New South Wales Development Pathways Report

December 2021

A report for New South Wales Department of Planning, Industry and Environment

Important notice

PURPOSE

The document has been prepared for New South Wales Department of Planning, Industry and Environment under a Statement of Work signed on 9 April 2021 to inform the New South Wales Consumer Trustee and Market Participants of AEMO's analysis of four alternative Development Pathways that achieve the infrastructure investment objectives (IIOs) of the New South Wales Government's Electricity Infrastructure Roadmap.

DISCLAIMER

This document or the information in it may be subsequently updated or amended. AEMO has made reasonable efforts to ensure the quality of the information in this document but cannot guarantee that information, forecasts and assumptions are accurate, complete or appropriate for your circumstances.

This document does not include all of the information that an investor, participant or potential participant in the National Electricity Market might require, and does not amount to a recommendation of any Alternative Development Pathway or related investment.

This document does not constitute legal or business advice. Anyone proposing to use the information in this document (which is subject to assumptions and includes information, modelling and forecasts from third parties) should independently verify its accuracy, completeness and suitability for purpose, and obtain independent and specific advice from appropriate experts.

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

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

VERSION CONTROL

Version	Release date	Changes
1.0	7/12/2021	First release

Executive summary

In this inaugural 2021 *Development Pathways Report* for the New South Wales Department of Planning, Industry and Environment (the Department), AEMO analyses four alternative Development Pathways to achieve the infrastructure investment objectives (IIOs) of the New South Wales Government's Electricity Infrastructure Roadmap (the Roadmap). The Roadmap IIOs require at a minimum the construction by 31 December 2029 of generation infrastructure that generates approximately 33,600 gigawatt hours (GWh) of eligible renewable energy in New South Wales, as well as 2 gigawatts (GW) of long-duration (eight-hour) storage.

The Department commissioned AEMO to prepare this report for provision to and consideration by the New South Wales Consumer Trustee in selecting a Development Pathway. AEMO has assessed the Development Pathways against criteria aligned with the *Electricity Infrastructure Investment Act 2020* (NSW) objects, which include to:

- Improve **affordability** for New South Wales consumers.
- Maintain the **reliability and system security** of the power system for New South Wales consumers.
- Improve the **sustainability** of electricity supply in New South Wales.
- Encourage investment by **reducing risk for investors and consumers**.

While this report discusses the comparative strengths and weaknesses of four alternative Development Pathways, it does not endorse or recommend any single Pathway. The analysis is based on information available prior to finalising AEMO's 2021 *Inputs, Assumptions and Scenarios Report* (IASR). Further detailed analysis and optimisation will be needed to explore the costs and benefits of network infrastructure augmentations assumed in the Development Pathways, and to understand how the Development Pathways should evolve in response to future market conditions, including greater electrification of other sectors such as transport. Some of this additional analysis will be considered in AEMO's Draft 2022 *Integrated System Plan* (ISP). **Table 1** summarises the four Development Pathways considered in the report.

Each candidate Development Pathway has an annual commissioning schedule of renewable generation and long-duration storage in New South Wales over a 20-year outlook, underpinned by a common set of transmission developments.

The four alternative Development Pathways explore different rates at which the New South Wales Consumer Trustee could tender for renewable capacity to meet the Roadmap objectives.

Table 1 Summary of alternative Development Pathways modelled

Development Pathway	Purpose	Description
Early	Explore variable renewable energy (VRE) developments as early as possible.	The earliest possible VRE commissioning schedule, using available network connection points prior to network augmentations being built.
Renewable Energy Zone (REZ) Aligned	Explore VRE developments in line with the schedule of network augmentations.	While developments are relatively early, this deploys VRE capacity with foresight of expanded network infrastructure capacities, delaying until REZ augmentations enable 500 kilovolt (kV) connections rather than connecting to existing networks, where appropriate.
Supply Chain Adjusted	Explore VRE developments with specific regard to potential supply chain constraints.	Considering the maximum developed renewable capacity observed historically, this develops capacity more gradually than other modelled alternatives, minimising the risk of supply chain disruption and constraints across the next decade. This Development Pathway incorporates an annual maximum build of VRE in New South Wales capable of generating approximately 6,000 GWh per annum until 2030. After 2030 this limit is increased to 7,600 GWh per annum, assuming the capability of the supply chain will have expanded within the next 10 years.
Late	Explore VRE developments as late as possible.	Examines the costs and benefits of delayed investment to minimise disruption to incumbent generation and maximise the opportunity for lower development costs in future years.

All four Development Pathways reach the Roadmap's minimum IIOs for construction of variable renewable energy (VRE) and long-duration storage capacity by 2030, but at different rates, as **Figure 1** and **Figure 2** show. AEMO has assumed the same network infrastructure augmentations are needed in all four Development Pathways to efficiently connect new generation and storage capacity. Further work is needed to refine this assumption. In the 2022 ISP, AEMO will consider a range of other network development opportunities that may help achieve the Roadmap's IIOs more efficiently, using the latest scenarios, inputs and assumptions from the 2021 IASR (Draft 2022 ISP to be published in late 2021).

Figure 1 VRE builds to 2030 under each Development Pathway

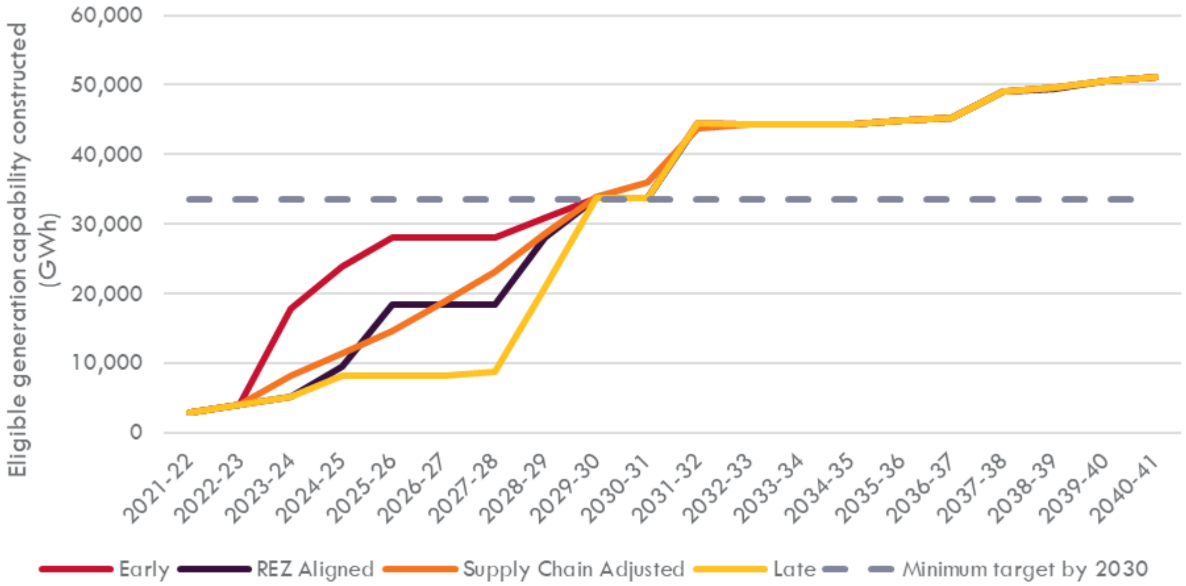
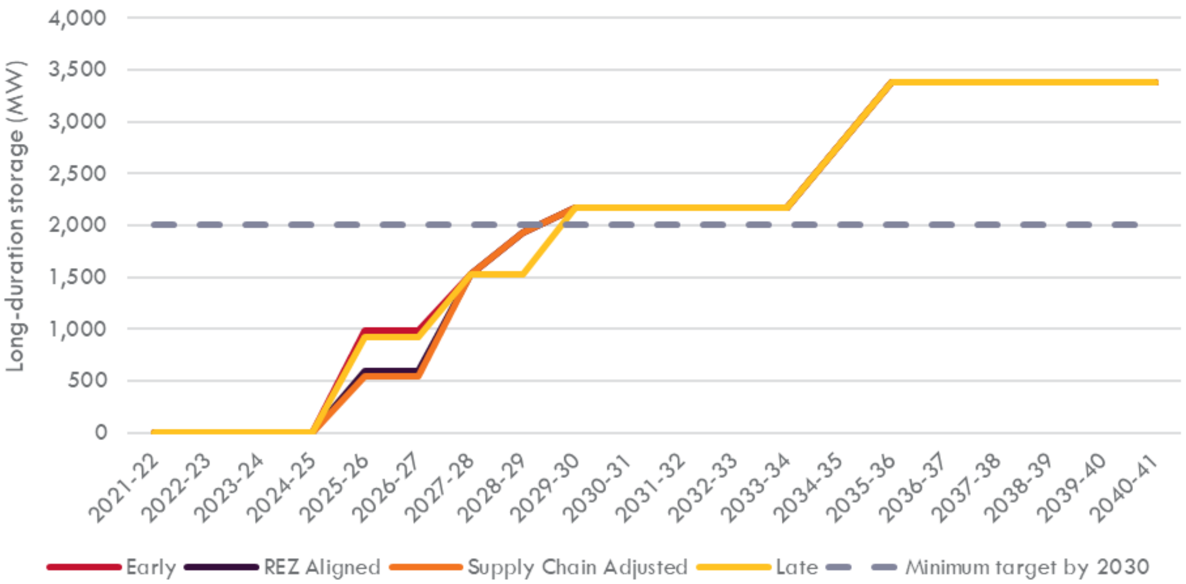


Figure 2 Storage builds to 2030 under each Development Pathway



AEMO has found the following key similarities across the Development Pathways:

- All four Development Pathways are expected to deliver **reliability**, maintaining supply adequacy within the National Electricity Market (NEM) reliability standard.

- All four Development Pathways result in similar **total costs** to New South Wales consumers. Development Pathways with lower wholesale costs typically lead to higher scheme costs, such that costs overall only differ on net present value (NPV) basis by at most 3%.
- The **technology mix** is similar, with the modelling generally preferring wind to solar generation and pumped hydro storage to batteries. However, the modelled preference for wind generation and pumped hydro storage does not reflect a stated preference for the New South Wales Consumer Trustee in awarding Long-Term Energy Service (LTES) Agreements.
- Long-duration **storage** is developed at similar rates across all Development Pathways and helps reduce VRE curtailment. If pumped hydro developments were delayed, the modelling shows increased costs to consumers.
- All Development Pathways see VRE development in similar **locations**, focused extensively in the Central West Orana and New England renewable energy zones (REZs) where new network infrastructure capacity is assumed to be available. That said, there may be VRE projects in other locations, not explicitly modelled, that the New South Wales Consumer Trustee considers deliver greater value to New South Wales electricity consumers.
- All Development Pathways will require material **supply chain expansions**. In all but Supply Chain Adjusted, the Development Pathways feature at least one year in which more than 3 gigawatts (GW) of VRE capacity is expected to be connected in the next decade (the state's highest recorded level of connections to date is 1.5 GW). The model indicates these spikes in development typically coincide with assumed withdrawal of large coal-fired generators. This may pose challenges for sourcing equipment and labour, processing approvals, and engaging with communities to gain social license.
- All four Development Pathways rely on the assumed **network infrastructure development** – including key REZ transmission projects connecting to the Central West Orana and New England REZs, and Sydney Ring reinforcement – to effectively deliver the required energy to meet the IIOs.
- The **risk of slower demand growth**, or reduced demand due to large load closures, affects all Development Pathways similarly; increased subsidies would be needed in each case to compensate for lower wholesale electricity prices.
- If the modelled risks (early coal closure, slower demand growth, delays in pumped hydro or network development) were compounded, every Development Pathway's prospects of delivering the IIOs would be impacted.

The key points of difference are:

- While all Development Pathways see **curtailment of VRE** generation due to excess generation at times, the fastest (and largest cumulative) impact is in the Early Pathway, because more VRE connects in the early years and long-duration storage is unable to be built fast enough. This impact is exacerbated if network augmentations are delayed.
- As expected, the cumulative **reduction in emissions** in both the NEM and New South Wales is proportional to the speed of VRE development. The Early Pathway delivers the most emission abatement.
- Forecast **scheme costs** (including network infrastructure costs) in all Development Pathways follow a similar path in the second decade, but through the 2020s the Early Pathway costs are higher, given the scale of development and level of curtailment expected.
- Development Pathways with more rapid early deployment of VRE are more resilient to earlier, unexpected coal closures and delays in pumped hydro or other committed firm capacity.
- The just-in-time build of the Late pathway provides the least flexibility to adapt to delays in network infrastructure build, supply chain constraints, early coal closures, or other system events that would result in increased cost to consumers or even failure to meet the minimum roadmap objectives.

Table 2 compares how AEMO and EY's modelling assessed each Development Pathway against the criteria aligned with the Roadmap objects, including the total cost of each Development Pathway to consumers. It shows minor differences in **overall costs to consumers** (the sum of wholesale costs and scheme costs), with the Late Pathway optimised to meet the minimum objectives of the Roadmap at the lowest cost if potential supply chain constraints and delivery risks are ignored.

Table 2 Development Pathway performance across criteria that aligns with Roadmap objects

Development Pathway	Total cost (NPV $ billion)	NEM reliability standard met?*	Cumulative NEM CO_2e emissions by 2040 (MT)	Maximum annual VRE build to 2030 (GWh equivalent)
Early	36.57	Likely	1,329	13.4
REZ Aligned	36.91	Likely	1,363	9.6
Supply Chain Adjusted	36.06	Yes	1,355	5.4
Late	35.78	Likely	1,389	13.2

* The reliability standard assessment was only undertaken for the Supply Chain Adjusted Development Pathway, but the results provide a level of comfort that the other Development Pathways are likely to deliver similar levels of reliability.

This first *Development Pathways Report* needed to be prepared as soon as practicable after July 2021 to help inform the New South Wales Consumer Trustee's first tender plan. This meant that the modelling has been conducted without detailed information and costings on future REZ network infrastructure projects and other network augmentations. Future updates of this report will be informed by the 2022 ISP and the Network Infrastructure Strategy currently being prepared by the Energy Corporation of New South Wales (EnergyCo), allowing for co-optimisation of generation, storage, and network infrastructure to meet the Roadmap objectives using the latest IASR. This may lead to slightly different outcomes to what is presented in this report, particularly in the second decade of each Development Pathway's 20-year outlook.

Contents

Tables

Figures

1. Introduction

1.1 Purpose of this report

This inaugural 2021 *Development Pathways Report* analyses four alternative Development Pathways that achieve the infrastructure investment objectives (IIOs) of the New South Wales Government's Electricity Infrastructure Roadmap (the Roadmap).

The New South Wales Department of Planning, Industry and Environment (the Department) commissioned AEMO to prepare this report for the New South Wales Consumer Trustee's consideration in selecting a Development Pathway. While comparative strengths and weaknesses of alternative Development Pathways are discussed in this report, no single Development Pathway is endorsed or recommended.

Development Pathway refers to an annual construction schedule of renewable generation and long-duration storage in New South Wales over a 20-year outlook. Each Development Pathway is underpinned by network infrastructure developments that enable the efficient connection of renewable generation and energy storage.

In discussing the various Development Pathways considered in this report, indications in respect of certain technologies and locations have been provided. However, this should not be interpreted as reflecting the projects, technology or locations to which the New South Wales Consumer Trustee will ultimately award Long-Term Electricity Supply (LTES) Agreements. LTES Agreements will be awarded based on which projects represent the highest value for New South Wales electricity consumers.

1.2 Approach to informing the delivery of the Roadmap

1.2.1 Roadmap objectives

The Roadmap IIOs require at a minimum the construction by 31 December 2029 of generation infrastructure that generates approximately 33,600 gigawatt hours (GWh) of eligible renewable energy in New South Wales, as well as 2 gigawatts (GW) of long-duration (eight-hour) storage. The generation volume operationalises the *Electricity Infrastructure Investment Act 2020* (NSW) (the EII Act) objective to construct generation infrastructure that generates at least the same amount of electricity in a year as:

- 8 GW of generation capacity from the New England renewable energy zone (REZ),
- 3 GW of generation capacity from the Central-West Orana REZ, and
- 1 GW of additional generation capacity.

To convert the above capacity into a generation equivalent, the mix of solar and wind generation from the Step Change scenario in AEMO's 2020 *Integrated System Plan* (ISP) was used as a guide.

The development of this infrastructure aims to achieve the objectives of minimising costs for New South Wales electricity consumers while ensuring sufficient generation and storage infrastructure is developed to meet both the reliability standard and the energy security target (EST) defined in Part 3 of the EII Act.

1.2.2 Developing alternative Development Pathways to inform the New South Wales Consumer Trustee

In collaboration with the Department, AEMO developed a suite of four alternative Development Pathways. While the Development Pathways each achieved the minimum objectives of the EII Act, each explored different rates of development of wind and solar generation, supported by long-duration storage, and different degrees of coordination of generation and network infrastructure opportunities.

AEMO used market modelling conducted by Ernst & Young (EY) to evaluate the Development Pathways, exploring both the impact to New South Wales consumers directly and the indirect consumer impact of increased competition affecting incumbent electricity generation.

1.2.3 Assessing the merits of each Development Pathway

The merits of the Development Pathways have been quantitatively and qualitatively assessed against criteria aligned with certain objects of the EII Act, specifically to:

- Improve **affordability** for New South Wales consumers.
- Maintain **reliability and system security** of the power system for New South Wales consumers.
- Improve the **sustainability** of electricity supply.
- Encourage investment by **reducing risk for investors and consumers**.

Affordability

A key objective of the EII Act is to minimise costs for New South Wales electricity consumers.

In assessing performance against this objective, three categories of costs are considered:

- **Wholesale costs** – the total electricity component of New South Wales bills, as assessed through forecasting of the electricity spot price paid collectively by all New South Wales electricity consumers. For this assessment, the forecast spot price was assumed to be a good indicator of the relative wholesale cost of electricity across the Development Pathways, avoiding the need to consider the contract market.
- **Scheme costs –** minimum payments to new generation and storage infrastructure developed under the EII Act. As a proxy for actual LTES Agreement payments, these scheme costs are assumed to be the additional revenue required for eligible projects to make their required rate of return. These payments, if needed, will be made through the LTES Agreements that will be agreed with eligible projects.
- **Network costs** – the cost of network infrastructure that is collectively passed through to the bills paid by all New South Wales electricity consumers. For the purpose of this analysis, only additional transmission augmentations beyond those that have received regulatory approval were considered, given that the cost recovery of those approved network infrastructure projects is not influenced by the Roadmap. Network augmentations that are not directly attributable to REZ connections associated with the Roadmap[1] but are key enablers have only half of the development costs included in the network costs, and are assumed in all Development Pathways.

The **total New South Wales consumer costs** are the sum of the three components above. AEMO used the net present value (NPV) of the total cost over the modelling horizon in comparing Development Pathways.

Reliability and security

To ensure the Development Pathways achieve a reliable power system across the forecast horizon, AEMO has assessed the ability of the proposed generation and storage developments, in combination with the assumed network developments, to meet demand, to confirm that the reliability standard and Interim Reliability Measure (IRM) is met.

Reliability is assessed against:

- Until 30 June 2025, the IRM, set to ensure that sufficient supply resources and inter-regional transfer capability exist to meet 99.9994% of annual demand for electricity by helping keep expected unserved energy (USE) in each region to no more than 0.0006% in any year, and

---

[1] This includes the Sydney Reinforcement project, South West New South Wales stability improvement project, and HumeLink project.

- From 1 July 2025, the reliability standard which is a maximum expected USE in a region of 0.002% of the total energy demanded in that region for a given financial year.

AEMO applied a statistical simulation approach, aligned with the approach used to assess reliability forecasts in its *Electricity Statement of Opportunities* (ESOO) to forecast expected USE, which was then compared against the relevant reliability standard[2].

Sustainability

Because the rate of variable renewable energy (VRE) development differs between the Development Pathways, the rate of decarbonisation also differs. To show how effective each Development Pathway is in reducing carbon emissions, AEMO has reported and compared the cumulative emissions across the NEM.

Risks to consumers

To support this overall assessment, AEMO assessed the resilience of each Development Pathway across a range of sensitivities and alternative assumptions, each of which explores an individual influence, or a small number of key influences, on the overall net benefits of each Development Pathway for New South Wales consumers.

This report identifies drivers that were assessed as resulting in similar levels of risk across the Development Pathways separately to those drivers that may provide more significant differences between Development Pathways.

1.3 Structure of this report

This report provides the following key sections:

- Section 1 introduces the purpose and approach to inform the delivery of the Roadmap.
- Section 2 describes the modelling approach adopted in quantifying the benefits of alternative development pathways to deliver the IIOs.
- Section 3 discusses and compares alternative Development Pathways, including the projected success of each alternative Development Pathway in delivering the objectives of the Roadmap.
- Section 4 assesses the resilience of each alternative Development Pathway, quantifying the key differences affecting the benefits of each Development Pathway under expected market conditions, as well as assessments of each Development Pathway's resilience to unexpected but plausible alternatives. The section also provides additional discussion for the New South Wales Consumer Trustee's consideration.

[2] At the Department's request, this analysis was only conducted for the Supply Chain Adjusted Pathway, however the similarities in reserve levels between Development Pathways provide a level of confidence that the reliability standard would be met in all Development Pathways.

2. Modelling approach

For each Development Pathway, EY conducted half-hourly market modelling simulations over the 20-year horizon to forecast the future capacity mix in the National Electricity Market (NEM), as well as generation and wholesale price outcomes.

EY's key assumptions in this modelling were consistent with AEMO's Draft *Inputs, Assumptions and Scenarios Repor*t (IASR), published in December 2020, and AEMO's 2020 ESOO demand forecasts because modelling commenced before the 2021 IASR and 2021 ESOO were published. Updates to assumptions to reflect latest developments in distributed photovoltaics (PV) and large-scale generation and storage commitments were incorporated where practical, but differences remain between assumptions used in this report, the final assumptions and demand forecasts published in the 2021 IASR and 2021 ESOO and the final IASR assumptions to be used in AEMO's 2022 ISP.

This section highlights where assumptions materially deviate from AEMO's July 2021 IASR, lists the key network infrastructure assumptions common to all Development Pathways, and provides contextual information to help understand the outcomes of the EY modelling.

Details of assumptions and methodology used by EY in the assessment are outlined in EY's *New South Wales Roadmap development pathway modelling – Methodology and assumptions* report.

2.1 Key assumptions in assessing Development Pathways

The assessment of the Development Pathways was informed by a common set of assumptions that underpin the market modelling. The majority of the assumptions are consistent with AEMO's Central scenario assumptions as described in AEMO's Draft 2021 IASR. These assumptions were later finalised in the final 2021 IASR, and some key discrepancies exist between the Central scenario's assumptions and the final scenario parameters in the final 2021 IASR (including that the 'Central scenario' itself has been replaced with two alternative scenarios in the IASR).

AEMO has sought, as far as practicable, to incorporate interim and draft inputs from the Draft 2021 IASR dataset, however there are some key differences between the modelled assumptions used in this assessment and the final published scenario parameters in the final 2021 IASR and 2021 ESOO which are described below:

- AEMO's final 2021 ESOO demand forecasts incorporate significant potential for long-term electricity consumption growth, particularly in futures with strong decarbonisation objectives, as other sectors of Australia's economy utilise the NEM to decarbonise through electrification.
- The Development Pathways incorporate draft uptake forecasts for distributed PV, for the final 2021 IASR developed for the Net Zero 2050 scenario. This represents a material increase in PV uptake to that assumed in the Draft 2021 IASR's Central forecast (which reflected the 2020 ESOO), and a relatively minor differential to the final 2021 ESOO's distributed PV component.
- The Central West Orana REZ Transmission project assumed in the Development Pathways report was based on the design assumed in the 2020 ISP delivering approximately 3,000 megawatts (MW) transfer capability, whereas a refined augmentation providing 3,900 MW transfer capability is included in the final 2021 IASR.
- The Development Pathways apply weighted average cost of capital (WACC) assumptions to generation and long-duration storage built under the Roadmap based on analysis from the National Australia Bank undertaken in November 2020 for the Department[3]. These WACCs were not adopted in the 2021 IASR.

---

[3] Available at https://www.energy.nsw.gov.au/sites/default/files/2020-11/NSW%20Electricity%20Infrastructure%20Roadmap%20-%20WACC%20Report.pdf.

- New peaking gas generation at Tallawarra B and Kurri Kurri was included in the modelling, as was approximately 500 MW of additional solar generation capacity recently committed or anticipated in New South Wales, based on the May 2021 Generation Information Page[4].

2.1.1 Assumed network infrastructure augmentations based on best estimates of requirements

AEMO anticipates three types of network infrastructure developments will be necessary to enable efficient development, connection and operation of the renewable energy developments required by the EII Act:

- **Network infrastructure developments to maintain reliability and security as coal generation withdraws from the market.** AEMO's 2021 ESOO highlighted the forecast reliability impacts of network congestion following closure of coal-fired generation in the Sydney/Newcastle/Wollongong area (see Section 3.3.2 for more detail). Network infrastructure developments such as the Sydney Reinforcement project identified in the 2020 ISP would be one option to alleviate network congestion so more supply can be delivered to the Sydney/Newcastle/Wollongong area at peak times. Development of the HumeLink network infrastructure project would also help realise the reliability benefits associated with Snowy 2.0.
- **REZ network infrastructure developments.** The 2020 ISP demonstrated that the network in New South Wales is not able to accommodate significant additional generation within New South Wales REZs without additional network infrastructure. Of note, the Central West Orana Transmission Link and expansion to the North West New South Wales and New England REZs were all identified in the 2020 ISP as part of the optimal development path.
- **Interconnector developments to efficiently share diverse resources across the NEM.** Increased interconnection between regions enables more efficient sharing of resources and, where possible, also serves to connect to REZs as an alternative to dedicated REZ network infrastructure. For example, the anticipated Project EnergyConnect forms a new link between New South Wales and South Australia. It provides South Australia with access to lower cost generation, increased reliability and security, and increased access to REZs. Often, segments of interconnectors also increase the network capability of REZs (such as Queensland New South Wales Interconnector [QNI] Medium), and therefore can form the initial stages of an interconnector development.

AEMO has prepared this 2021 *Development Pathways Report* without key network and REZ information, including network options and costings, that will in future be provided by the Infrastructure Planner, EnergyCo, and/or TransGrid.

As such, AEMO needed to estimate those network infrastructure augmentations most likely to be of significance to New South Wales in the coming decades, prior to the 2022 ISP's complete cost-benefit assessment, and in the absence of complete information.

To develop the process used to select a network augmentation schedule, AEMO referred to:

- 2020 ISP modelling.
- The Draft 2021 IASR.
- Exploratory modelling performed by EY and AEMO.

This exploratory modelling indicated that a set of candidate network augmentations would potentially provide strong benefits to meet the Roadmap objectives, minimising costs to New South Wales consumers and maintaining reliable supply, particularly to Greater Sydney as the New South Wales coal fleet begins to exit the market.

This set of augmentations was assumed for all alternative Development Pathways. **Table 3** lists the network augmentations, and the rationale for their selection. Given the information available when this assessment

[4] At https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information.

was undertaken, relatively few alternative options were comparable with respect to their ability to facilitate the achievement of the Roadmap objectives at efficient cost.

Table 3 New South Wales network augmentation schedule and timing

Name	Assumed commissioning year	Description	Rationale for selection
QNI Minor	2021	Increase southerly and northerly transfer limit between Queensland and New South Wales (Option 1A from 2020 ISP).	Committed project.
EnergyConnect	2024	New AC interconnection between Wagga Wagga and Robertstown via Buronga.	Anticipated project as per AEMO 2021 IASR.
Central West Orana REZ transmission project[5]	2024	New transmission link between Bayswater and Wollar (see 2020 ISP Appendix[6]).	Anticipated project as per AEMO 2021 IASR.
South West New South Wales stability improvement	2024	Represents a new 330 kilovolt (kV) line between Darlington Point and Dinawan substations. (Option 1A, TransGrid TAPR 2020[7]).	New generation in excess of network limit. Cost effective solution identified in Transgrid's current RIT-T[8].
HumeLink	2026	Additional 500 kV AC circuits between Maragle, Bannaby and Wagga Wagga.	Actionable project in 2020 ISP.
Sydney Ring 500 kV – North and South paths	2027	New transmission links reinforcing the network north and south of Sydney. (TransGrid Transmission Annual Planning Report [TAPR] 2020[7]).	Significant USE expected without this network infrastructure augmentation or equivalent new generation/ storage located in the Sydney area.
New England REZ	2027	New transmission links from Bayswater to Uralla and a new Uralla substation (TransGrid TAPR 2020) [7].	New generation in excess of network limit. Network augmentation in line with 2020 ISP.
QNI Medium – west of the path (New South Wales segments only)	2027	New transmission between Uralla and Boggabri, between Boggabri and Uarbry and a new Boggabri Substation (Option 2E from AEMO's 2020 ISP[6]).	New generation in excess of network limit. Network augmentation in line with 2020 ISP.

The augmentation schedule above provides a high-level indication of future network topology, augmentation cost, and transfer capability. It does not represent a complete optimisation of network and generation investments. Further work is being progressed, including through the 2022 ISP, to determine the optimal size and timing of these network developments for all consumers. The assumed New England REZ network infrastructure development, in particular, has influenced the location and timing of VRE development included in each of the four Development Pathways, and should be further evaluated.

[5] The modelled augmentation for this analysis is based on the design proposed in the 2020 ISP. This design for Central West Orana REZ transmission project has since been revised and the augmentation now provides more network capability, as outlined in the 2021 IASR. This refined augmentation was not available when this modelling commenced. This may lead to slightly more REZ development in Central West Orana and slightly less in New England, but this has not been considered in this analysis. It is also not considered to be material for the New South Wales Consumer Trustee given that the Development Pathways are not location-specific.

[6] At https://aemo.com.au/-/media/files/major-publications/isp/2020/appendix--3.pdf?la=en.

[7] At https://www.transgrid.com.au/what-we-do/Business-Planning/transmission-annual-planning/Documents/2020%20Transmission%20Annual%20Planning%20Report.pdf.

[8] See https://www.transgrid.com.au/projects-innovation/improving-stability-in-south-west-nsw.

For this inaugural *Development Pathways Report*, it has not been possible to complete optimised network development assessments and detailed design analysis. Ideally, the Development Pathways would consider the most appropriate generation and long-duration storage investments that efficiently utilise the existing transmission network, and invest in new transmission developments as and when most appropriate. At this stage in planning, AEMO cannot complete a detailed and optimised network design, due to the uncertainty of generation connections. For each network augmentation in the schedule, a number of variations – such as line route, technical parameters, and substation locations – is possible. A more comprehensive assessment of these variations and costs should be conducted when more information is available. Such assessments are expected to be undertaken by AEMO as part of the ISP and by the Energy Corporation of New South Wales (EnergyCo) as part of its Network Infrastructure Strategy (NIS) for New South Wales. For the purpose of this report and its conclusions, AEMO considers the estimations applied in identifying the appropriate network investments to enable the initial Development Pathways analysis are prudent and appropriate. Further, the assessment of the Development Pathways against the specified criteria is not expected to be materially impacted by slight modifications to these network developments.

These network infrastructure augmentations have regard to development timelines as identified in the Draft 2021 IASR. Some augmentations (or non-network alternatives), particularly those related to reinforcing supply into Sydney, may need to be commence immediately to achieve the preferred timing.

Additional transmission augmentations that are outside the New South Wales region have been included, considering developments recommended from the 2020 ISP[9].

Some projects, while actionable in the 2020 ISP, have been excluded (see Table 4). These have been excluded either because the drivers of benefit have materially changed from the 2020 ISP, or because decision rules around cost estimates have not been met. The benefits of these projects will be reassessed in the 2022 ISP.

Table 4 Notable network infrastructure projects (partly) in New South Wales excluded from the augmentation schedule

Name	Description	Rationale for exclusion
QNI Medium – Queensland segments	New transmission between Boggabri Substation and Darling Downs.	Need for additional firm capacity from Queensland now provided by New South Wales generation as part of New South Wales roadmap. Interconnector utilisation not significantly changing in modelling.
Victoria New South Wales Interconnector (VNI) West	New interconnection between Victoria and New South wales, involving a new 500 kV high voltage alternating current (HVAC) double circuit line from a new substation north of Ballarat to Wagga Wagga either via Shepparton or Kerang.	The latest cost estimate as per the 2021 IASR for VNI West exceeded the cost threshold identified in the 2020 ISP decision rules for VNI West[10].

The interaction between the ISP, the New South Wales Consumer Trustee's 2021 IIO Report, and the EnergyCo's NIS for New South Wales will inform future iterations of this *Development Pathways Report*.

2.2 Wind and pumped hydro dominate development under the New South Wales Roadmap

The Roadmap will result in the development of 33,600 GWh per year of new[11] renewable generation in New South Wales, supported by long-duration energy storages.

[9] Additional augmentations include Marinus Link (Stage 1), Western Victoria, and the Gladstone grid reinforcement project.

[10] See Table 12 of the 2020 ISP, at https://aemo.com.au/-/media/files/major-publications/isp/2020/final-2020-integrated-system-plan.pdf?la=en.

[11] New, recently committed or anticipated, according to the eligibility criteria of the Act, which includes projects committed after 14 November 2019.

This capacity represents a significant refresh of the region's electricity generation mix. Modelling indicates that by 2025-26, complemented by distributed PV systems and existing hydroelectric generation, renewable energy in New South Wales may increase to surpass the annual generation from the region's coal fleet, particularly as coal power stations begin to exit the market.

Development to meet the renewable energy objectives

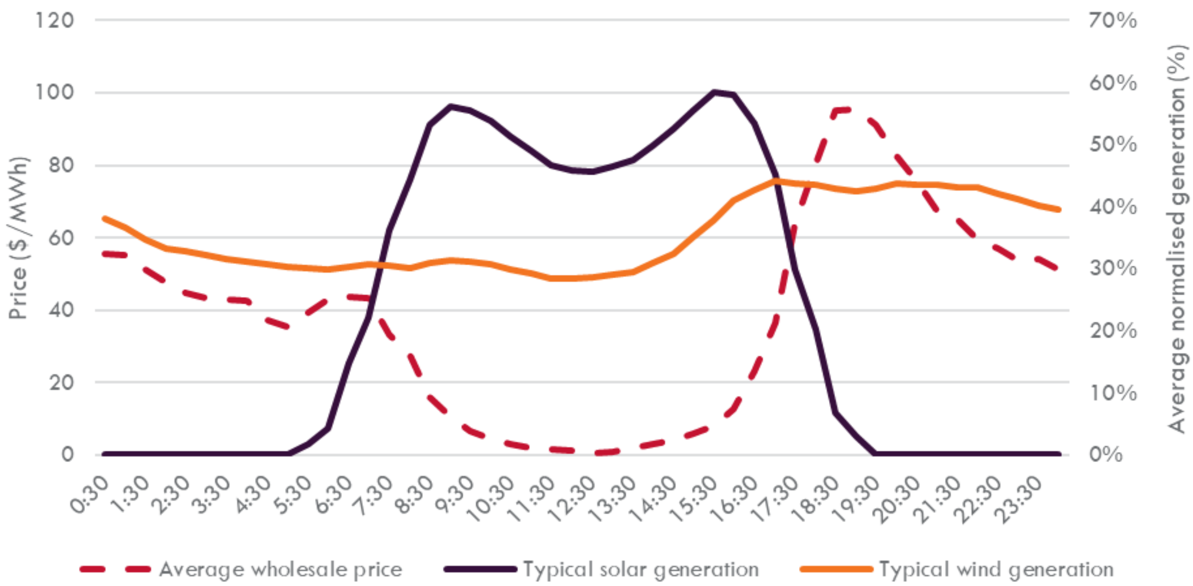
In assessing the development of renewable generation to meet the Roadmap minimum objectives, the modelling chooses between wind and solar generation[12] based on the overall impact on total costs for New South Wales electricity consumers.

The modelling generally favours wind generation in all Development Pathways, although this does not reflect a stated preference for the New South Wales Consumer Trustee in awarding LTES Agreements. Through the tender process there are likely to be a range of projects from eligible technologies that submit competitive offers. Project-specific features such as resource quality, cost, correlation with demand, and regional benefits may result in the New South Wales Consumer Trustee determining that a different technology mix is ultimately preferred in delivering the overall objectives of the EII Act.

Wind is not necessarily the lowest-cost technology. The preference for wind over large-scale solar generation in the modelling is due to wind generation capturing a higher average revenue from the wholesale market. New solar projects are highly correlated with other solar generation across the NEM, including distributed PV systems. Wind generation, on the other hand, has much higher resource diversity both geographically and intra-day, meaning it is more likely to be generating at times of higher operational demand, such as during the evening peak which typically occurs near or after sunset. Given the high penetration of distributed PV, wholesale prices in the middle of the day are relatively low, whereas the diversity of wind generation results in a higher average impact on wholesale price for each additional turbine installed. This higher average revenue may be expected to lower any LTES Agreement payment required by wind generators, relative to solar generation projects.

The stronger correlation between wind output and spot price (which in turn is typically higher during high demand periods) is highlighted in **Figure 3**.

Figure 3 Time of day relationship between VRE generation and spot market price, 2024-25



[12] The New South Wales Consumer Trustee's preferred 2021 Development Pathway will be technology-agnostic, with all eligible technologies being considered in tenders.

Development to meet the long-duration storage objectives

The IIOs require the construction of 2 GW of long-duration storage, where "long-duration" is defined as being capable of generating at registered capacity for eight hours or more. In modelling this need, AEMO has focused on two major storage technologies – pumped hydro and battery storage.

In the modelling outcomes, pumped hydro generation was preferred over eight-hour battery storage considering the assumed levelised cost of each technology. Despite having a higher outright capital cost, pumped hydro's longer technical and economic life (40 years compared to 20 years for battery storage) means pumped hydro is expected to have lower levelised cost and therefore require less additional revenue through LTES Agreements.

However, pumped hydro developments are highly variable and site-specific, and several considerations may favour a battery storage preference:

- Pumped hydro costs can vary significantly considering each project's geological conditions, compared to the assumed capital cost.
- Pumped hydro developments have much longer lead times for development and construction, and are more exposed to development delays.
- Pumped hydro projects are typically less flexible to hasten commissioning if the capacity is required earlier than expected. Battery storage projects are more likely to be able to respond to accelerated coal withdrawals to help manage reliability and system security if required (considered further in Section 0).
- There is greater forecast potential for cost reductions for battery storages than pumped hydro, as shown by the difference between the "Central" and "High VRE" scenarios in CSIRO's GenCost projections[13], which are used as the basis for both 2022 ISP modelling and this assessment.
- Pumped hydro projects rely on appropriate geological and geographical conditions, and good site locations for pumped hydro may not be good locations for connecting to the transmission system. This may lower the relative benefits associated with the increased operational flexibility provided by these projects, relative to battery storage projects that have relatively few development site restrictions.
- Battery storage solutions may be more capable of accessing additional revenue streams not considered in this modelling. For example, ancillary service markets have, in recent years, provided additional revenue opportunities for battery projects.

As such, there is a strong potential for battery storage projects (or other emerging storage technologies) to compete against pumped hydro projects in the tender process for long-duration storage.

Battery storage projects within the Sydney/Newcastle/Wollongong area (of any duration) may also assist in meeting peak demand requirements and reduce the need for the Sydney Reinforcement transmission project. Work is ongoing (including in the 2022 ISP) to determine whether network or non-network options will deliver greater benefits for consumers. Pumped hydro projects cannot as easily be constructed in these areas.

---

[13] At https://www.csiro.au/-/media/News-releases/2020/renewables-cheapest/GenCost2020-21.pdf.

3. Comparing alternative Development Pathways

3.1 Summary

The four Development Pathways explore different rates under which the New South Wales Consumer Trustee could tender for VRE and long-duration storage to meet the Roadmap objectives. **Table 5** outlines the four alternative Development Pathways modelled.

Table 5 Summary of alternative Development Pathways modelled

Development Pathway	Purpose	Description
Early	To explore VRE developments as early as possible.	The earliest plausible VRE commissioning schedule, using available network connection points prior to network augmentations being built.
REZ Aligned	To explore VRE developments in line with the schedule of network augmentations.	While developments are relatively early, this deploys VRE capacity with foresight of expanded network infrastructure capacities, delaying development (where appropriate) until REZ augmentations enable 500 kV connections rather than connecting to existing networks.
Supply Chain Adjusted	To explore VRE developments with specific regard to potential supply chain constraints.	Considering the maximum developed renewable capacity observed historically, this Development Pathway develops capacity more gradually than other modelled alternatives, minimising the risk of supply chain disruption and constraints across the next decade. This alternative Development Pathway incorporates an annual maximum build of VRE in New South Wales capable of generating approximately 6,000 GWh per annum until 2030. After 2030 this limit is increased to 7,600 GWh per annum, assuming that within the next ten years the capability of the supply chain will have expanded.
Late	To explore VRE developments as late as possible.	Examines the costs and benefits of delayed investment to minimise disruption to incumbent generation and maximise the opportunity for lower development costs in future years.

Each Development Pathway results in different levels of investment, operating costs and savings for New South Wales consumers, but also differing levels of risk if assumptions do not eventuate as expected. These differences, costs, and risks are discussed further in the following sections.

3.2 Key difference between Development Pathways is speed of VRE development

3.2.1 Renewable generation construction

The primary difference in how the Development Pathways are defined relates to the pace of renewable generation development.

Figure 4 shows the cumulative development of equivalent VRE generation capability in each Development Pathway relative to the target of 33,600 GWh, and **Figure 5** shows the annual build of VRE in terms of generation capability[14]. All the Development Pathways achieve this target by 2029-30, and all exceed the target beyond 2030-31 as new VRE and long-duration storage are the lowest-cost options to replace generation from retiring coal fired power stations.

Figure 4 VRE generation development for each Development Pathway (GWh)

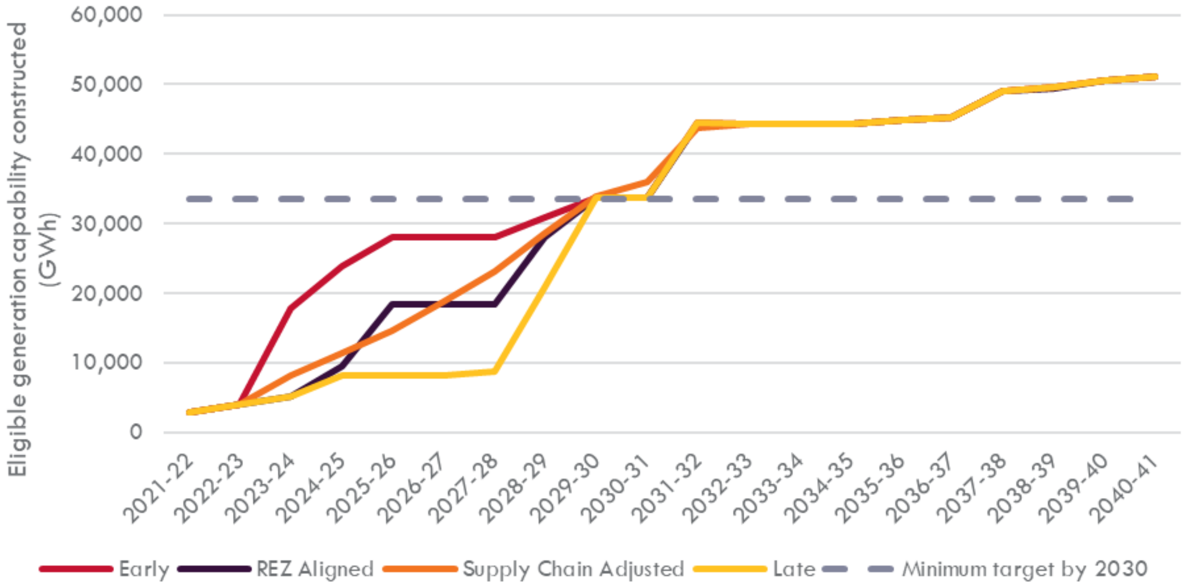
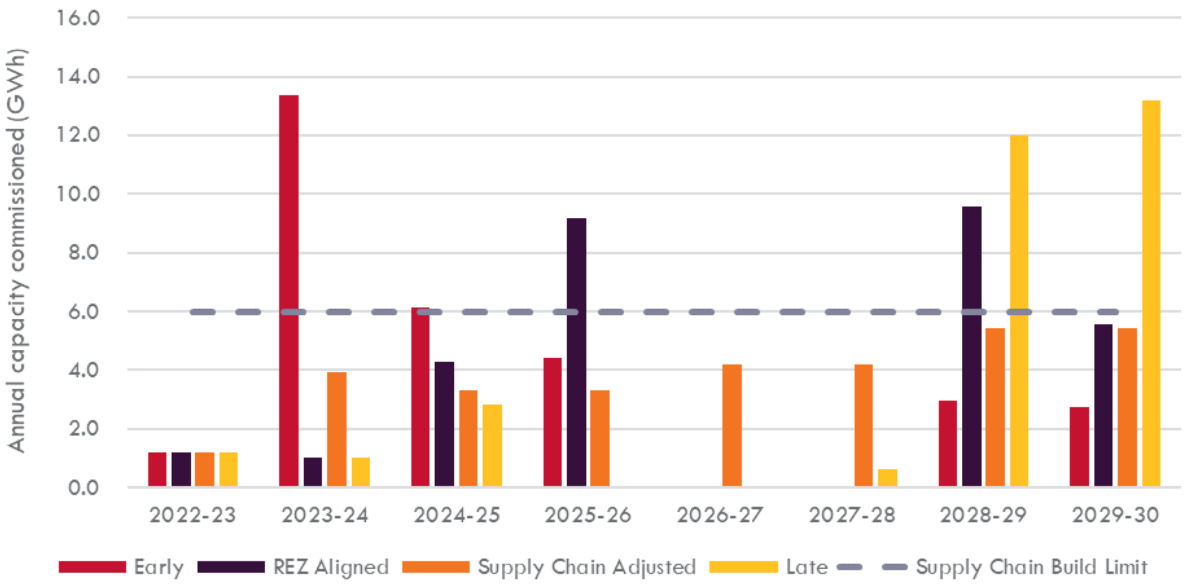


Figure 5 New annual VRE generation development for each Development Pathway (GWh)[15]



The Early, REZ Aligned, and Late Pathways each show different periods of rapid VRE development, often aligned with coal withdrawals or the commissioning of network infrastructure augmentations. In contrast, the

[14] Generation capability refers to how much generation would be produced if all available VRE was dispatched. Actual generation may be lower due to network congestion or over-supply (economic curtailment)

[15] New developments include projects that are committed or anticipated, as defined in the accompanying Assumptions Report, primarily based on committed and anticipated projects from AEMO's May 2021 Generation Information release.

Supply Chain Adjusted Pathway follows a smoother VRE build trajectory, avoiding 'boom and bust' cycles of development in the next decade.

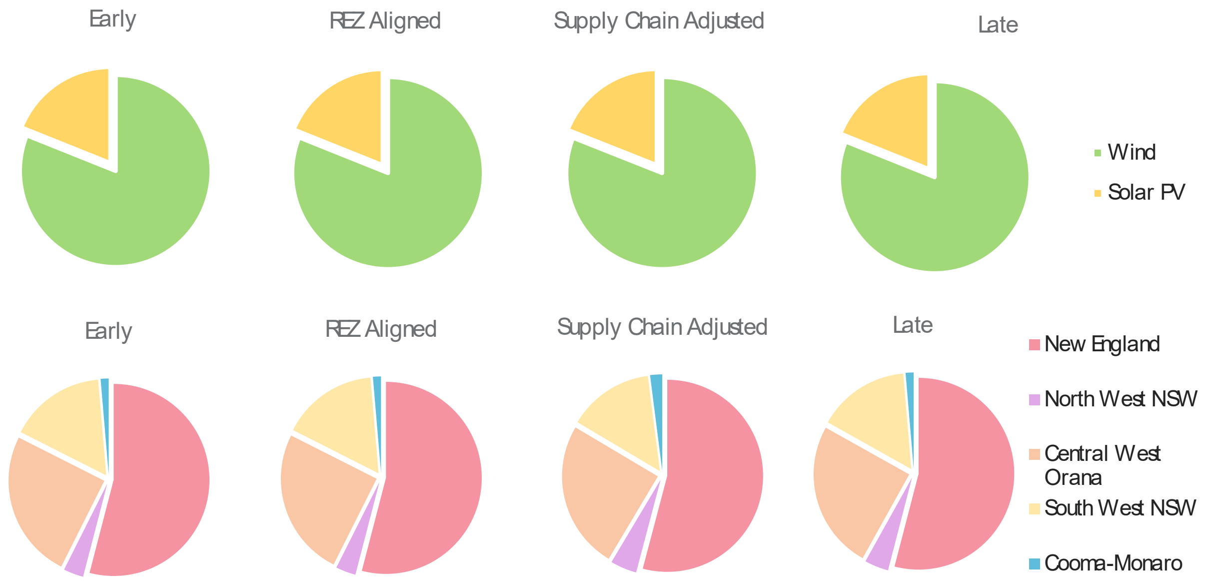
Historically, a maximum of approximately 1.5 GW VRE has committed to connect in New South Wales in any given year (equivalent to approximately 4,600 GWh assuming a 35% capacity factor), and the capability of New South Wales to expand the supply chain is an anticipated outcome of the Roadmap. However, in some Development Pathways, a material expansion of the supply chain would be required to fulfil the Development Pathway trajectories. In all but the Supply Chain Adjusted Pathway, more than 9 GWh of new VRE generation would need to be delivered in at least one year of the next decade. This is well in excess of the historical maximum installation rate, and could be logistically challenging, as discussed in Section 4.2.1.

3.2.2 Similar development by technology and location across the Pathways

Wind generation is favoured over solar in all Development Pathways, for reasons discussed in Section 2.2.

Figure 6 shows that the share of wind and solar development across the Development Pathways is relatively consistent.

Figure 6 Modelled renewable capacity development (GW) by technology and location for each Development Pathway by 2039-40



Similarly, the figure shows that the location of renewable generation development is also relatively consistent across the Development Pathways. The Central West Orana and New England REZs are heavily favoured due to their substantial transmission access (made available through assumed network infrastructure augmentations) and availability of renewable resources, and minimal development across the other REZs reflects constraints on transmission and resource availability.

If the network infrastructure augmentations were not developed as assumed, more capacity may connect to other parts of the existing transmission network to deliver the IIOs. Depending on the location and type of generation installed, this may lead to lower costs to consumers by reducing and/or avoiding transmission investments (if both the renewable resource quality and transmission access was not significantly worse than the REZs), or higher cost. This will be explored further in the 2022 ISP.

3.2.3 Renewable curtailment due to low prices and network congestion is forecast for all Development Pathways, but exacerbated in the Early Pathway

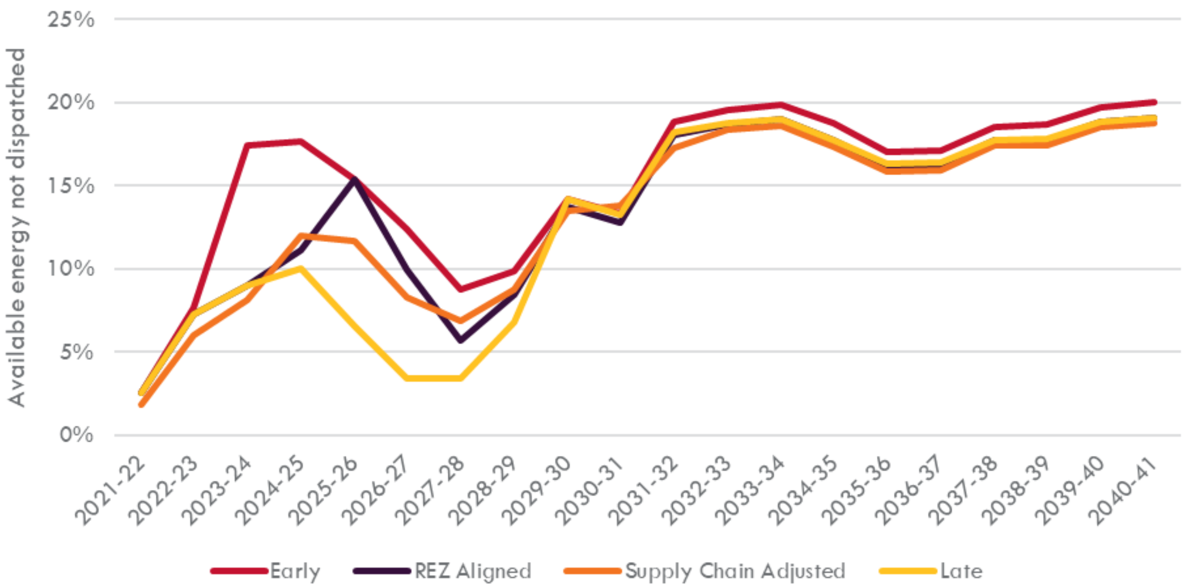
The substantial increase in the penetration of VRE in each Development Pathway results in a general increase in the level of curtailment. It is important to recognise that this curtailment will not necessarily deter investment and thereby inhibit the Roadmap from achieving its objectives. Curtailment is likely to be a feature of any high VRE system, and actions to reduce curtailment (such as additional network infrastructure augmentations or further storage development) may be economically inefficient, increasing costs to New South Wales consumers compared to the alternative of leaving VRE curtailed.

The curtailment occurs for three reasons:

- An excess of renewable generation at certain times.
- Limits on available storage capacity.
- The impact of transmission limitations.

As shown in **Figure 7**, curtailment is forecast to rise as new VRE is commissioned. The rise in the Early Pathway is particularly steep, given the substantial early VRE development in this Development Pathway and the lack of deep storage available in the near term. The primary cause of curtailment in these early years is an excess of VRE generally, which results in economic curtailment of energy oversupplies during low-priced periods. Curtailment is forecast to fall in the mid-2020s due to a combination of factors including coal retirements, the development of Snowy 2.0 and HumeLink, and the development of additional long-duration storage under the Roadmap. These factors help effectively increase the flexibility of the system, enabling VRE to operate more frequently at high output, and reduce curtailment.

Figure 7 Forecast of annual available VRE not dispatched in each Development Pathway



In the late 2020s, further VRE development is expected to occur, with projected curtailment again rising to a steady level of between 15% and 20% of total VRE availability for the remainder of the modelling horizon. The modelling suggests that it is cheaper to increase the LTES Agreement payments to compensate VRE for loss of revenue due to curtailment than to invest in more network infrastructure and storage. The optimal mix of transmission investment, storage investment, and VRE development will be further examined in the 2022 ISP.

3.2.4 Modelled early coal withdrawals observed in all Development Pathways, to different degrees

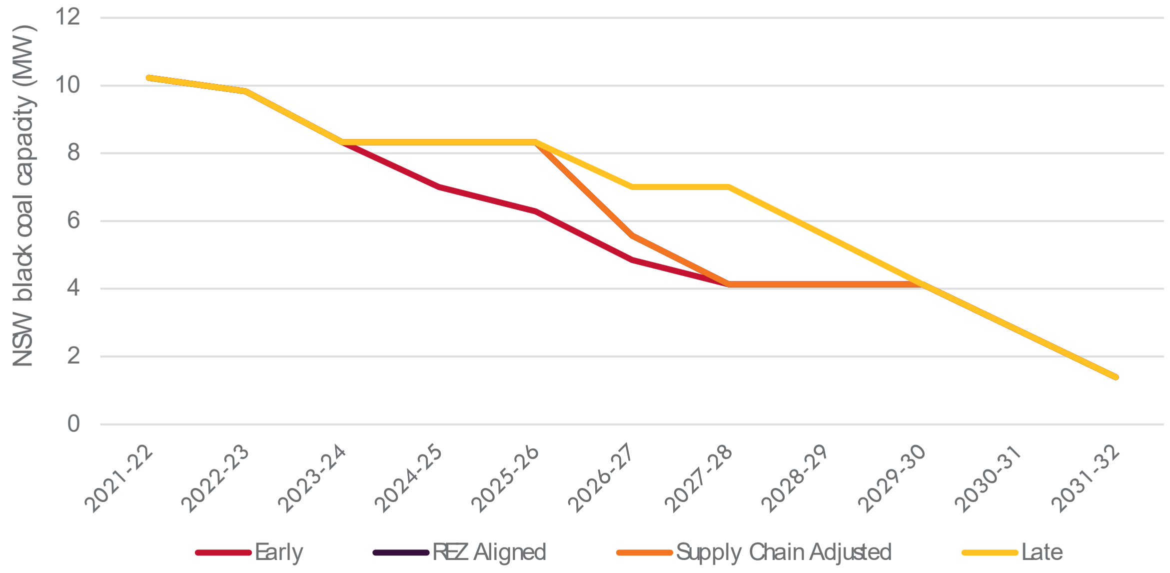
As noted in AEMO's 2021 ESOO, the accelerated rate of change in the energy industry has implications for the ongoing financial viability of existing thermal generation, particularly coal-fired generation that is less able to rapidly adjust generation levels in response to changes in market prices. This was highlighted by announcements in the last year that owners were bringing forward the closures of Yallourn Power Station (by four years, to 2028), two units at Eraring Power Station (one unit by two years, to 2030 and one unit by one year, to 2031) and Mount Piper Power Station (by two years, to 2040). One unit of Torrens Island B Power Station has also been mothballed for a three-year period commencing October 2021, with the owner saying this decision was in response to challenging market conditions[16]. In the last month, the Chief Executive Officers of AGL Energy and Alinta have indicated that early closures of both the Loy Yang A and B power stations is becoming increasingly likely due to financial and operating pressures resulting from the rise in renewable generation development[17].

Increases in renewable generation development are forecast to place further downward pressure on wholesale prices in New South Wales, and other regions.

In the market modelling, earlier economic coal-fired generation withdrawals and new operating strategies have been assessed as likely in response to low capacity factors and volume-weighted spot prices. In reality, withdrawal of such generation capacity from the market is subject to the commercial decisions of the relevant asset owners, who must consider a complex range of commercial factors including maintenance costs, supplier and customer contracts, end of life remediation costs and competition from other coal plants, all of which are unable to be reflected in a market model. Accordingly, the timing of such withdrawals is subject to a high degree of uncertainty.

Figure 8 demonstrates the modelled variation in withdrawal timings under each Development Pathway.

Figure 8 Modelled coal withdrawal schedule in each Development Pathway



The Early, REZ Aligned, and Late Pathways assume the timing of coal withdrawals is known well in advance, allowing renewable generation development to be co-ordinated with the closures. This leads to spikes in development in years when large coal-fired generators are assumed to withdraw, as seen in **Figure 5**. In

[16] See AGL's media release at https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2021/july/agl-to-mothball-one-unit-at-torrens-b-in-south-australia?zcf97o=vlx3ap.

[17] See https://www.afr.com/policy/energy-and-climate/alinta-concedes-coal-plant-may-shut-15-years-early-20211012-p58z8x.

contrast, the Supply Chain Adjusted Pathway allows for a steady build of renewable generation ahead of closures.

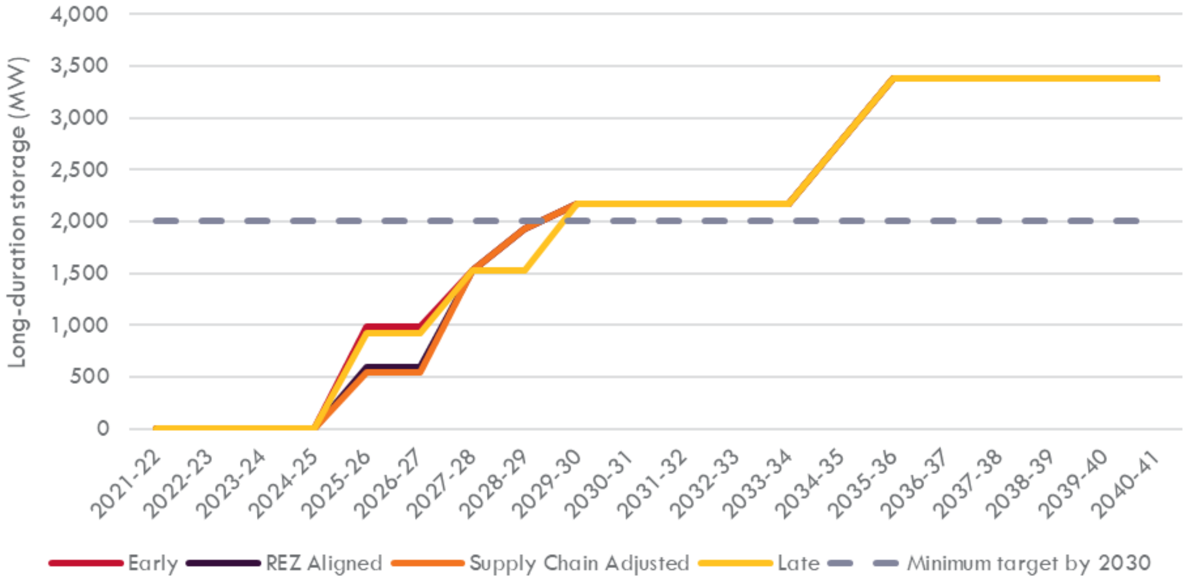
Given that the timing of the withdrawals is highly uncertain, Development Pathways that have a supply 'buffer' in case coal closures occur without sufficient advanced warning to develop alternative generation, storage, and network infrastructure solutions are less exposed to potential price volatility and reliability concerns. The resilience of the Development Pathways is discussed further in Section 4.

3.2.5 Long-duration storage development is relatively consistent across all Development Pathways

The target of developing 2 GW of the long-duration storage is forecast to be met in each of the Development Pathways, with development trajectories shown in **Figure 9**. The long-duration storage candidates considered are located across the New England, Central West Orana, and Hunter-Central Coast REZs, with earliest commissioning dates having been provided by the Department.

Despite the varying pace of VRE development and coal retirements, the Development Pathways all display relatively similar long-duration storage developments. With the exception of the Early Pathway, long-duration storage is typically built one year ahead of, or at the same time as, coal withdrawal. This is not so in the Early Pathway, as the long lead time for pumped hydro projects would prohibit any from being developed before the next uncommitted coal withdrawal is assumed. Long-duration battery storage may be able to be delivered with shorter lead times, but based on costs assumed in the modelling, this technology alternative did not deliver lower cost outcomes for consumers, and was not required to maintain reliability of supply.

Figure 9 Long-duration storage development



3.3 Assessing the performance of each Development Pathway against Roadmap objectives

Table 6 compares and contrasts the performance of each Development Pathway against several criteria, including affordability, reliability, sustainability, and development delivery risks.

Table 6 Development Pathway performance across criteria aligned with Roadmap objectives

Development Pathway	Total cost (NPV $ billion)	Reliability standard met?	Cumulative NSW CO_2e emissions by 2040 (MT)	Cumulative NEM CO_2e emissions by 2040 (MT)	Maximum annual VRE build to 2030 (GWh equivalent)
Early	36.57	Likely	284	1,329	13.4
REZ Aligned	36.91	Likely	306	1,363	9.6
Supply Chain Adjusted	36.06	Yes	303	1,355	5.4
Late	35.78	Likely	329	1,389	13.2

3.3.1 Total consumer costs across the Development Pathways

The market developments and outcomes described earlier in this chapter are the key drivers of the wholesale and scheme cost components which vary between the Development Pathways, as can be seen in **Table 7**. Despite the Development Pathways deviating substantially with respect to their trajectories of VRE development, the variance in the NPV of total system cost is, at most, $1.1 billion across all the Development Pathways. This is because an inverse relationship exists between the wholesale and scheme cost components, with lower wholesale costs (and therefore lower spot prices and revenues for generation) generally resulting in higher scheme costs. These cost components are discussed in more detail below. The two Pathways with lowest total consumer costs are the Supply Chain Adjusted and Late Development Pathways.

Table 7 NPV of cost components ($ billion)

Development Pathway	Wholesale costs	Scheme costs	Total costs	Difference from minimum
Early	31.0	5.6	36.6	0.8
REZ Aligned	32.0	4.8	36.9	1.1
Supply Chain Adjusted	31.0	5.0	36.1	0.3
Late	30.9	4.8	35.8	0.0

Wholesale costs

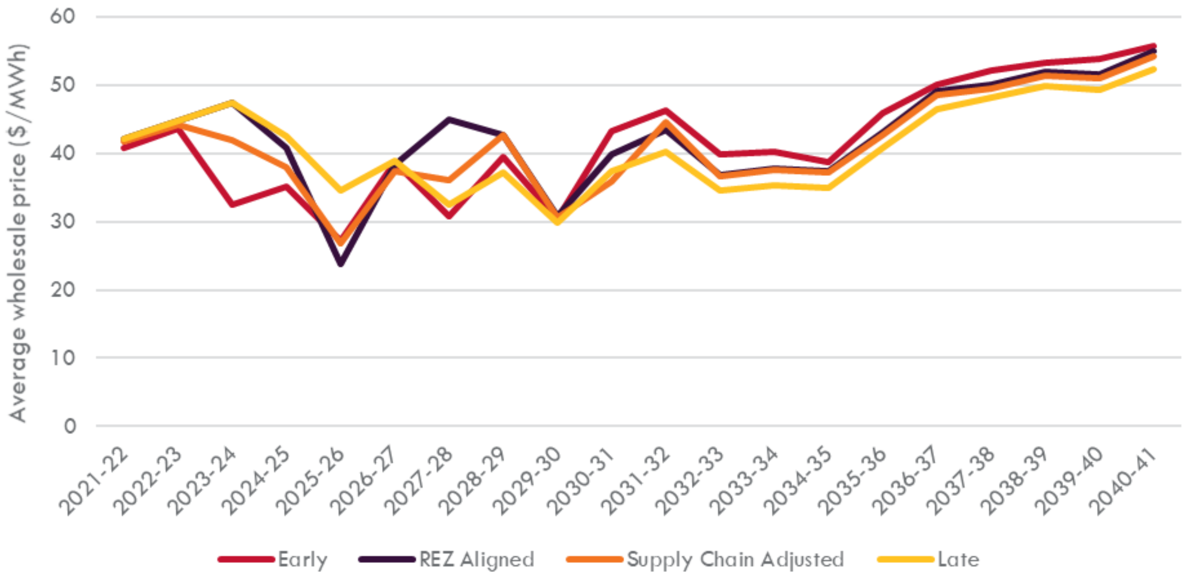
For the purpose of this analysis, the wholesale cost to New South Wales consumers is based on spot prices for electricity and excludes consideration of contract markets. Although it is the largest driver of differences in total consumer costs between the alternative Development Pathways, the differences in spot prices are relatively subtle, as shown in **Figure 10**.

The forecast wholesale prices reflect a reasonable reduction on current and futures prices, driven by several factors that are expected to lower prices:

- New developments (and increasing VRE penetration) are expected to increase the supply available to market, increasing the competitiveness of generator bidding.
- Increasing DER uptake
- Introduction of the New South Wales peak demand reduction scheme.
- Return to service of presently unavailable capacity (such as the Callide Power Station in Queensland).

The up and down nature of the price forecast reflects the "lumpy" nature of modelled coal withdrawals. Generally, spot prices are modelled to rise immediately following a coal withdrawal, then decline as more VRE is developed, before rising again with the next coal withdrawal.

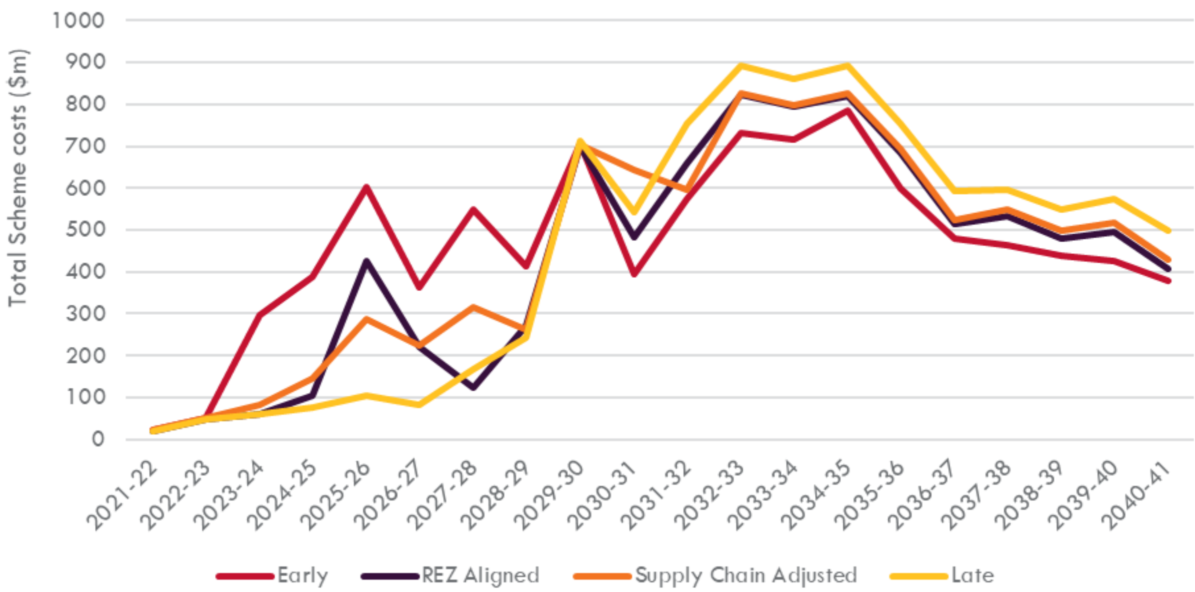
Figure 10 Forecast average New South Wales spot prices in all Development Pathways



Scheme costs

Scheme costs represent the total cost paid by the New South Wales Consumer Trustee under the LTES Agreements with generators and long-duration storage projects. For the purpose of this analysis, it is calculated as the difference between the total levelised cost of energy for a project, and the wholesale revenue received over the life of that project. Given that scheme costs are based on the amount required to ensure new developments are able to make their required rate of return, they generally have an inverse relationship with wholesale prices. This is shown when the scheme costs presented in **Figure 11** are compared with the wholesale prices presented in **Figure 10**. This inverse relationship helps moderate differences between the Development Pathways' total scheme costs.

Figure 11 Forecast scheme costs in all Development Pathways



The Early Pathway is forecast to experience sustained higher costs throughout the 2020s, with the highest volume of VRE curtailment given the scale of early developments spread across new and existing network connections. This contributes to the VRE developments needing additional revenue through LTES Agreement payments as a result of lower wholesale revenues.

Transmission costs

Transmission costs include the cost of new augmentations attributable to the achievement of the IIO. In particular, augmentations designed to enable efficient connection and operation of new VRE in New South Wales are incorporated into the transmission costs. This includes the anticipated Central West Orana initial augmentation, New England connections, and the New South Wales components of the QNI augmentation that further enable REZ connection and transfer capacity.

Other augmentations that partly contribute to the Roadmap objectives are included at a discounted cost (50%). This is in recognition of the broader benefits these augmentations are likely to have for operating the market in a secure and reliable manner, including stability improvements to the South West New South Wales grid, and reinforcement of the Sydney Ring, particularly to improve reliability following coal withdrawals.

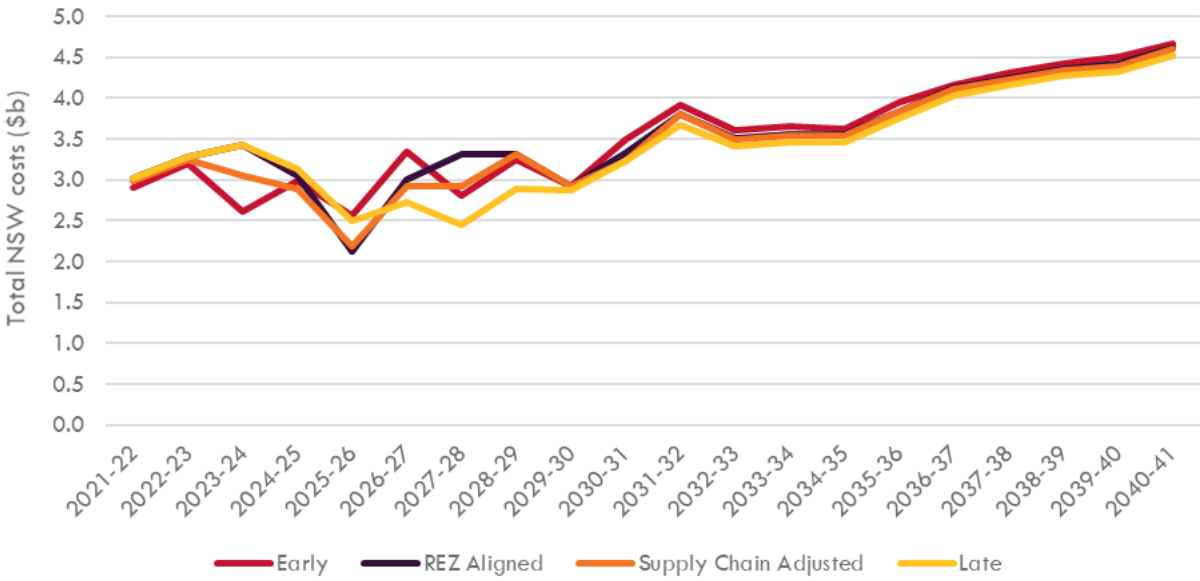
As detailed in Section 2.1.1, the network infrastructure augmentations are assumed to be the same across the Development Pathways. As such, there are no differences in the transmission costs incurred and passed through to New South Wales consumers, and these costs are therefore not material to this comparison of the Development Pathways.

Total New South Wales consumer costs

Summing the three cost components results in the total New South Wales consumer costs shown in **Figure 12**, with the NPVs provided in **Table 7**. The Late Pathway applies the purest optimisation to meet the IIO of the Roadmap, minimising total costs to New South Wales consumers, absent consideration of supply chain constraints, and assuming perfect foresight with respect to coal withdrawals. It therefore delivers the lowest cost in NPV terms of the suite of Development Pathways.

For those Development Pathways with a slightly higher cost, the difference is often due to a short-lived increase, and converges after several years once coal withdrawals harmonise across the Development Pathways. For example, approximately half the difference between the NPV of the total costs between the REZ Aligned and Late Development Pathways is due to the difference in consumer costs in a single year (2027-28), when the two Development Pathways differ most in VRE development and coal withdrawal solutions.

Figure 12 Total New South Wales consumer costs



3.3.2 Reliability is maintained across all Development Pathways

AEMO conducted detailed reliability modelling on the Supply Chain Adjusted Pathway to confirm that the reliability standard and IRM is met in accordance with the Roadmap objectives.

Expected USE is determined through probabilistic, time-sequential modelling at the interval level using Monte-Carlo simulations of security-constrained optimal dispatch. AEMO compares the probability-weighted USE assessment against the reliability standard and identifies the potential for the reliability standard to be exceeded. Any forecast reliability gap in a given year is based on expected USE not meeting the relevant reliability standard.

The methodology applied for calculating the expected USE in 2021-22 to 2030-31 is consistent with that used for AEMO's ESOO, documented in the *ESOO and Reliability Forecasting Methodology*[18]. A slightly simplified approach was taken to calculate expected USE beyond the next decade due to the inherent uncertainty in outcomes (including network congestion) in the longer term.

Based on the analysis, the reliability standard is forecast to be met in the Supply Chain Adjusted pathway throughout the 20-year planning horizon.

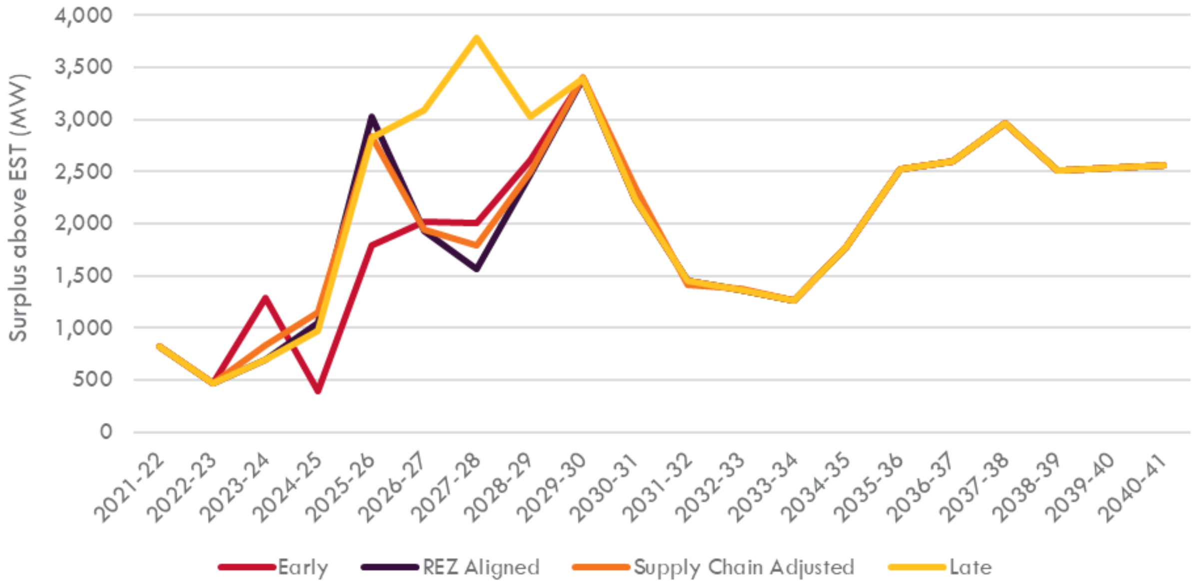
Fundamental to this favourable reliability outcome is the assumed network investment to reinforce Sydney Ring. Without this network augmentation, or significant additional investment in generation and storage within the Sydney/Newcastle/Wollongong region, AEMO's 2021 ESOO identified that 0.008% of New South Wales load may be shed involuntarily in 2030-31. The extent of expected load shedding in the Sydney/Newcastle/Wollongong region if USE reached 0.008% would be of a scale equivalent to 250,000 to 750,000 households being without power for an average of three events per year, with each event lasting approximately five hours, typically during very high temperature conditions (40°C days).

Detailed reliability modelling was not undertaken for the other Development Pathways due to time constraints, but instead, a state-wide Energy Security Target (EST) assessment was undertaken as a proxy for reliability. For this purpose, AEMO assessed whether there was sufficient firm generation, storage, and interconnector capacity in each Development Pathway to meet maximum consumer demand during a summer heatwave (10% probability of exceedance [POE] demand) while maintaining a reserve margin to account for the unexpected loss of the region's two largest available generating units. The assessment did not take into consideration major intra-regional transmission network limitations that could constrain availability of firm generation, storage and interconnector capacity at times of peak demand.

The forecast of reserves in excess of this margin are shown in **Figure 13** below. As all Development Pathways have similar surplus reserves, it is assumed that if the Supply Chain Adjusted pathway meets the reliability standard, the other Development Pathways would also.

[18] At https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2021/esoo-and-reliability-forecast-methodology-document.pdf?la=en.

Figure 13 Statewide Energy Security Target (as proxy for reliability standard)



Emissions abatement

The rate of VRE development in New South Wales and modelled New South Wales coal withdrawals has a material influence on CO_2-e emissions in New South Wales and the broader NEM. The Development Pathways with more rapid VRE development are forecast to have the fastest emissions reduction and greatest impact on cumulative emissions, as shown in **Figure 14** (for New South Wales) and **Figure 15** (for the NEM).

Figure 14 Forecast New South Wales emissions trajectories in all Development Pathways

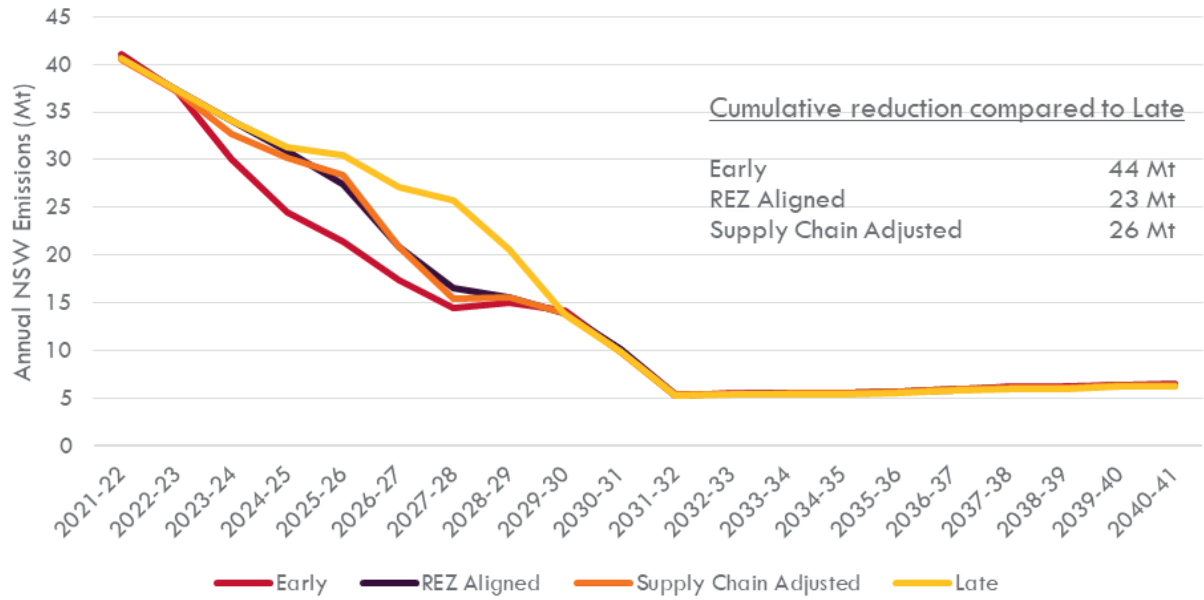
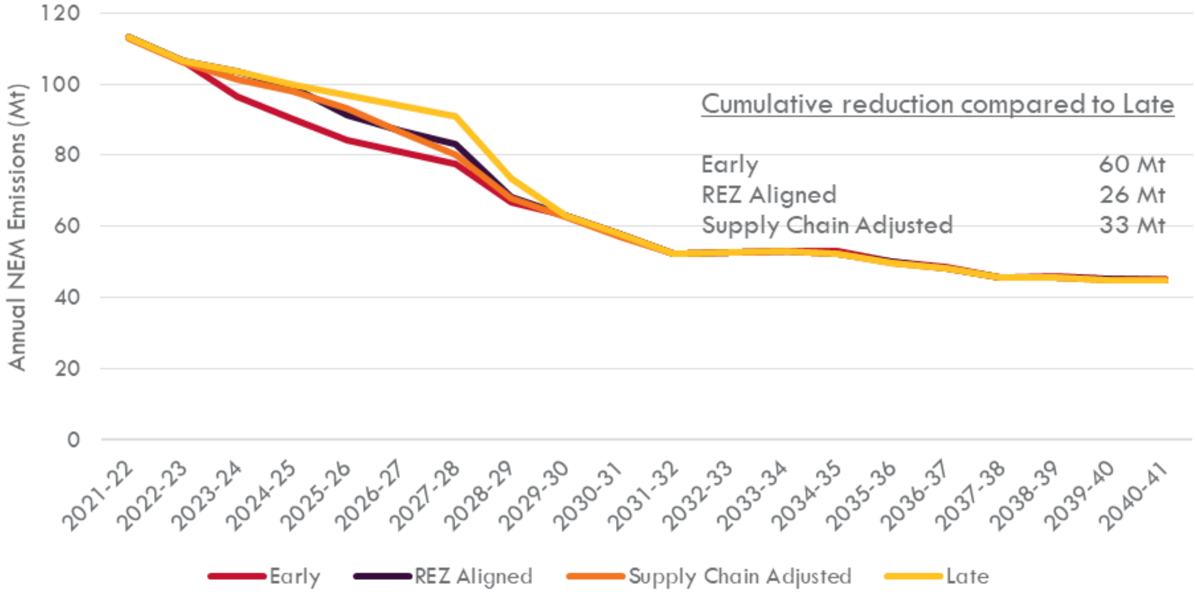


Figure 15 Forecast NEM emissions trajectories in all Development Pathways



4. Assessing the risks and resilience of alternative Development Pathways

4.1 Pathways demonstrate differing resilience to several key uncertainties

As outlined in Section 3.3, each Development Pathway provides a similar overall trajectory for costs associated with the Roadmap, with Pathways delivering lower wholesale costs typically requiring higher scheme subsidies to eligible generators. The variance in expected total cost to New South Wales consumers is approximately $1.1 billion (in NPV terms), or 3% of total costs.

There is, however, a wider band of uncertainty regarding the resilience of each Development Pathway if alternative assumptions apply. A number of sensitivities have been explored, testing the influence of alternative key assumptions to demonstrate the resilience of the Development Pathways to known uncertainties. The sensitivities assessed the projected impact of:

- Earlier than expected closure of coal generation in New South Wales (see Section 4.1.1).
- Earlier than expected closure of coal generation in Queensland (Section 4.1.2).
- Slower demand growth, due to slow economic recovery and industrial closures (Section 4.1.3).
- Delays in network development (Section 4.1.4).
- Delays in pumped hydro development (Section 0).

While each sensitivity changed a key assumption, the modelling did not re-optimise the technology mix, location, and timing of generation and long-duration storage in response.

In most cases, these sensitivities showed a similar impact in all Development Pathways. Earlier than expected closure of coal generation in New South Wales or Queensland most materially impacted the relativity of New South Wales consumer costs across the Development Pathways, with earlier VRE developments being more resilient than late developments, provided subsequent economic coal withdrawals are also delayed.

Delays in pumped hydro development may be more of a risk for Development Pathways with an earlier build, as more generation may be curtailed. That said, these same early builds may be more resilient to delays in network development as the early connections are not dependent on new network augmentations to connect.

4.1.1 Risk of early coal closures in New South Wales significantly impacts the ranking of the Development Pathways

The New South Wales spot price is sensitive to coal retirements. Therefore, variations in the timing of coal retirements have the potential to significantly impact New South Wales consumer costs.

Two alternative approaches were modelled to consider this impact across the Pathways:

- A sensitivity which assumed coal retirements occur as per the timings determined in the Early Pathway without providing any ability to respond.
- A sensitivity which assumed sufficient notice of an early retirement of Eraring Power Station in 2025-26 (or equivalent), allowing an appropriate development response.

Table 8 shows the results of the early coal closure sensitivity, indicating that the more rapid Development Pathways are more resilient to early coal closures than the Late Pathway. The Late Pathway would expose New South Wales consumers to a greater relative cost, if long-duration storages and new VRE developments were not commissioned and available to replace lost capacity and energy from any such closure.

However, the results presented are an upper bound on this relative impact, given the assumed inability of the New South Wales Consumer Trustee or broader market to respond to earlier coal closures, for example by bringing forward both renewable and storage developments. The effectiveness of this adaptation from the New South Wales Consumer Trustee would depend on both the notice provided for closure and the speed with which additional renewable generation or storages could be procured.

Table 8 Modelled impact of early coal closure sensitivity on consumer costs ($ billion)

	Early	REZ Aligned	Supply Chain Adjusted	Late
Consumer costs with expected assumptions	36.57	36.91	36.06	35.78
Consumer costs with coal closure sensitivity	36.57	39.50	38.33	41.71
Difference		+2.59	+2.27	+5.93

In addition to the early closure sensitivity, modelling was done to identify the ideal response to an announced early closure of a major New South Wales coal power station. For the purposes of the modelling, this was assumed to be the Eraring Power Station closing in 2025-26, to test whether the New South Wales Consumer Trustee would have the ability to respond. AEMO has not received any information that suggests this eventuality is likely, and closure of any other coal generator in New South Wales of similar size would yield similar results.

While it is not appropriate to consider this an alternative Development Pathway, it does present an optimised modelling solution of the generation response with perfect foresight of a closure. Alternative Development Pathways that are in reasonable proximity to the outcomes within this investigation are notionally going to be more resilient to an early closure.

Due to the adaptive nature of this sensitivity, the early closure of one coal-fired power station improves the economic conditions for the remaining thermal plant, resulting in the delayed withdrawal of other power stations. Therefore, the net impact on the Development Pathways was more muted than the unexpected coal closure sensitivity where no future market response (such as delayed closures) was contemplated.

Much like the Late Pathway, this sensitivity did not apply any other constraints that restricted or expedited developments to achieve earlier deployment; the VRE and storage developments reflect a re-optimised development outlook with foresight of the thermal generator withdrawals.

Figure 16 shows that this optimised sensitivity ('Coal early exit') developed with perfect foresight of an early coal exit would prefer earlier VRE investments than the Late Pathway. It also demonstrates that the earlier VRE developments observed in the REZ Aligned and Supply Chain Adjusted Development Pathways would appropriately prepare New South Wales consumers for an earlier closure of this magnitude.

While the REZ Aligned and Supply Chain Adjusted scenarios observe similar VRE development outcomes to the perfect foresight Coal early exit sensitivity, the foresight of early coal closure would be expected to trigger the need for earlier long-duration storages. The added firm capacity and operational flexibility provided by long-duration storages are observed to be most efficient if delivered earlier in this sensitivity, with the development schedule very similar initially to the Early Development Pathway, as shown in **Figure 17**.

Figure 16 Renewable energy development for each of the Development Pathways compared to optimised development with perfect foresight of an early coal retirement

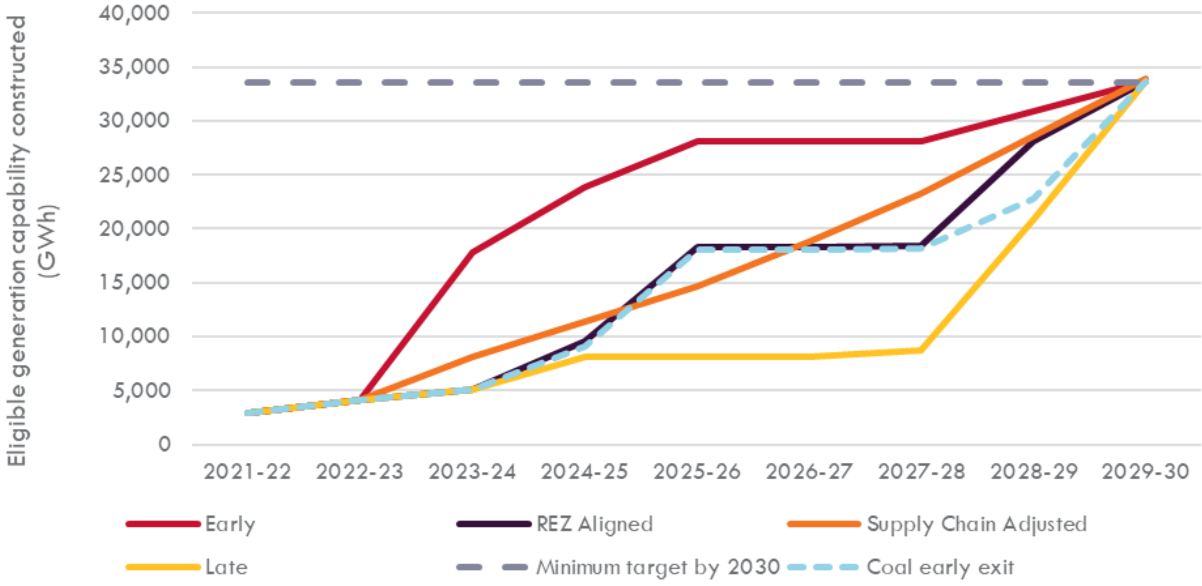
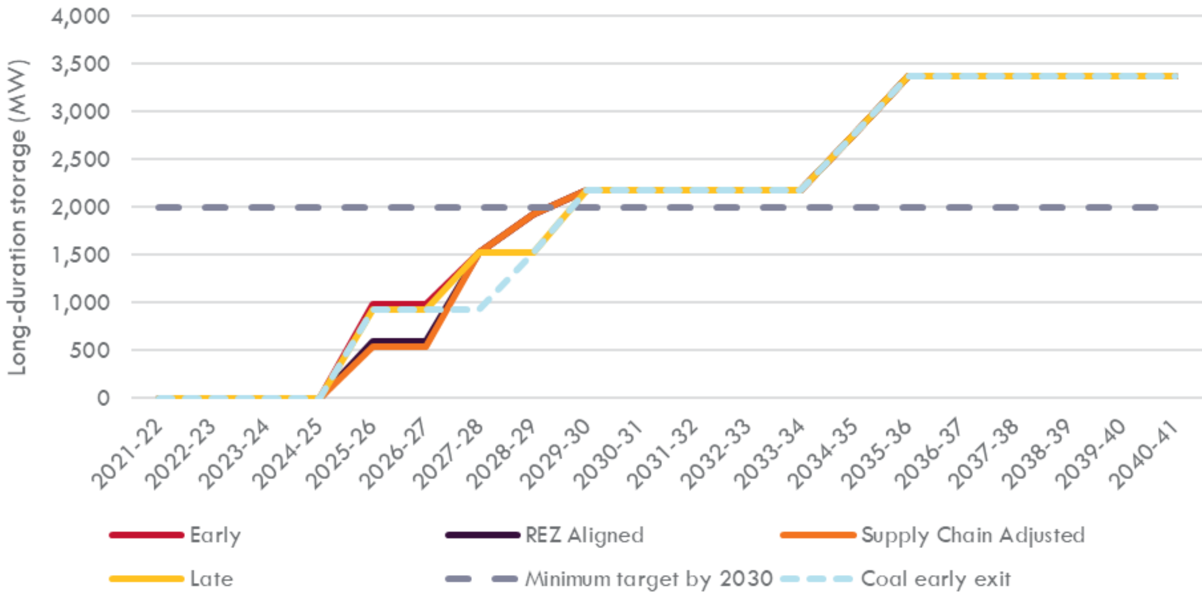


Figure 17 Long-duration storage development for each of the Development Pathways compared to optimised development with perfect foresight of an early coal retirement



4.1.2 Queensland coal closures favour Development Pathways with earlier VRE development

As New South Wales has typically imported more energy from neighbouring regions than it has exported, the operation of inter-state coal generation may influence the preferred Development Pathway for the New South Wales Roadmap. Extended outages in Queensland (for example, if Callide Power Station remained offline indefinitely) are expected to lead to higher costs to New South Wales consumers, irrespective of the preferred Development Pathway. This is because the impact of a significant Queensland coal closure on increasing New South Wales wholesale prices would more than offset the associated reduction in scheme costs as eligible projects receive naturally higher market revenues. In such circumstances, pathways that naturally provide a faster rate of VRE development may provide greater resilience to such challenges than later investments (thereby providing greater resilience to coal withdrawal irrespective of whether the capacity was in New South Wales or Queensland).

4.1.3 Slow demand growth does not increase total consumer costs

The risk of over-investment is largely managed through a staged tender plan strategy. This allows the New South Wales Consumer Trustee to minimise the over-development of generation if industrial closures occur, while still meeting minimum IIOs.

The impact of lower demand growth and industrial load closures was tested by applying assumptions based on the Slow Change scenario as presented in the Draft 2021 IASR and 2020 ESOO. This scenario, distinct from the conditions forecast for the core Central scenario applied to all other modelling, examines sustained lower economic growth, as the economy more slowly recovers from COVID-19. Given economic difficulties, some large industrial consumers are assumed to close, reducing operational demand.

The results presented in **Table 9** show that this sensitivity had very little impact on the relativity between the Development Pathways. Total consumer costs are lower across all Development Pathways due to forecast spot price collapse resulting from excessive oversupply, as compared to outcomes with expected Central scenario assumptions. If the market considered these Slow Growth conditions as persisting, accelerated thermal generation withdrawal may occur that would allow spot prices to bounce back. This response was not modelled in this sensitivity.

Table 9 Impact of slow demand growth on consumer costs ($ billion)

	Early Pathway	Late Pathway	Additional cost of Early Pathway
Consumer costs with expected assumptions	36.57	35.78	0.79
Consumer costs with Slow demand growth sensitivity	23.00	23.10	-0.10
Difference	-13.57	-12.68	

In all Development Pathways, the primary impact of the Slow demand growth sensitivity was on the scale of subsidies required to make whole the revenue stream of contracted investments, particularly in the absence of additional market response (such as more accelerated thermal generation withdrawal).

4.1.4 Impacts of delayed network infrastructure investments

A common theme across all Development Pathways is that network infrastructure investment is necessary to efficiently deliver the development needs of the Roadmap (as outlined in Section 2.1.1).

In the event that network infrastructure developments (or viable non-network alternatives) are delayed, the impacts to generation developments and the efficacy of LTES Agreement tender plans may be impacted. The tender plans will be technology- and location-agnostic, however AEMO anticipates that many development options will rely on new transmission corridors, or transmission upgrades to reduce the risk of transmission congestion and curtailment. Delays to these upgrades would likely inhibit the efficient connection and commissioning of contracted projects.

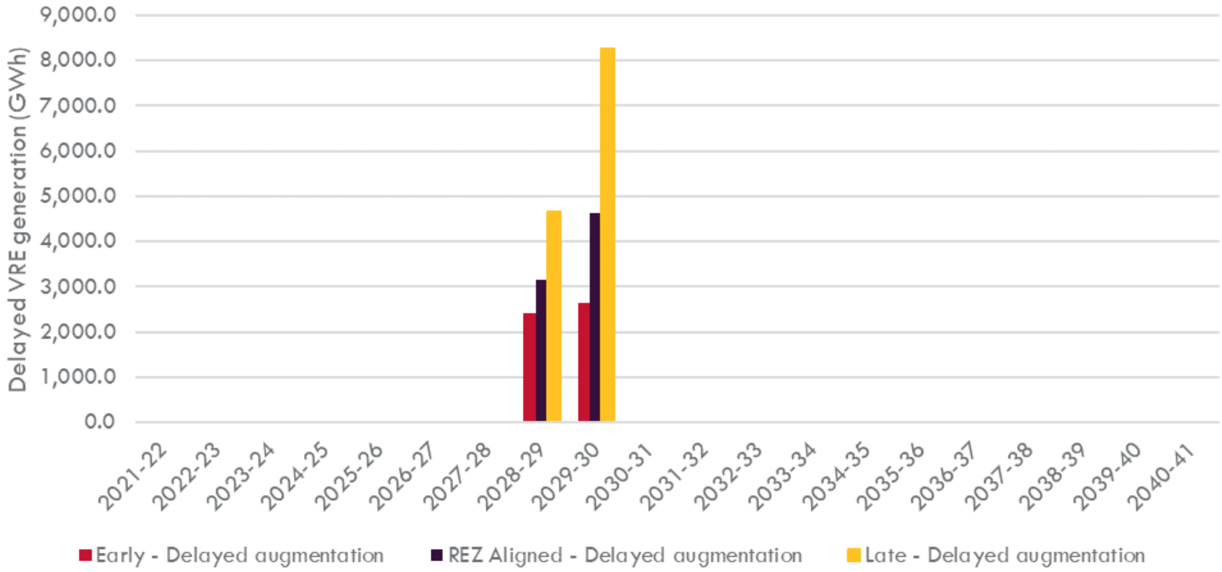
A sensitivity was run to test the impact of a two-year delay in the completion of two major augmentations, both assumed to be operational by 2027:

- Works associated with the New England network augmentation.
- Works associated with some New South Wales components of QNI developments.

The delayed delivery of these projects does pose a number of risks to the ability to deliver the minimum IIOs by the legislated date. In Development Pathways that rely on new network infrastructure developments to facilitate new VRE connections, delayed augmentations may defer VRE connections to after 2030. It is important to note, however, that this sensitivity assumes there has already been a commitment to construct the VRE and storage in accordance with the Development Pathway at the time a delay in network augmentation becomes apparent. It is therefore assumed to be too late to relocate infrastructure investment to other areas within New South Wales where spare existing network capacity may exist.

Figure 18 below demonstrates the magnitude of impact across the two Development Pathways with greatest and least impact, showing that up to 8,000 GWh of generation may be affected if network infrastructure was delayed in the Late Pathway, and as little as 2,000 GWh in the Early Pathway.

Figure 18 Scale of deferred connections if network infrastructure augmentations were delayed



Notwithstanding the risk that the minimum objectives of the Roadmap may not be achieved by 2030 in this sensitivity, the impact of the Development Pathways on New South Wales consumer costs is relatively robust to this change, as shown in **Table 10**. In the event of delayed network augmentation, the total forecast cost to consumers increases slightly more in the Early Pathway than in the Late Pathway, because the delay leads to more VRE curtailment in the Early Pathway.

Table 10 Impact of delays in network augmentations on consumer costs ($b)

	Early Pathway	Late Pathway	Additional cost of Early Pathway
Consumer costs with expected assumptions	36.57	35.78	0.79
Consumer costs with Delayed network augmentation sensitivity	36.91	36.06	0.85
Difference	0.34	0.28	

4.1.5 Deliverability risks of pumped hydro projects can be managed

The development of long-duration storage under the Roadmap (see Section 3.2.5) showed that under all Development Pathways development of pumped hydro in the mid-2020s was forecast to deliver lowest costs to consumers.

However, pumped hydro costs are highly uncertain and site-specific, and risks of delays during planning and construction are likely to be higher than for other generation and/or storage technologies. Pumped hydro storages rely on suitable site conditions, which may not be clarified until development commences, which in turn may delay delivery and risk increasing costs to consumers.

Given these potential risks, two alternative long-duration storage assumptions have been applied to the Late Pathway to test the impact of:

- Delays in the delivery of pumped hydro projects, delaying long-duration storage developments up to four years to account for potential delivery impediments.
- Eight-hour batteries being the long-duration storage technology of choice, rather than pumped hydro (assuming the same development trajectory).

The impact on consumer costs is shown in **Table 11**, which indicates that a delayed delivery of pumped hydro projects by up to four years increases consumer costs by $0.27 billion in the Late Pathway. The Late Pathway Development Path has high surplus reserves before 2030, and may be more capable of absorbing the challenges associated with delayed long-duration storages than other Development Pathways. It is also increasingly likely that compound events, such as early coal withdrawals or delayed network infrastructure investments, would amplify the impact to consumers, although these analyses have not been simulated.

Table 11 Impact of pumped hydro delays or replacement with battery storage on consumer costs, Late Pathway ($ billion)

	Impact
Delayed pumped hydro	0.27
Replacement with battery storage	0.60

To maintain the optimal storage development associated with the Development Pathway with delayed availability of pumped hydro projects may necessitate the development of long-duration batteries instead. Batteries of this duration are expected to be higher cost than pumped hydro projects' assumed cost trajectory. This alternative would help protect consumers from any supply scarcity risks in the event of pumped hydro storage delays or early coal exits, but has been forecast to cost approximately $600 million more on an NPV basis than presented using expected cost assumptions of pumped hydro (should it be available at the earlier timeframes).

The cost assumptions for battery storage are sourced from the CSIRO's GenCost project. The GenCost assumptions provide scenarios that take into account uncertainty in future cost projections. The "Central" forecast is used as the basis for this analysis, however an alternative "High VRE" scenario is also provided that assumes much more rapid cost reductions in battery storage.

If battery costs were to follow a trajectory more similar to the GenCost High VRE outlook, the cost of battery storage would be much lower than assumed and could therefore be a more cost-effective option. This may mean that if battery storages needed to be procured instead of pumped hydro (due for example to delivery timelines or pumped hydro costs), this would come at a lower additional cost, or it may mean that procuring batteries, potentially at an earlier time, may become the most cost-effective solution.

4.1.6 Compounding delays may materially increase risks, but Development Pathways are unlikely to present significant differences

A Development Pathway, of any form, will require significant coordination and investment to deliver the IIOs, and the economic efficiency of any Development Pathway is contingent on the assumptions eventuating as expected. Delays in network infrastructure developments, tender auctions, long-duration storage development, and generation connection and commissioning will all be key delivery variables for the Roadmap.

Of particular importance is the reliability of the Development Pathway and the resilience of each Development Pathway to single and compound events.

In particular, the reliability of New South Wales electricity supply depends on the commitment of Snowy 2.0 and Kurri Kurri projects, and the anticipated development of Tallawarra B peaking gas turbine. Together these three projects are expected to provide over 3 GW of firm capacity to the New South Wales grid progressively from 2023-24 (1 GW) to 2026-27 (an additional 2 GW). AEMO's 2021 ESOO highlighted the importance of these projects in maintaining reliability below the Interim Reliability Measure (to 2024-25) and the reliability standard (to 2030-31).

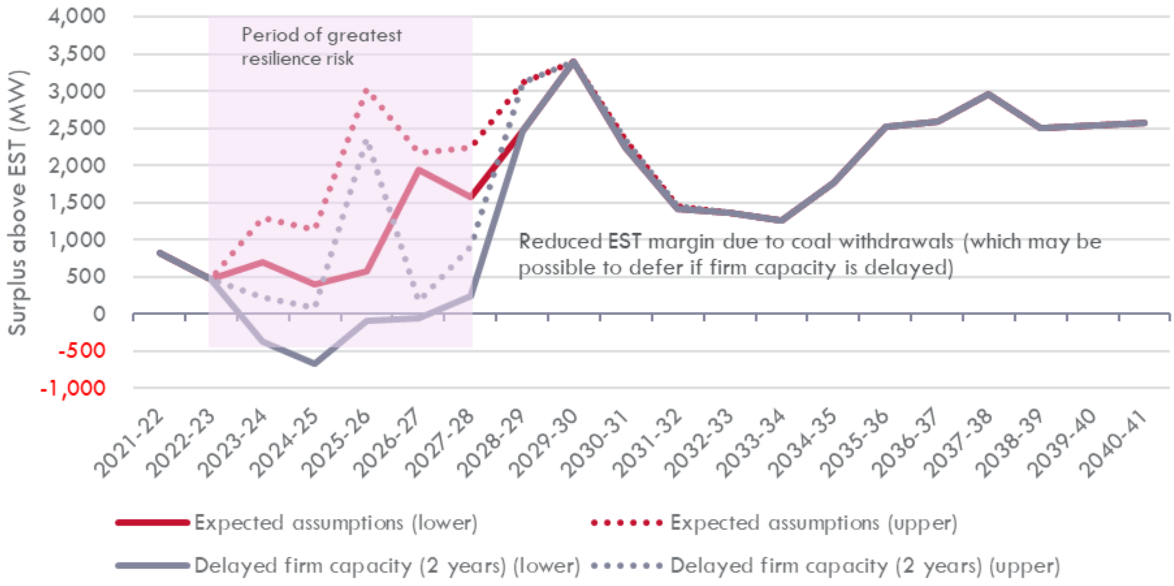
The development of the HumeLink transmission project is necessary to enable the Snowy 2.0 capacity to provide firm supply to central New South Wales consumers. This project is yet to receive regulatory approvals.

With such significant firm capacity developments underpinning the reliability assessment, the risk of delays to any or all of these projects may significantly increase the risk of achieving the IIOs under all Development Pathways.

However, the Development Pathways that invest in new VRE projects earlier (the Early, REZ Aligned, and Supply Chain Adjusted Development Pathways) would likely experience a lesser price impact from such events, and may be more resilient to each event individually (as outlined in Section 3.3.2), meaning that the magnitude of the impact of compound events may be lower than other Development Pathways.

Figure 19 below demonstrates the reliance of the system on the three key firm capacity projects listed above (including associated network infrastructure for Snowy 2.0) to maintain reserves at, or above, the state-wide EST[19]. The figure shows that if the projects each experienced a two-year commissioning delay, there may be insufficient reserve margin to maintain reliability in 2023-24 and 2026-27.

Figure 19 Variance in state-wide Energy Security Target reserves with two-year commissioning delays to key firm capacity projects



4.2 Additional considerations for the Development Pathways

4.2.1 The Development Pathways must recognise supply chain and social licence risks

In delivering the developments required for the Roadmap, AEMO has considered the logistical feasibility of each Development Pathway, including both development supply chain limitations and social licence concerns.

[19] The state-wide EST has been assessed as a proxy for the reliability standard for some Development Pathways. It is based on calculations stipulated by the Electricity Infrastructure Investment Regulation 2021 prior to the amendments that came into effect 12 November 2021) and excludes consideration of limits on major transmission infrastructure that may constrain availability of firm capacity assumed available to New South Wales electricity customers during peak demand periods.

The Development Pathways each expand the capacity of VRE and long-duration storage developments to levels significantly above existing capacity in New South Wales. In 2020-21, 1.5 GW of VRE committed to connect in New South Wales, and expansion of the supply chain is an anticipated outcome of the Roadmap.

In some Development Pathways, a material expansion of the supply chain would be required to fulfil the development pathway trajectories. Based on independent analysis provided to the Department by MBB Group, a maximum build of more than 2 GW to 3 GW per year could be challenging to sustain, due to labour and material constraints. In all Development Pathways (other than the Supply Chain Adjusted Pathway), more than 3 GW of new installations would need to be delivered in at least one year of the next decade, and therefore bring risk that the targeted developments would not be able to be achieved in practice due to these potential civil construction constraints. Furthermore, the annual installation volumes in these Development Pathways vary significantly from year to year, potentially making it more challenging to mobilise and maintain the workforce and construction plant required to deliver the Development Pathway.

This could lead to increased development costs, for example, due to competition for key equipment and labour, heightened risk of delays in approval processes, and potentially greater challenges in fostering community support. As such, Development Pathways that rely on rapid development surges may pose greater risks than those with a smoother development pipeline. Moreover, a long, sustainable pipeline of development is likely to be more attractive for contractors and investors.

To build social licence, early and consistent engagement with local stakeholders and communities will be important and will help establish a sustainable development path for current and future REZs. The Development Pathways presented in this report have not yet taken account of social licence.

4.2.2 Electrification of other fuels in a decarbonised future will impact long-term development needs

Fuel-switching, in the form of electrification as a direct substitution for fossil fuels, is one of the most cost-effective decarbonisation options for Australia's energy-intensive economy. Electrification and electricity consumption for the purposes of producing green hydrogen (for domestic consumption and /or international exports) has the potential to materially increase electricity consumption in New South Wales (and the NEM) and has not been incorporated within the assumptions applied in this *Development Pathways Report*.

In the 2021 IASR and 2021 ESOO, AEMO considered a broad range of sectors (beyond transport) with potential to be electrified. These forecasts reflect a range in the potential magnitude and timing of impacts to demand over the next decade if household, business, and industrial energy users switch to electricity to decarbonise, reduce energy costs, and, in some cases, increase fuel efficiencies.

The timing and scale of sectors seeking to increase energy efficiency, lower greenhouse gas emissions, and reduce costs by fuel-switching to electricity – or, later in the outlook, potentially hydrogen – is a major source of uncertainty. The influence that potential load growth may have on the New South Wales Consumer Trustee's tender plans should be limited in impact for the early stages of the Roadmap. Therefore, there is a low risk that the current exclusion of significant electrification is material to the selection of an initial Development Pathway. Given the uncertainty, it is prudent for medium- to long-term development recommendations to be informed by the 2022 ISP, and subsequent iterations of the *Development Pathways Report*, to ensure this impact is properly considered with regards to both the needs for long-duration storages and the development for VRE.

4.2.3 Identifying efficient renewable energy resources that sit within existing transmission capabilities

This *Development Pathways Report* has a strong relationship with the ISP, with the *Development Pathways Report* producing a roadmap for New South Wales development that informs, and is informed by, the ISP's NEM-wide investment roadmap.

The modelling for this report has identified that two key REZ transmission projects – connecting to the Central-West Orana and New England REZs – will be critical in delivering the required energy to meet the

IIOs. That said, there may be opportunities for some tenders to fall outside of the existing REZ definitions, or in alternate locations such as:

- Two offshore-wind zones (OWZs) off the Hunter and Illawarra coastlines.
- “Non-REZ” locations along the existing 500 kilovolt (kV) network between Mount Piper and Bayswater, taking advantage of existing network infrastructure capability particularly as coal retirements may increase the availability of this transmission connection.

Utilising existing transmission corridors may increase the efficiency of meeting the Roadmap’s objectives, reducing the capacity of new transmission connections that may be required, so long as VRE resources are of sufficiently good quality. These resources have not been considered in this *Development Pathways Report* but will be considered in the 2022 ISP.

The 2022 ISP will assume the generation and storage development schedule of the New South Wales Consumer Trustee’s preferred Development Pathway, but allow the location of this infrastructure within New South Wales to be re-optimised with network infrastructure development. This modelling will use the finalised assumptions from the 2021 IASR, and consider the broader ISP scenario collection. It is unlikely that early developments will be materially impacted by these new assumptions and scenarios given the anticipated status of the Central West Orana REZ transmission project. However, it is possible that, using the latest information available, the 2022 ISP may demonstrate that alternative locations for VRE and storage developments in the medium and long term, and different network augmentations, may provide greater value for New South Wales electricity consumers.

Glossary

This document uses many terms that have meanings defined in the National Electricity Rules (NER). The NER meanings are adopted unless otherwise specified.

Term	Definition
committed projects	Generation that is considered to be proceeding under AEMO's commitment criteria (see Generation Information on AEMO's website, link in Table 1).
curtailment	In this report, curtailment refers to the reduction in generation dispatch, due to one of three reasons: • an excess of renewable generation at certain times, • limits on available storage capacity, or • transmission limitations.
Development Pathway	In this report, an annual construction schedule of renewable generation and long duration storage in New South Wales over a 20-year outlook
distributed PV	Includes rooftop systems and other smaller non-scheduled PV capacity.
electrical power	Instantaneous rate at which electrical energy is consumed, generated, or transmitted.
electrification	Switching to electricity from other fuel sources.
firm capacity	Firm capacity can be dispatched to maintain balance on the power grid. It can include generation on the grid, storage, demand resources behind the meter, flexible demand, or flexible network capability.
generating capacity	Amount of capacity (in megawatts) available for generation.
generating unit	Power stations may be broken down into separate components known as generating units and may be considered separately in terms (for example) of dispatch, withdrawal, and maintenance.
infrastructure investment objectives (IIOs)	From the New South Wales Government's Electricity Infrastructure Roadmap, requiring at a minimum the construction by 31 December 2029 of generation infrastructure that generates approximately 33,600 GWh of eligible renewable energy in New South Wales, as well as 2 GW of long-duration (eight-hour) storage
Inputs, Assumptions and Scenarios Report (IASR)	AEMO's description of inputs, assumptions and scenarios used in its forecasting and planning methodologies and reports.
Integrated System Plan (ISP)	AEMO's 30-year whole-of-system plan that provides an integrated roadmap for the development of the NEM.
Interim Reliability Measure (IRM)	A measure in place until 30 June 2025 to ensure sufficient supply resources and inter-regional transfer capability exist to keep expected USE in each NEM region to no more than 0.0006% of demand in any year.
Long-Term Energy Service (LTES) Agreement	Awarded by the New South Wales Consumer Trustee to LTES Operators who will build and operate infrastructure for eligible renewable generation and storage projects.
mothballed	A generation unit that has been withdrawn from operation but may return to service at some future point.
net present value (NPV)	The present value of annual costs and benefits from now until the end of the forecast horizon (20 years in this report).

Term	Definition
non-scheduled generation	Generation by a generating unit that is not scheduled by AEMO as part of the central dispatch process and has been classified as a non-scheduled generating unit in accordance with Chapter 2 of the NER.
peak demand	Highest amount of electrical power delivered, or forecast to be delivered, over a defined period (day, week, month, season, year) either at a connection point or simultaneously at a set of connection points.
renewable energy zone (REZ)	An area prioritised for development of renewable generation because it has high quality renewable resources and can access a strong transmission network where good network capacity is available.
reliability standard	The reliability standard for generation and inter-regional transmission elements in the NEM is defined in NER 3.9.3C as a maximum expected USE in a NEM region of 0.002% of the total energy demanded in that region for a given financial year.
unserved energy	Unserved energy is the amount of energy that cannot be supplied to consumers, resulting in involuntary load shedding (loss of consumer supply). The USE that contributes to the reliability standard excludes unserved energy resulting from multiple or non-credible generation and transmission events, network outages not associated with inter regional flows, or industrial action (NER 3.9.3C(b)).
variable renewable energy (VRE)	Renewable energy that fluctuates, such as solar or wind generation.