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 grid-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 National Electricity Rules.

5.1 Overview of transmission projects over the forecast period

As with the 2022 ISP, the 2024 Draft 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 17 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.
- **Seven actionable projects**, for which work should commence or continue 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 will be at full capacity by the end of 2032.
- **A set of future ISP projects in each state** and to connect Queensland and New South Wales. 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 optimal development path are selected by AEMO to meet power system needs and optimise market benefits to the NEM[23]. AEMO considers optimal timings will 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 delivery dates are in the hands of transmission network service providers (TNSPs).

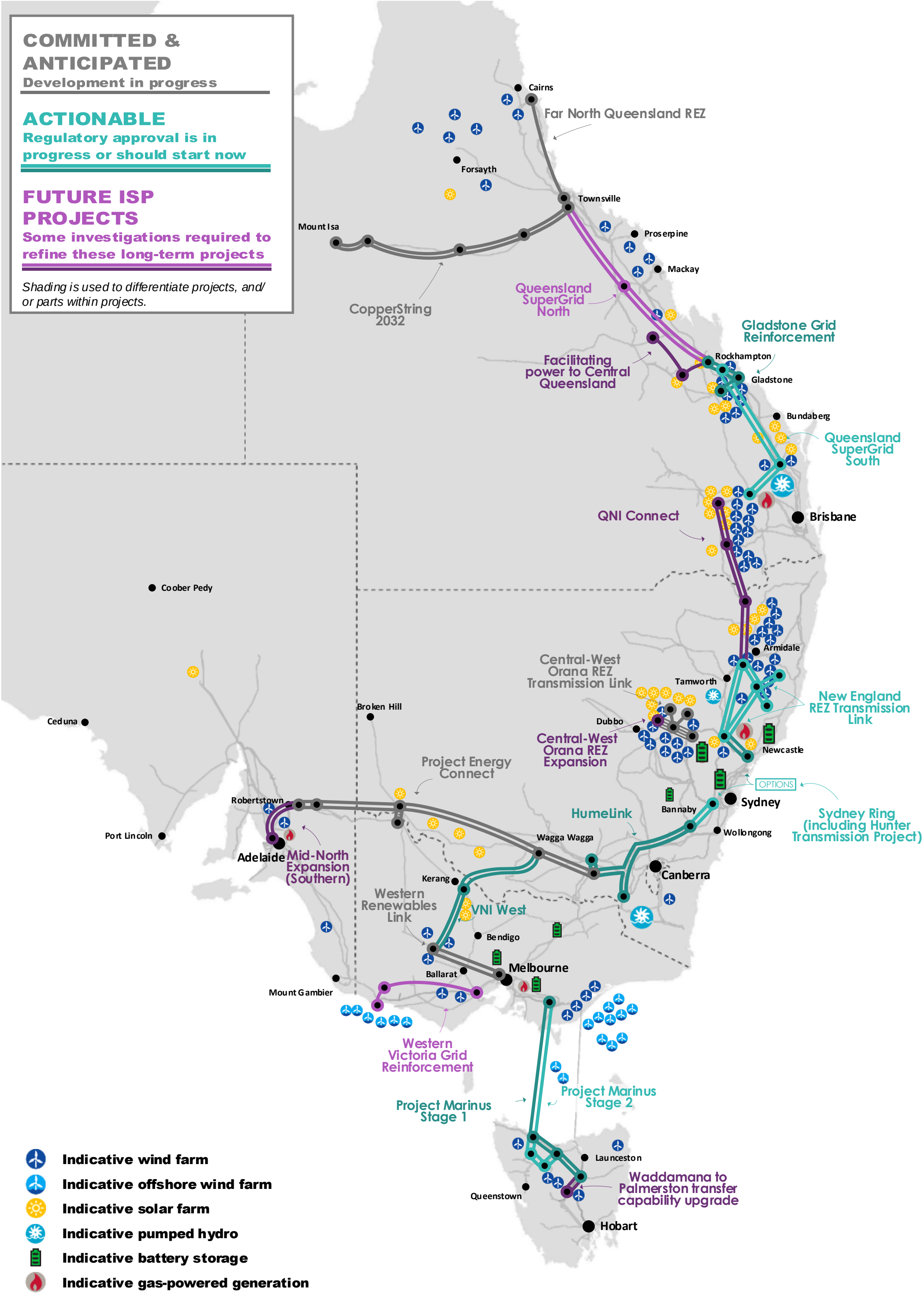
[23] The ISP must specify the identified need for each project (NER r 5.22.6(a)(6)(v)), with credible options able to be implemented in sufficient time to meet the identified need (r 5.15.2(a)).

Table 4 Network projects in the Draft 2024 ISP optimal development path

Committed and anticipated ISP projects		In service timing advised by proponent	Full capacity timing advised by proponent
Far North Queensland REZ		April 2024	April 2024
Project EnergyConnect[A]		Stage 1 April 2024 Stage 2 December 2024	Stage 1 July 2024 Stage 2 July 2026
Western Renewables Link		July 2027	July 2027
Central West Orana REZ Transmission Link		January 2028	August 2028
CopperString 2032[B]		June 2029	June 2029
Already actionable projects *(confirmed in this Draft ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent**
HumeLink[C]	ISP	Northern Circuit July 2026 Southern Circuit December 2026	Northern Circuit July 2026 Southern Circuit December 2026
Sydney Ring *(Hunter Transmission Project and investigation of southern network options)*	NSW[D]	December 2027	December 2027
New England REZ Transmission Link	NSW[D]	September 2028	September 2028
Victoria – New South Wales Interconnector West (VNI West)	ISP	December 2028	December 2029
Project Marinus[E]	ISP	Stage 1 June 2030 Stage 2 June 2032	Stage 1 December 2030 Stage 2 December 2032
Newly actionable projects *(as identified in this Draft ISP)*	**Actionable framework**	**In service timing advised by proponent**	**Full capacity timing advised by proponent**
Gladstone Grid Reinforcement[F]	QLD[G]	September 2029	September 2029
Queensland SuperGrid South[F]	QLD[G]	June 2031	June 2031
Future ISP projects			
Interconnectors	Queensland – New South Wales Interconnector (QNI Connect)		
New South Wales	Central West Orana REZ Expansion, Hunter-Central Coast REZ Expansion, Cooma-Monaro REZ Expansion.		
Queensland	Darling Downs REZ Expansion, Facilitating Power to Central Queensland, North Queensland Energy Hub Uplift, Queensland SuperGrid North.		
South Australia	Mid North REZ Expansion.		
Tasmania	Waddamana to Palmerston transfer capability upgrade, North West Tasmania REZ Expansion.		
Victoria	Western Victoria Grid Reinforcement, Eastern Victoria Grid Reinforcement.		

A. The capacity release and timing is conditional on availability of suitable market conditions and good test results.
B. CopperString 2032 will be built and owned by the Queensland Government, continuing the commitment made through the Queensland Energy and Jobs Plan that all the state's transmission assets will be 100% publicly owned. This project was not actioned through the ISP framework.
C. 'Northern Circuit' is between Bannaby and Gugaa. 'Southern Circuit' is between Bannaby and Maragle, and Maragle and Gugaa. Transgrid has advised the Southern Circuit has been programmed to December 2026 for optimal delivery.
D. These are actionable New South Wales projects. They will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework. New England REZ Transmission Link includes additional scope compared to 2022 ISP, with the proponent date only applying to the original scope.
E. Project Marinus includes MarinusLink and North West Transmission Developments (NWTD) projects. Project proponent dates represent modelling dates and are under negotiation. 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.
F. Project proponent dates are subject to further refinement.
G. These are actionable Queensland projects. They may progress under the *Energy (Renewable Transformation and Jobs) Bill* 2023 (Qld) rather than the ISP framework.

Figure 17 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 1,000 MW or more, and are required in all scenarios by 2050.

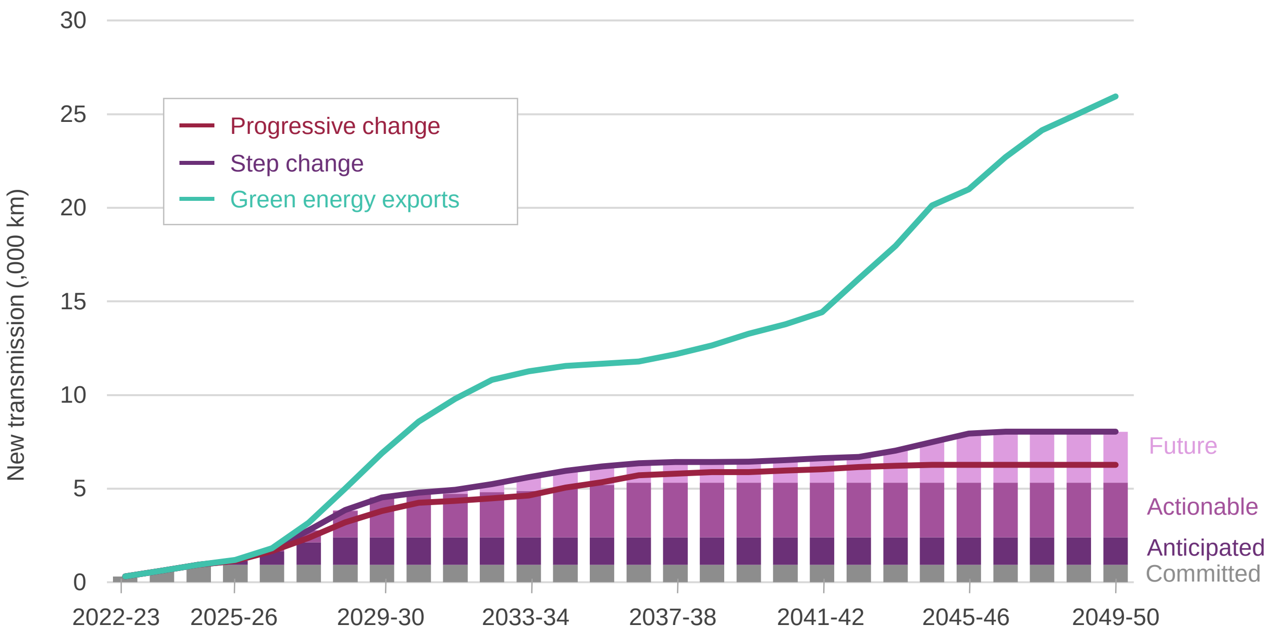
Total transmission, by scenario

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 18.

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.

Figure 18 New transmission in least cost development paths (kms, 2022-23 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[24] (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.	April 2024, Powerlink
	Project EnergyConnect	A new 330 kV double-circuit interconnector between South Australia and New South Wales.	Stage 1 July 2024 and Stage 2 July 2026[A], Transgrid and ElectraNet
Anticipated	**Western Renewables Link**	A 500 kV double-circuit network upgrade to provide additional capacity to the Western Victoria REZ.	July 2027, AEMO Victoria Planning
Anticipated	**Central-West Orana REZ Transmission Link**	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**	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.

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 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 RIT-T as detailed below. For those actioned under state frameworks, the processes in that legislation apply.

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

Table 6 Actionable network projects in the optimal development path

Project	In service timing advised by proponent	Full capacity timing advised by proponent	Brief description Cost estimates in $2023	Actionable framework
HumeLink[A]	Northern Circuit July 2026 Southern Circuit December 2026	Northern Circuit July 2026 Southern Circuit 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
Sydney Ring *(Hunter Transmission Project and investigations on southern network options)*	December 2027	December 2027	High capacity 500 kV transmission network to reinforce supply to Sydney, Newcastle and Wollongong load centres. $926 million ±50% (northern option)	New South Wales[B]
New England REZ Transmission Link	September 2028	September 2028	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. $3.69 billion ± 50%. This cost estimate includes the three separate projects. The scope of this project is subject to ongoing consultation with EnergyCo.	New South Wales[B]
Project Marinus[C]	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
Victoria – New South Wales Inteerconnector West (VNI West)	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
Gladstone Grid Reinforcement[D]	September 2029	September 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[E]
Queensland SuperGrid South[D, E]	June 2031	June 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[E]

A. 'Northern Circuit' is between Bannaby and Gugaa. 'Southern Circuit' is between Bannaby and Maragle, and Maragle and Gugaa. Transgrid has advised the Southern Circuit has been programmed to December 2026 for optimal delivery.
B. These are actionable New South Wales projects. They will progress under the *Electricity Infrastructure Investment Act 2020* (NSW) rather than the ISP framework. New England REZ Transmission Link includes additional scope compared to 2022 ISP, with the proponent date only applying to the original scope.

C. Project Marinus includes MarinusLink and North West Transmission Developments (NWTD) projects. Project proponent dates represent modelling dates and are under negotiation. 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.
D. These are actionable Queensland projects. They may progress under the *Energy (Renewable Transformation and Jobs) Bill* 2023 (Qld) rather than the ISP framework.
E. Project proponent dates are subject to further refinement.

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 delivery date	Brief description Cost estimate in $2023
Interconnectors			
QNI Connect	2033-34	2030-31	Adds capacity between southern Queensland and New England, following development of the New England REZ Transmission Link. $2,518 million (±50%).
New South Wales			
Central-West Orana REZ Extension	2040-41	2030-31	Follows the initial Central-West Orana Transmission Link (Anticipated project) to enable additional REZ capacity. Upgrades existing transmission lines to 500 kV. $243 million (±50%).
Hunter-Central Coast REZ Extension	Option 2: 2029-30 Option 2a: 2044-45	Option 2: 2027-28 Option 2a: 2030-31	Adds two transfer capacity upgrades from the REZ to Sydney-Newcastle-Wollongong via Singleton. Further joint planning is required to clarify whether the capacity for this future ISP project can be achieved. This project may change for the final 2024 ISP. $59 million (±50%) for Option 2. $106 million (±50%) for Option 2a.
Cooma-Monaro REZ Extension	2045-46	2030-31	Enables transfer capacity for the Cooma-Monaro REZ in New South Wales. $512 million (±50%).
Queensland			
Queensland SuperGrid North	Timing dependent on Queensland Government policy decisions	2032-33	Adds transfer capacity between Central and North Queensland, while enabling build of a further 3 GW of renewable generation across Northern Queensland, Barcaldine and Isaac REZs and a further 800 MW of renewable generation to be built in the North Queensland Clean Energy Hub REZ. $4,184 million (±50%). SuperGrid North's timing depends on the approval of Pioneer-Burdekin, which is currently progressing through Queensland decision-making processes and does not yet meet the criteria to be an anticipated project for the ISP. AEMO recognises the Queensland Government's commitment to build SuperGrid North

Project	Optimal timing *Step Change*	Earliest feasible delivery date	Brief description Cost estimate in $2023
			and understands that this project may become an actionable Queensland project in the future.
Darling Downs REZ Extension	2034-35	2027-28	Enables additional renewable generation to be dispatched in Darling Downs REZ. $28 million (±50%). The Darling Downs REZ Extension will also facilitate transmission of this generation to load centres in the locality of Brisbane.
Facilitating Power to Central Queensland	2035-36	2030-31	This upgrade option would improve the generation capacity across Northern Queensland, facilitate transmission of generation to load centres in Central Queensland, and support further renewable generation to be dispatched across Isaac and Barcaldine REZ. $173 million (±50%).
North Queensland Energy Hub Expansion	2042-43	2030-31	The North Queensland Clean Energy Hub REZ is at the north-western section of Powerlink's network and has excellent wind and solar resources. While AEMO is now considering the CopperString 2032 project as an anticipated project after outcomes from joint planning with Powerlink and the Queensland Government, the ISP recommends further expansion of the REZ to further unlock renewable resources. The Energy Hub expansion would allow additional renewable generation to be dispatched in North Queensland Clean Energy Hub REZ. $651 million (±30%).
South Australia			
Mid-North REZ Expansion	Option 1: 2045-46 Option 2: 2045-46	Option 1: 2027-28 Option 2: 2027-28	These upgrades would enable renewable generation potential in South Australia's Mid North, Yorke Peninsula, Leigh Creek, Roxby Downs, Eastern Eyre and Western Eyre Peninsula REZs to supply the Adelaide region. AEMO notes that transmission capacity required within South Australia is highly related to load commitment in that region. AEMO and ElectraNet will undertake joint planning between the Draft 2024 ISP and final 2024 ISP on this matter. $416 million (±50%) for Option 1. $740 million (±50%) for Option 2.
Tasmania			
North West Tasmania REZ Expansion	2029-30	2027-28	The North West Tasmania REZ extension project unlocks hosting capacity for variable renewable generation in this REZ, providing additional transmission capacity after Project Marinus Stage 1 is built. This project provides opportunity for high quality renewable generation resources from this REZ to be exported over to the mainland through MarinusLink and increases the transfer capacity between Sheffield to Hampshire Hills where potential generation could come in. $28 million (±30%).
Waddamana to Palmerston transfer capability upgrade	Option 1: 2029-30 Option 2: 2041-42	Option 1: 2027-28 Option 2: 2032-33	The Waddamana to Palmerston transfer capability upgrade in the Central Highlands REZ would unlock hosting capacity for renewable generation in this REZ, providing additional transmission capacity after Project Marinus Stage 1 is built and also additional capacity after Project Marinus Stage 2 is built.

Project	Optimal timing *Step Change*	Earliest feasible delivery date	Brief description Cost estimate in $2023
			This project provides opportunity for high quality variable renewable energy resources from this REZ to be exported over to the mainland through MarinusLink. $201 million (±30%) for Option 1. $274 million (±30%) for Option 2.
Victoria			
Western Victoria Grid Reinforcement	2034-35	2032-33	The Western Victoria Grid Reinforcement project increases transfer capacity out of South-West Victoria REZ to consumers. The project is considered a future ISP project and was formulated through preparatory activities undertaken by AEMO Victorian Planning as an outcome from the 2022 ISP. This project would facilitate development of high quality onshore and offshore renewable generation through South-West Victoria. Cost is $1,297 million (±30%). AEMO National Planning is undertaking joint planning with AEMO Victorian Planning and VicGrid to further investigate options that support onshore and offshore renewable generation development, including through the VicGrid-led Victorian Transmission Plan process, and will incorporate these into the final 2024 ISP.
Eastern Victoria Grid Reinforcement	2035-36	2030-31	Modelling identifies a need for additional transfer capacity between Latrobe Valley and Melbourne to accommodate increased onshore and new offshore wind power generation. The Victorian Government has outlined its vision for offshore wind and has set targets for 2 GW of offshore wind capacity by 2032, 4 GW by 2035 and 9 GW by 2040. The 2023 *Victorian Annual Planning Report* (VAPR) identified emerging limitations in the Melbourne Eastern Metro network. AEMO Victorian Planning has proposed network reconfiguration at Hazelwood 220 kV switchyard for after the retirement of the Yallourn Power Station, to utilise 220 kV lines between Latrobe Valley and Melbourne. In addition, more transfer capacity from Latrobe Valley to Melbourne would be required. AEMO National Planning is undertaking joint planning with AEMO Victorian Planning to incorporate preferred options to address Melbourne Eastern Metro network constraints and possible additional options to increase the existing capacity between the Latrobe Valley and Melbourne, and will incorporate these in to the final 2024 ISP. No cost is provided as options are being joint planned. ISP modelling provides transmission capacity uplift using options provided in the 2023 *Transmission Expansion Options Report.*

6 Storage and gas to firm renewables

Renewable energy connected by transmission, **firmed with storage and backed up by gas** is the lowest cost way to supply electricity to homes and businesses throughout Australia's transition to a net zero economy.

While hydro generation is consistent, solar and wind are variable resources, so 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.

Storage, along with hydro and gas generation and other investments, also 'firm' up the renewables to help maintain grid stability and inertia, smooth out volatile frequencies, and balance out fast changes in supply and demand.

Gas generation can provide back-up supply during long periods of 'dark and still' renewable droughts, particularly in the winter, and rare times of extreme peak demand.

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 throughout Australia's transition to a net zero economy.

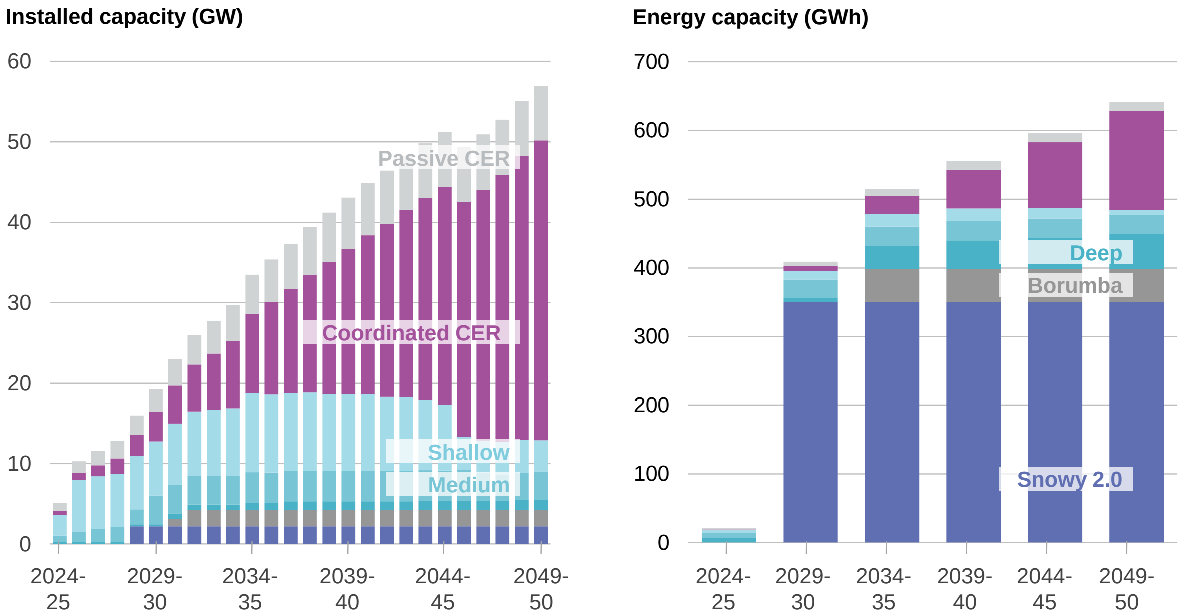
6.1 Storage of varied depths and technologies

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 33 GW / 514 GWh of storage capacity in 2034-35, rising to 57 GW / 642 GWh of storage capacity in 2049-50. 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 virtual power plant, 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.

Figure 19 Storage installed capacity and energy storage capacity, NEM (2024-25 to 2049-50, *Step Change*)



6.2 Storage for intra-day shifting

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

In total, approximately 12.7 GW of utility-scale storage is forecast to be needed by 2030, with an optimal mix of 2.4 GW as deep, 3.6 GW as medium and 6.7 GW as shallow storage: see Figure 19.

Growth in consumer energy resources

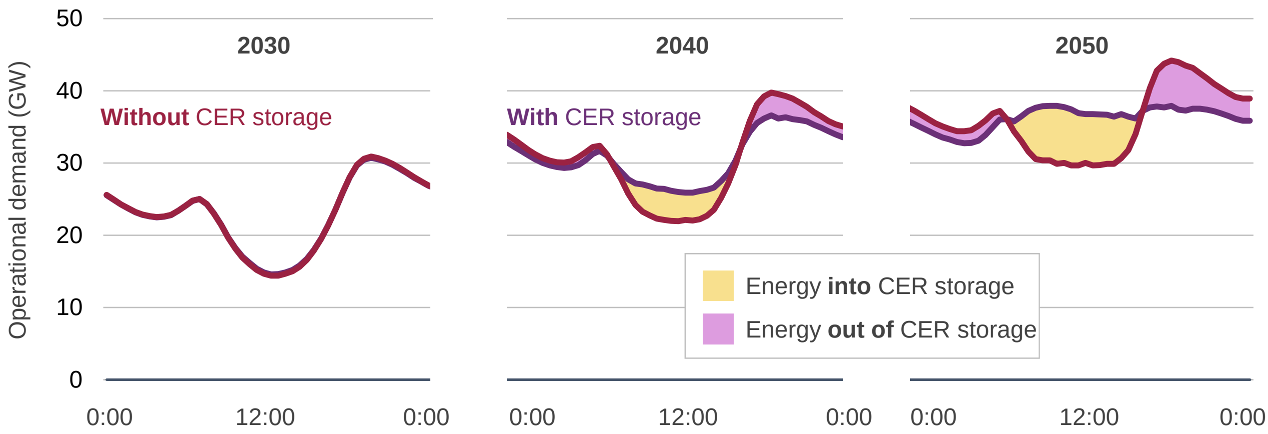
For the NEM as a whole, the three charts in Figure 20 (over page) show the rising impact of consumer-owned solar and batteries on forecast hour-by-hour grid demand. They help smooth out the NEM operational demand curve considerably.

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.

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 65% of the NEM's energy storage capacity.

Figure 20 Impact of coordinated CER on average operational demand by time of day, NEM (GW, 2030 to 2050, *Step Change*)



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 19 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 rooftop 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

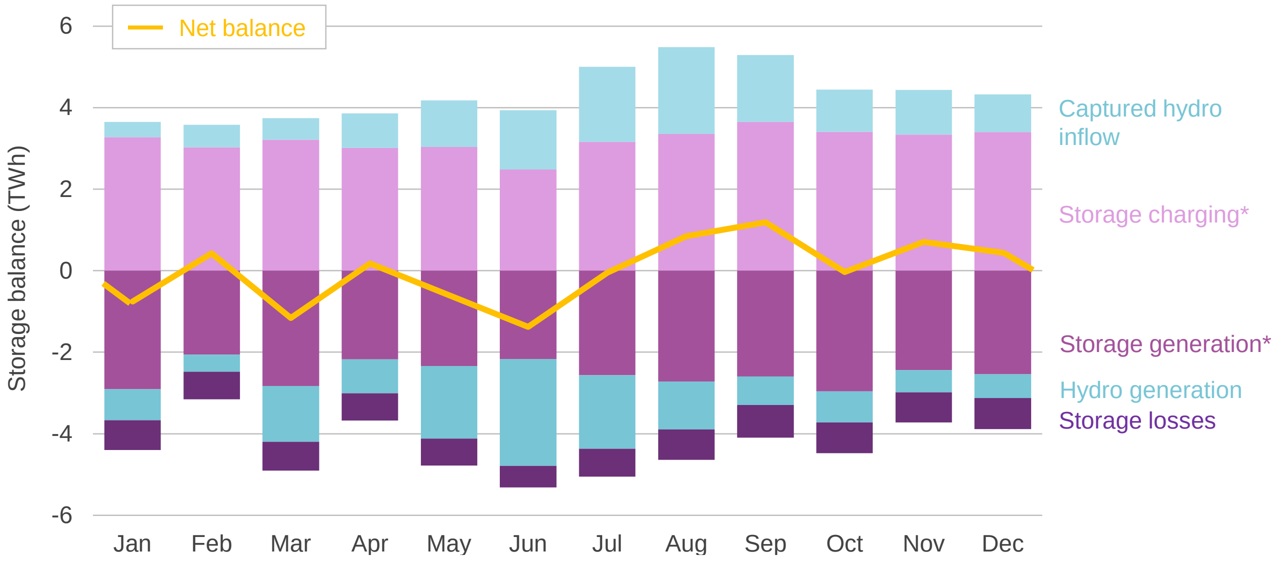
Deep storage, able to dispatch electricity for more than 12 hours continuously, can smooth out day-to-day variations in demand and renewable supply. The deepest storage available to the NEM are its existing deep-reservoir hydro assets, which can also mitigate renewable droughts and balance energy across 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), and Borumba and Kidston (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 21 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 almost 4 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.

Sound planning and energy management seek to minimise the need for deep storage and gas back up. However, 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 21 **Storage and hydro energy balances, NEM** (TWh, 2040, Step Change)



Note: Pumped hydro included as large-scale storage, not as hydro

6.4 Flexible gas for renewable droughts and peaking

Electricity from gas-powered generation (GPG) 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.

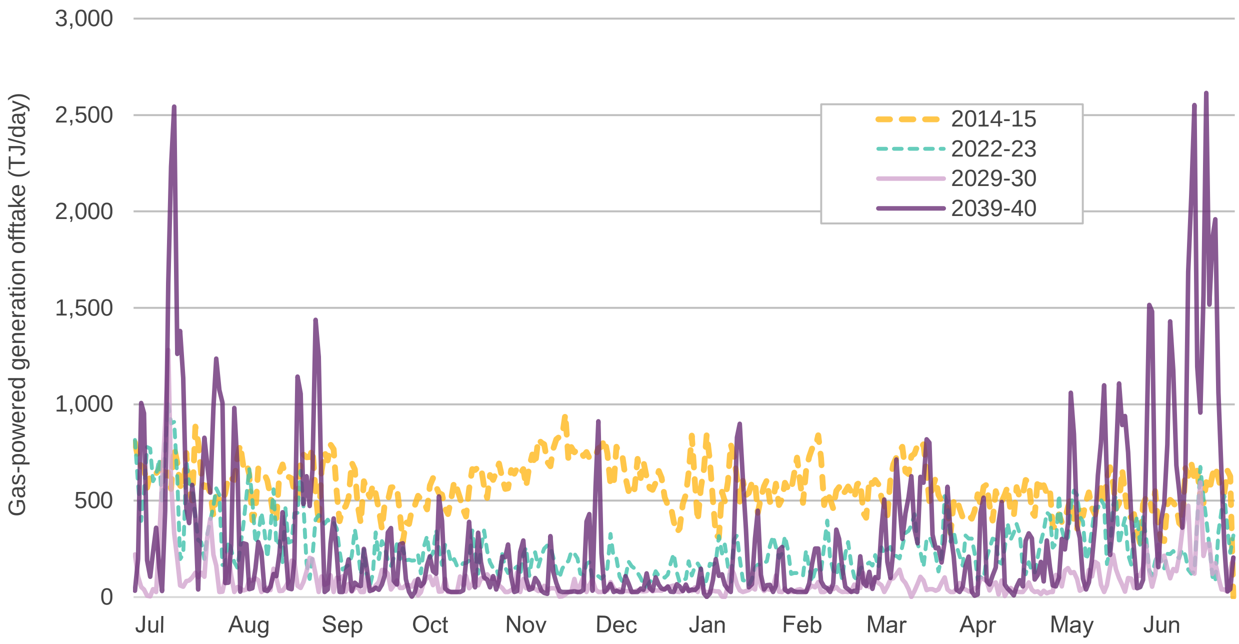
Growth in flexible gas generation

In total, the NEM is forecast to need 16.2 GW of gas-powered generation. Of the existing 11.2 GW capacity, about 8 GW is forecast or announced to retire, so that capacity would be replaced and another 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 some days in winter, for the reasons discussed in Section 6.3 above.

This is a change in the role of GPG from more continuous ‘mid-merit’ gas to a strategic, back-up role. Figure 22 shows that change in role, from relatively stable supply in 2015, to the forecast winter peaks in 2040. These peaks are forecast to test the limitations of the gas supply network, and solutions will be needed to address them.

Figure 22 **Gas-powered generation offtake, NEM** (TJ/day 2014-15 and 2039-40, *Step Change*)



Gas network impacts on gas powered generation

Gas for electricity generation is 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. During such conditions, use of locally stored secondary fuels (such as diesel or hydrogen), demand response, or other firming resources may be used to maintain reliable electricity supply. More on-site gas, diesel or hydrogen storages may be needed to secure this strategic reserve.

Avoiding gas network bottlenecks should also be considered in siting new gas-powered generation. Location decisions for new generators will need to consider availability of gas infrastructure (including pipelines and gas storages), future gas supplies, secondary fuels and proximity to electrical loads.

Hydrogen as a potential alternative generation fuel

Some gas generators may be configured to use an alternative fuel, such as diesel, bio-diesel, hydrogen or even a mix of those. Policies in New South Wales, South Australia and Queensland are supporting investment in hydrogen-ready turbines. The Draft 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 feel 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[25], 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.[26]

Batteries also improve the utilisation of new and existing transmission lines. Several large-scale grid batteries[27] 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, backed up at times by gas when required: see Section 6.4 above.

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

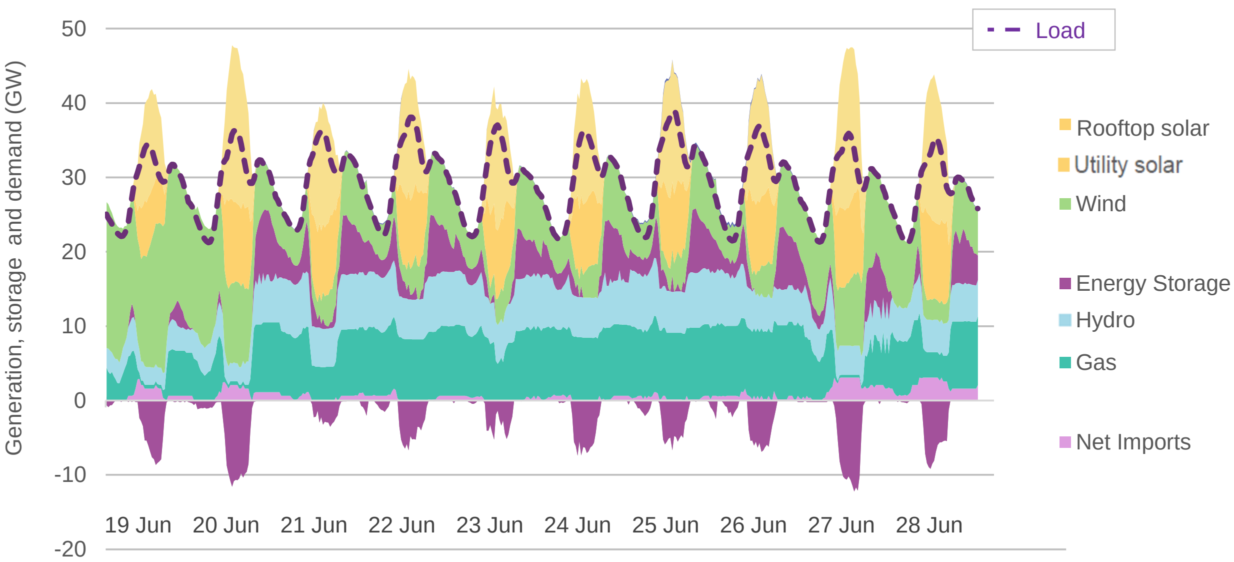
[26] Note that the ISP modelling is an energy-only model and does not consider the co-optimisation of batteries for both their energy dispatch and system service roles. AEMO takes this conservative approach as it expects FCAS markets to remain of finite depth and quickly saturate as more battery projects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

[27] 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).

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, leaving only renewable droughts that affect considerable portions of the NEM as the key concern.

Historical weather patterns suggest that longer 'dark and still' periods of up to 3 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[28]. The test showed that the power system would remain reliable and secure (see Figure 23) but reliability risks would be elevated, particularly if major generator or transmission outages occur.

Figure 23 Operability through eight-day renewable drought, NEM except Queensland



[28] 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, firmed with storage and backed up by gas **is the lowest-cost way to supply electricity to homes and businesses throughout Australia's transition to a net zero economy**.

Part B laid out the major elements of the ISP's optimal development path: by 2050 it forecasts 126 GW of utility-scale renewables, 86 GW of rooftop solar and other distributed solar, 74 GW of firming technology, and new transmission and modernised distribution networks will 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 and cost 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 and puts downward pressure on energy costs through the energy transition. All of the transmission projects in the ODP are needed. Overall, the ODP investments would:

- optimise benefits for all who produce, consume and transport electricity in the market,
- provide both investment certainty and the flexibility to reduce emissions faster if needed,
- guide $121 billion in essential capital investment to help sustain and grow Australia's $2 trillion annual economy and the social services on which its people depend,
- progress $16.4 billion in transmission investment[29] that would deliver $17 billion in net market benefits to consumers (see below),
- connect emerging areas of renewable generation to regional industries and urban businesses and households,
- firm variable renewable energy with batteries, pumped hydro storage and gas-powered generation, and

[29] This value does not include the cost of commissioned, committed or anticipated projects.

- create new economic and job opportunities, particularly in regional areas.

The annualised capital cost of all generation, storage, firming and transmission infrastructure in the ODP has a present value of $121 billion in the *Step Change* scenario to 2050[30]. Of this cost, transmission projects amount to $16.4 billion, or 13.5% of the total. This would pay itself back, and deliver the additional $17 billion net market benefit noted above. The equivalent upfront capital cost for generation, storage, firming and transmission infrastructure in the ODP has a present value of $138 billion in the *Step Change* scenario to 2050 (as some technical life remains after 2050 for the long-lived assets).

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 final shortlist of 18 candidate development paths. These include a 'counterfactual' path 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.

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 towards their later *Progressive Change* timing, or brought forward towards their earlier *Green Energy Exports* timing.
- **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 rankings 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, and two stood out on both rankings.

[30] This value does not include the cost of commissioned, committed or anticipated projects.

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 (see Section 3.2). AEMO can use these additional tests to select the ODP, in its professional judgement.

The tested sensitivities were on the speed of decarbonisation, the level of energy efficiency measures, alternatives to electrification, constrained supply chains, the impact of major pumped hydro projects, and a higher and lower discount rate. A new sensitivity was one of reduced social licence, developed with input from ISP Consumer Panel and the Advisory Council on Social Licence: see Appendix 8.

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.

The ODP includes the list of actionable and future projects that have been outlined in Chapter 5.

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.

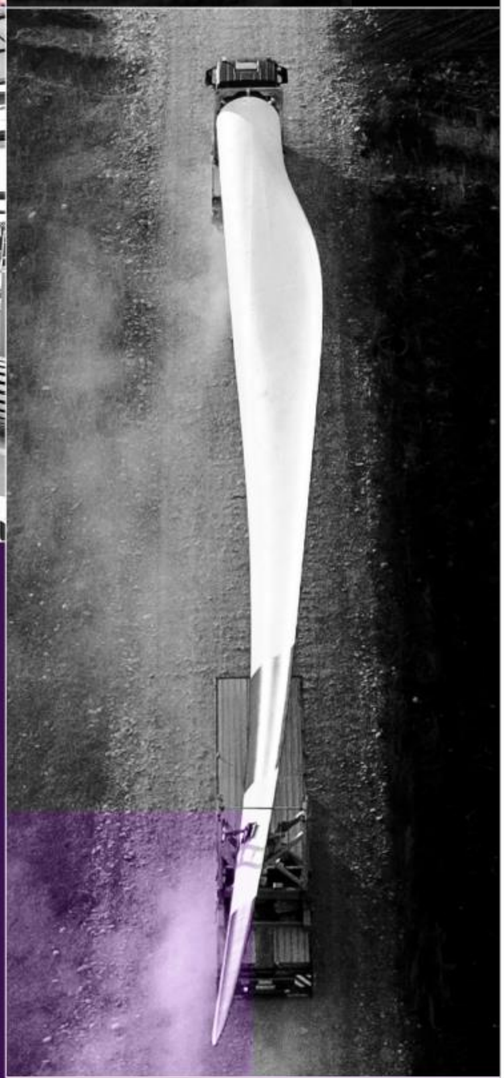
Alternative paths result in either more reliability risks or greater costs or both, and many substantially so. For example, regional landholders and communities have very reasonably raised underground cables as an alternative in visually sensitive areas. However, their costs range from four to 20 times 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's 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 20 years, fulfil the NEM's security and reliability requirements, meet government policy settings and manage risk through a complex transformation.

Both the energy transition and the ODP need to be delivered.

In Part C:

- **Section 8 – Risks to delivery of the ODP and to the energy transition.** Investment in infrastructure remains urgent. Yet market and policy settings do not yet address the risks of coal retirement, and social licence and supply chain issues challenge delivery.
- **Section 9 – Finalising the 2024 ISP.** AEMO will continue to take an inclusive and consultative approach. It will consider and respond to submissions on the Draft 2024 ISP, and conduct any further analysis needed to finalise the 2024 ISP.

Identifying the ODP is only a very small contribution to Australia's energy future. It's 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

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 do not yet address the risks of 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 careful management and risk 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 plants retire is real and growing, and a risk that must be avoided. Unplanned generator outages are increasing, as coal plant 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, progress on planned projects is being slowed by community acceptance, cost pressures, investment uncertainty, supply chain issues and workforce shortages.

The expansion of the federal Capacity Investment Scheme on 23 November 2023 recognises this urgency, giving additional support for the development of 32 GW of new capacity nationally, including 23 GW of renewable energy and 9 GW of clean dispatchable capacity[31].

[31] Australian Government. 'Capacity investment scheme', November 2023. At Capacity Investment Scheme | energy.gov.au.

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 uncertainty for infrastructure investment,
- Risk of early retirements of coal-fired generation plants
- 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 uncertainty for infrastructure investment

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

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, which would leave the NEM very little time to respond. 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. More action is needed to make sure that system services, resource adequacy and operational capability are in place in time for coal retirements.

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.

Risk that CER are not adequately integrated into grid operations

Consumer-owned assets offer significant system benefits and offset the need for grid-scale investment. They offer the potential for significant net market benefits being shared both by their owners and by energy consumers across the NEM: see Section 4.2.

Those benefits are maximised when two things happen:

- First, when owners link up with other owners to coordinate their CER as virtual power plants (VPPs), which is being facilitated by many retail market specialists and among businesses.
- Second, when those VPPs are integrated into the NEM to help support power system reliability and security. This 'orchestration' needs appropriate operational standards between the distribution grid and VPPs, and appropriate incentives and agreements with CER owners.

For this to happen, owners would need to see the benefits of orchestration, overcoming both technical complexity and a lack of perceived value[32], then trust the energy sector to deliver those benefits. 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.

Working collaboratively and gaining trust with regional and rural communities is essential to the success of the energy transition. The Draft 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

[32] Acil Allen. *Barriers and enablers for rewarding consumers for access to flexible DER and energy use*, June 2022. At https://www.datocms-assets.com/32572/1658964119-barriers-and-enablers-final-report-v2-352146-1-3-1.pdf.

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 Draft 2024 ISP, especially their input on a new sensitivity to explore social licence: see Appendix 8.

Risks in securing critical energy assets and workforce

The deep investments required in the ISP imply the need for thousands of critical energy assets – grid-scale generators and batteries, high voltage transmission lines and cables, synchronous condensers and transformers – and the people needed to instal and operate them.

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 Draft 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 63% by 2030, less than the 82% target, and NEM emissions would overshoot their 2029-30 emissions targets by approximately 155Mt CO_2-e[33].
- 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[34]. Costs for wind and solar have increased over the past year, largely due to

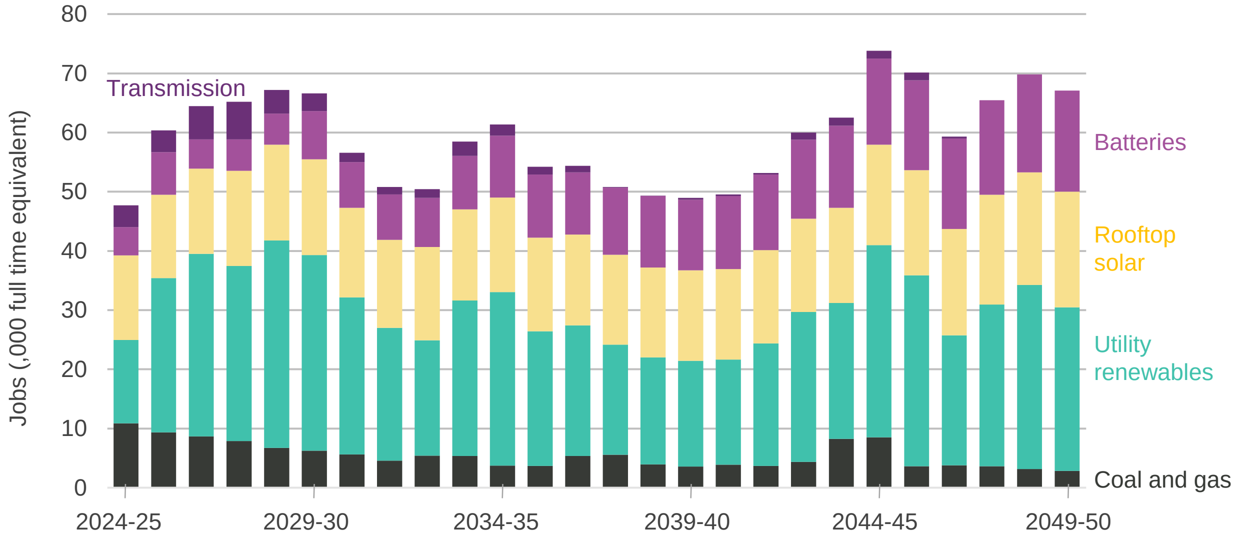
[33] The costs associated with the breach of these policies are not included in the sensitivity's net present value calculations.

[34] 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 new energy infrastructure is forecast to increase from approximately 48,000 in 2025 to over 70,000 across the horizon to 2050[35], 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.

Figure 24 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.

[35] This forecast is an estimate based on the Draft 2024 ISP results, using the workforce projections method provided by the Institute for Sustainable Futures for the 2022 ISP. AEMO will update this forecast for the final 2024 ISP to ensure alignment with the Institute's method and if required to reflect any relevant updates from the Infrastructure Australia *Market Capacity for Electricity Infrastructure* update due for release in December 2023.

9 Progressing the 2024 ISP

AEMO will continue to take a consultative and collaborative approach to prepare the 2024 ISP. Consultation with NEM stakeholders is critical to the ISP and more generally to AEMO's role as the NEM operator and national transmission planner.

This section sets out three streams of inclusive action to complete the 2024 ISP process:

9.1 **Consultation on the Draft ISP**, including a call for written submissions and invitations to participate in a range of additional engagement opportunities.

9.2 **Continued collaboration with industry and stakeholder bodies**. AEMO is committed to ensuring that extensive collaboration and advice informs the outcomes of the 2024 ISP for all jurisdictions.

9.3 **Further analysis in preparation for the 2024 ISP**, including on the distributional effects of the ODP, the power system performance and impacts of actionable projects, and analyses in response to submissions received on the Draft 2024 ISP.

AEMO looks forward to consulting with all stakeholders through to the completion of the 2024 ISP.

9.1 Consultation on the Draft ISP

AEMO welcomes and encourages written submissions from all stakeholders on the Draft 2024 ISP. AEMO has extended the required consultation period in acknowledgement of the summer holiday period and is seeking written submissions by 16 February 2024.

Table 8 lists the consultation and submission dates for the Draft ISP. Stakeholders can register for public and specialised forums (in the form of webinars) through the AEMO website[36].

After the table, AEMO provides guidance on the content of written submissions, as well as information about why AEMO is not calling for submissions on non-network options.

Table 8 Consultation and submission dates for the Draft ISP

Date	Event	Purpose
15 December 2023	Draft ISP published	Consult on the Draft 2024 ISP (including a preliminary optimal development path) and invite written submissions.
20 December 2023	Webinar	A public forum on the Draft ISP, with questions encouraged.
30 January 2024	Consumer Advocate pre-submission webinar	A specialised forum for consumer advocates to ask AEMO questions before submissions are due.
15 February 2024	Consumer Advocate verbal comment session	A specialised forum for consumer advocates to provide verbal comments.
16 February 2024	Written submissions close	Written comments from all stakeholders.
2 April 2024	Webinar	A public forum (date subject to change) to outline the contents of submissions received.

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

Guidance on written submissions on the Draft ISP

AEMO welcomes and encourages written submissions from all stakeholders on any aspect of the Draft 2024 ISP, including development path outcomes. AEMO particularly welcomes responses to the following questions:

1. Do you that the proposed optimal development path for transmission, generation and storage will support a reliable, secure and affordable NEM?

   If yes, what gives you that confidence? If not, what should be considered further, and why?

2. Do you think that the proposed timing and treatment of actionable projects in the Draft 2024 ISP will support a reliable, secure and affordable NEM? If yes, what gives you that confidence? If not, what should be considered further, and why?
3. Does the Draft 2024 ISP accurately reflect consumers' risk preferences? If yes, how so? If not, how else could consumers' risk preferences be included and what risks do you think are important to consider?
4. Do you have advice about how social licence can be further considered in the ISP, or advice on how to quantify the potential impact of social licence through social licence sensitivity analysis?
5. Do you have any feedback on the Addendum to the 2023 Inputs Assumptions and Scenarios Report, which is published alongside this report?

Written submissions providing feedback on the Draft 2024 ISP should be sent in PDF format to ISP@aemo.com.au and are required to be submitted by 6pm (AEST), Friday 16 February 2024.

AEMO requests that, where possible, submissions should provide evidence and information to support any views or claims that are put forward. AEMO will publish submissions on its website subject materiality and confidentiality requirements[37]. Please identify any parts of your submission that you wish to remain confidential and explain why.

Before submissions close, AEMO will host a 90-minute public forum in the form of a webinar, from 11.30am to 1pm (AEST) on Wednesday 20 December 2023. At the webinar, AEMO will present the key outcomes of the Draft 2024 ISP and will allow time for questions. Stakeholders can sign up to attend the webinar[38], and a recording will be posted on AEMO's website after the webinar[39].

No submissions for non-network solutions

AEMO is not calling for non-network solutions in this Draft 2024 ISP because:

- There are no newly actionable ISP projects in this Draft 2024 ISP.
- A number of previously actionable ISP projects remain actionable, either as actionable ISP projects, or as actionable New South Wales projects. For those projects, non-network options have either already been called for through previous ISP and IASR consultations, or should be

[37] This is consistent with AEMO's obligations under section 54 of the National Electricity Law.

[38] At https://events.teams.microsoft.com/event/7e14c9eb-42f5-490b-b81d-4d385b2ad1bd@320c999e-3876-4ad0-b401-d241068e9e60.

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

considered separately through the New South Wales Electricity Infrastrucuture Roadmap framework.

- It has identified two new projects as actionable Queensland projects. For those projects, non-network options may be considered separately through the Queensland Energy and Jobs Plan framework.

9.2 Continued engagement with stakeholders

AEMO thanks all TNSPs and jurisdictional bodies in the NEM for the regular and extensive joint planning undertaken through the development of the Draft 2024 ISP. AEMO will continue to collaborate closely with TNSPs and jurisdictional bodies until the release of the final 2024 ISP to make sure their specialist advice is incorporated in the ISP wherever possible.

AEMO will continue to engage with the ISP Consumer Panel and the Advisory Council on Social Licence. This will include:

- **ISP Consumer Panel.** The panel will provide a report about the Draft 2024 ISP to AEMO, including an assessment of the evidence and reasons supporting AEMO's conclusions in the Draft 2024 ISP, which AEMO will carefully consider in preparing the final 2024 ISP.
- **Advisory Council on Social Licence.** AEMO will continue to seek the council's input as relevant and appropriate on social licence matters.

AEMO thanks all stakeholders who have participated in the 2024 ISP process so far. Leveraging expertise from across industry, consumers and stakeholders is crucial for making sure the ISP remains a robust plan that supports the long-term interests of energy consumers. AEMO looks forward to continued engagement before the release of the final 2024 ISP by 28 June 2024.

9.3 Further analysis in preparation for the final 2024 ISP

AEMO will undertake additional analysis between the draft and final 2024 ISP to further validate the roadmap for the changes to the power system, and to provide additional information for stakeholders, industry and decision-makers.

Further analysis will include:

- The distributional effects of the ODP,
- Power system analysis to verify the performance of actionable projects,
- Sensitivity analysis to understand the impact of passive CER rather than orchestrated CER,
- Inclusion of a Value of Emissions Reduction (VER), if it becomes available,
- Further analysis on the impact of potential new load connection in South Australia due to a number of government and private sector projects under development, and
- Further analysis considered justified in response to submissions received on the Draft 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. 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.

Term	Acronym	Explanation
Cost-benefit analysis	CBA	A comparison of the quantified costs and benefits of a particular project (or suite of projects) in monetary terms. For the ISP, a cost-benefit analysis is conducted in accordance with the AER's Cost Benefit Analysis Guidelines.
Counterfactual development path	-	The counterfactual development path represents a future without major transmission augmentation. AEMO compares candidate development paths against the counterfactual to calculate the economic benefits of transmission.
Demand	-	The amount of electrical power consumed at a point in time. This quantity is typically expressed in megawatts (MW) or its multiples. Various definitions for demand, depending on where it is measured. For example, underlying demand means demand supplied by both CER and the electricity grid.
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.

Term	Acronym	Explanation
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.
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.
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 Draft 2024 ISP are available on AEMO's website[40].

Appendices to the Draft 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

- Draft 2024 *Integrated System Plan* – overview
- Draft 2024 ISP chart data
- Draft 2024 ISP generation and storage outlook
- Draft 2024 ISP Inputs and Assumptions workbook, including the latest input data used for the Draft 2024 ISP modelling.
- Draft 2024 ISP traces
- Summary of consumer risk preferences project
  - Attachment 1 Deloitte report consumer risk preferences
  - Attachment 2 Antenna report consumer risk preferences

Regulatory publications

- *Addendum to the 2023 Inputs Assumptions and Scenarios Report*
- *Update to 2022 Integrated System Plan*

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