Integrated System Plan Consultation

December 17

For the National Electricity Market

Important notice

PURPOSE

AEMO has prepared this document to provide information about, and invite feedback for, the proposed Integrated System Plan to be published June 2018. The Integrated System Plan will present a long-term strategic development plan (considering a range of scenarios) to deliver continued reliability and security, at least long-term cost for consumers, while meeting emissions reduction targets. AEMO proposes to incorporate the National Transmission Development Plan (NTNDP) into the Integrated System Plan.

In addition, this document has been prepared for the purposes of rule 5.20.1 of the National Electricity Rules.

This publication has been prepared by AEMO using information available at the date of publication.

DISCLAIMER

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VERSION CONTROL

Version	Release date	Changes
1	18/12/2017	
2	22/12/2017	Updated Figure 4 to correct remaining coal generation from 2047 to 2050

Executive summary

The energy industry transformation is gaining momentum at both ends of the energy supply chain – from large-scale generation and transmission to the distribution and consumer level. This change is creating opportunities and challenges to make the power system more productive and efficient, with the clear goal of delivering continued reliability and security at the lowest long-term cost for consumers, while meeting emissions reduction targets.

There is a pressing need for a nationally integrated strategic plan, which considers how these transformations affect the need for infrastructure development and how the essential technical requirements of the power grid will continue to be efficiently met, taking a perspective across the whole National Electricity Market (NEM).

To this end, under its role as NEM National Transmission Planner, AEMO is preparing an inaugural Integrated System Plan (ISP) for the NEM.

The *Independent Review into the Future Security of the National Electricity Market* (Finkel Review) recommended[1]:

> “By mid-2018, the Australian Energy Market Operator, supported by transmission network service providers and relevant stakeholders, should develop an integrated grid plan to facilitate the efficient development and connection of renewable energy zones across the National Electricity Market.

AEMO is calling this an Integrated System Plan (ISP), rather than an integrated grid plan, to reflect that over time, the ISP will by necessity consider a wide spectrum of interconnected infrastructure and energy developments including transmission, generation, gas pipelines, and distributed energy resources[2]. The June 2018 ISP is not the end of the process, but rather the first of many steps, with updates in future years to reflect the dynamically changing nature of the power system and the need to continually innovate and evolve strategies for the future.

The first ISP in June 2018 will deliver a strategic infrastructure development plan, based on sound engineering and economics, which can facilitate an orderly energy system transition under a range of scenarios. This ISP will particularly consider:

- What makes a successful renewable energy zone (REZ) and, if REZs are identified, how to develop them.
- Transmission development options.

As the ISP's purpose and scope encompass those which would normally be covered in AEMO's National Transmission Network Development Plan (NTNDP), the Australian Energy Regulator (AER) has permitted AEMO to defer the release of the 2017 NTNDP and integrate it into the ISP. This document sets out the material issues to be considered in the preparation of the ISP, including issues which would otherwise be dealt with in a 2017 NTNDP and 2018 NTNDP Consultation, as required by rule 5.20 of the National Electricity Rules.

AEMO is consulting broadly and extensively at all stages during the development of the ISP. This consultation paper sets out AEMO's proposed approach to delivering the June 2018 ISP and seeks feedback on specific questions, as well as any broader comments on its approaches and preliminary observations.

[1] Finkel et al., 2017. *Independent Review into the future security of the National Electricity Market* – recommendation 5.1, available at http://www.environment.gov.au/energy/national-electricity-market-review.

[2] Given the breadth of these considerations, AEMO will need to build up our capacity over time to continuously enhance the ISP analysis.

What are the key questions relating to long-term NEM infrastructure development?

Through consultation, AEMO has identified material questions facing infrastructure planners in the NEM, including:

- What is the best way to achieve the policy objectives of affordable, reliable, secure power and meeting emissions targets?
- In pursuing this pathway:
  - What are the least-regret generation and transmission developments which are most robust to different futures?
  - Could large-scale renewable generation in targeted zones provide an efficient solution for future power system development, and what storage and transmission investment would be needed to support such an outcome?
  - What is the optimal balance between a more interconnected NEM, which can reduce the need for local reserves and take advantage of regional diversity, thereby more efficiently sharing resources and services between regions, and a more regionally independent NEM with each region self-sufficient in system security and reliability?
  - To what extent could aggregated load shifting and price-responsive load management, made available through investment into distributed energy resources (DER), reduce the need for large-scale generation and transmission development to replace the existing generation fleet as it reaches end of life, while maintaining power system reliability and security?
- What is the optimal balance between the lowest-cost pathway and having the optionality to ramp up new development if required by circumstances, such as earlier than expected generator retirements, lower than expected DER uptake/orchestration, or higher than expected development of renewable generators?

DER can refer to distribution level resources, which produce electricity or actively manage consumer demand

Proposed scenarios to address these questions

The 2018 ISP will use scenario analysis to assess how efficient generation and transmission development may be impacted by a range of uncertainties. AEMO proposes a scenario design for the ISP which provides:

- A neutral outlook – a business as usual projection based on best available inputs/assumptions.
- Two bookend scenarios which explore futures with faster and slower rates of change, affecting the need for and timing of large-scale generation and transmission augmentations across electricity and gas[3].
- A number of conceptual sensitivities to explore the impacts of specific potential projects or policy changes, such as the proposed Snowy 2.0 pumped hydro project, proposed additional Bass Strait interconnection, and how highly orchestrated DER could influence future large-scale infrastructure developments.

The proposed scenario settings are designed to address the material uncertainties and questions identified above, with a particular focus on the range of possible development pathways for large-scale generation and transmission development.

Considerations in all scenarios

In all scenarios, AEMO will consider:

- The non-negotiable operational and technical requirements for a secure and reliable power system (sufficient resources, which are visible, predictable, and controllable for AEMO, and which provide essential technical attributes, such as frequency and voltage management).
- The extent and mix of dispatchable capability required to meet consumer reliability expectations. The provision of firm and flexible dispatchable capability in future will depend on the relative cost trajectories of pumped hydro, batteries, solar thermal, and (including fuel costs and limitations) gas-powered generation (GPG) and coal generation. Dispatchability broadly means the extent to which a generator's output can be relied on to 'follow a target' and adhere to a dispatch schedule at some future time.
- The extent of energy storage that could be developed, the optimal mix of short-term and long-term storage, and how this could change as the generation mix evolves.
- Energy efficiency, because the cheapest energy is that which is not used.
- The potential for future economic and operational benefits from REZs, including the need for transmission development to deliver energy from REZs to load centres.

[3] For the 2018 ISP, gas analysis will be restricted to high level constraints.

- The need for resource diversity. Technology cost trajectories indicate that wind and photovoltaic (PV) generation are now among the cheapest forms of new bulk energy generation globally[4], with cost reductions predicted to continue in Australia[5,6]. Optimising the diversity of this generation, to the extent it is economic, is key to delivering a smoother NEM-wide generation profile, and greater diversity may reduce the need to invest in local dispatchable resources to manage variability, and reduce costs for consumers. Diversity can be provided through:
  - Geographic location (to optimise contribution of either solar or wind across dispersed areas).
  - The integration of different technologies in one area (an optimal mix of wind, solar, and other technology).
  - Extending the time in which generation can contribute to the grid through storage, and optimising its contribution though demand shifting and response.
- The potential for orchestrating DER, to contribute toward delivering system security and reliability and reduce overall costs for consumers.
- The potential, where economically optimal and environmentally acceptable, for the operating life of existing large-scale generation to be extended through cost-effective maintenance/refurbishments, deferring the need for new infrastructure[7].
- Which transmission network developments efficiently promote increased competition across the NEM and improve power system security and reliability as the NEM transforms.
- The potential for new technologies to increase utilisation of the network and more efficiently provide services needed to operate the power system (for example, considering the role of HVDC VSC[8] for long distance transmission needs, along with technologies which increase utilisation of existing assets, and technologies which offer the ability to control and operate the power system more efficiently through advanced use of power electronics).

DER 'orchestration' means coordinating and optimising the operation of DER to meet the needs of the power system

Renewable Energy Zones

REZs are areas in the NEM where clusters of large-scale renewable energy can be developed to promote economies of scale in high-resource areas and capture geographic and technological diversity in renewable resources.

An efficiently located REZ can be identified by considering a range of factors, primarily:

- The quality of its renewable resources (wind or sun).
- The cost of developing or augmenting transmission connections to transport the renewable generation produced in the REZ to consumers.

Preliminary modelling indicates up to 30 GW of new wind and large-scale PV could be built in the NEM by 2037. In line with the recommendations of the Finkel Review, AEMO will:

- Identify and map prospective REZs across the NEM.
- Identify transmission network routes to most efficiently connect REZs to the existing network.
- Perform a high-level assessment of the relative economics of each REZ, to rank the most prospective ones and inform future decisions on how to develop the transmission network.

AEMO's preliminary analysis of renewable resources has identified potential locations for REZs (see Figure 1) which appear to align well with projects currently under consideration for transmission development in regions across the NEM:

- Far North Queensland (Powering North Queensland Plan[9]).
- New England Renewable Energy Zone in Northern New South Wales[10].
- Proposed expansion of the Snowy scheme, with associated transmission upgrades in New South Wales and Victoria.

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4 Lazard. *Levelised cost of energy 2017, available at* https://www.lazard.com/perspective/levelized-cost-of-energy-2017/.

5 Bloomberg New Energy Finance, 2017. *New Energy Outlook 2017, available at* https://about.bnef.com/new-energy-outlook/.

6 Hayward, J.A. and Graham, P.W. 2017, *Electricity generation technology cost projections: 2017-2050*, CSIRO, Australia.

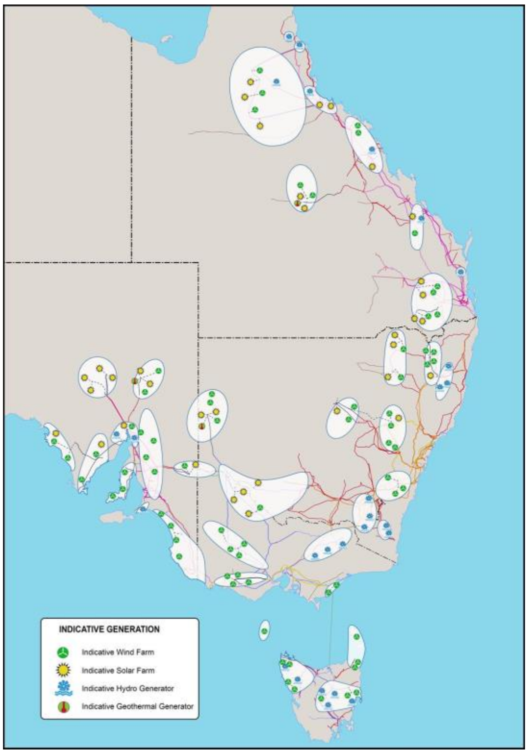
7 Other resources may be required to ensure increasing forced outage rates do not have a detrimental effect on overall reliability.

8 High-voltage direct current (HVDC) with voltage-source converters (VSC).

9 Queensland Government, 2017. Powering North Queensland Plan, available at https://www.dews.qld.gov.au/__data/assets/pdf_file/0003/1253541/Fact-sheet-Powering-North-Queensland-Plan.pdf.

10 TransGrid, 2017. Renewable Energy Hub, available at https://www.transgrid.com.au/news-views/lets-connect/consultations/current-consultations/Documents/Renewable%20Hub_Knowledge%20Report_TransGrid.pdf.

Figure 1 Range of potential REZs



- Western Victoria, where AEMO is undertaking a Renewable Integration Regulatory Investment Test for Transmission (RIT-T)[11].
- Eyre Peninsula in South Australia, where ElectraNet is undertaking a RIT-T.
- The intersection of South Australia, Victoria and New South Wales state boundaries, currently being assessed in ElectraNet's South Australia Energy Transformation RIT-T.
- Tasmania's Battery of the Nation Project[12].

Central Queensland and northern South Australia also appear to be prospective areas for REZs, but do not currently have related transmission development projects underway.

Each of these developments is currently proceeding on an individual basis. Consideration of all opportunities under an integrated, strategic plan for the nation may achieve improved outcomes for all consumers.

Further analysis needs to be completed before REZs and any associated infrastructure could be prioritised for development. This includes assessing factors such as:

- The total costs of such development relative to other options, including the costs of augmenting the existing transmission network or building new transmission to develop each REZ, along with the costs of any other developments to continue to be able to operate the power system securely once the REZs are developed.
- Which locations best capture generation diversity across the NEM to most reliably meet projected consumer demand.

Transmission development

The need for transmission development, previously driven by load growth, is now predominantly driven by the changing generation mix and the location of new generation. Transmission networks in the NEM, designed for transporting energy from coal and gas generation centres, must transform if they are to support large-scale development of non-synchronous generation in new areas.

At the same time, utilisation of some of the existing infrastructure is falling, and could fall further following large-scale retirements of existing power stations. Optimising utilisation of existing assets and any new development requirements will be vital to achieving lower-cost solutions for reliability. Transmission development could deliver benefits including:

- More efficiently sharing generation between NEM regions.
- Capturing the diversity of variable generation across different regions.
- Improving power system resilience through developing a more meshed network.
- Sharing system support services such as frequency and voltage support.
- In the longer term, increasing the capacity of interconnection between NEM regions could be pivotal to meeting Australia's long-term energy targets, providing the advantage of the geographic diversity of renewable resources so regions could export power when there is local generation surplus, and import power when needed to meet supply.

Modelling for the 2016 NTNDP indicated that new or upgraded interconnection between adjacent NEM regions may be economic over the next 20 years[13]. AEMO proposes to re-evaluate these projections under the ISP scenarios.

Transmission solutions have asset lives in excess of 50 years, and while initial investment costs can be very high, due to the long distances involved, they provide benefits such as greater competition in supply and improved diversity and

[11] Regulated Investment Test Transmission – the necessary evaluation to justify a proposed upgrade to or new regulated transmission development.

[12] Hydro Tasmania, 2017. Battery of the Nation, available at https://www.hydro.com.au/energy/battery-nation.

[13] AEMO. 2016 NTNDP, available at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan.

resiliency of the system to changes in supply resources, including retirements and increased dependencies on DER. This demonstrates the importance of looking at diverse scenarios and examining the entire energy supply chain so the integrated, national plan for energy infrastructure is sufficiently robust to different futures.

After consultation, the ISP will provide a staged transmission investment development plan for the power system, starting with least-regret upgrades, while considering the need to manage potential risks of unexpected, low probability situations which might create an urgent need for additional capacity (such as unexpected withdrawal of capacity from the NEM).

Consultation process

The rigorous process of consultation and engagement for the ISP has begun already and will continue through to mid-2018. This process will support the ISP for the NEM grid achieving coordinated, cost-effective development which delivers reliable and secure supply, at least cost to consumers across the NEM, while meeting emissions reduction targets.

This consultation paper outlines AEMO's observations on the material factors which will contribute to an ISP for the NEM. The observations in this paper are based on preliminary analysis, indicative modelling, and stakeholder discussions before publication, and should not be interpreted as conclusions.

Submissions are not limited to the specific consultation questions contained in each chapter, and not all questions are expected to be answered in each submission. AEMO welcomes feedback on any observations or approaches outlined in this report (including the material issues, AEMO's preliminary views on how to deal them and the inputs and assumptions set out in Appendix A), and welcomes both concisely written submissions and feedback provided through other meetings or discussions. All feedback will be considered and will help deliver final recommendations in the ISP to be published by AEMO in mid-2018.

Questions on which AEMO seeks feedback

Ref.	Questions
1.1	The material questions the ISP seeks to address are in Section 1.3.1. Are there any other questions the ISP should address?
1.2	The scenarios the modelling will use to inform the ISP are outlined in Section 1.4. Recognising the time limitations to produce the first ISP in mid-2018, are these suitable scenarios to address at a high level? Should these be expanded in more detailed analysis following the first high level ISP?
2.1	What are the key factors which can enable generation and transmission development to be more coordinated in future?
3.1	Does this analysis capture the full range of potential REZs in eastern Australia?
3.2	What other factors should be considered in determining how to narrow down the range of potential REZs to those which should be prioritised for development?
3.3	What are the potential barriers to developing REZs, and how should these be addressed?
4.1	Have the right transmission options been identified for consideration in the ISP?
4.2	How can the coordination of regional transmission planning be improved to implement a strategic long-term outcome?
4.3	What are the biggest challenges to justifying augmentations which align to an over-arching long-term plan? How can these challenges be met?
4.4	Is the existing regulatory framework suitable for implementing the ISP?

Address and due date for submissions

AEMO is seeking email submissions from all persons interested in the development of an Integrated System Plan. If you would like to make a submission, please email it to ISP@aemo.com.au.

AEMO recognises that this consultation is taking place over the holiday period, however, the timing and extent of work required to deliver the ISP in mid-2018 present exceptional circumstances.

Stakeholder input to modelling (questions 1.1 and 1.2) must be received by 2 February 2018 to be incorporated.

Written submissions on other questions and matters are welcome until 28 February 2018.

AEMO will continue to engage and consult with industry through the first half of next year as the 2018 ISP is developed.

Publication of submissions

AEMO will aim to give interested stakeholders open access to the drivers behind our modelling, assumptions, and final report. Submissions will be published on our website with the final report and other supporting material.

Please indicate to AEMO if there are any parts of your submission you would like kept confidential, and note that it will be difficult for us to incorporate confidential material in the ISP, because the ISP will be developed in a transparent and public process. AEMO may publish that information, but will consult with you first.

Contact

AEMO welcomes questions or requests for further information. Please contact AEMO at ISP@aemo.com.au any time.

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Preliminary messages

- The Integrated System Plan (ISP) will present a long-term strategic development plan (considering a range of scenarios) to deliver continued reliability and security, at least long-term cost for consumers, while meeting National Electricity Market (NEM) emissions reduction targets.
- AEMO continues to develop improvements to our modelling and analysis, to better reflect the changing dynamics in the NEM.
- AEMO has consulted and collaborated extensively with key stakeholders to develop this consultation paper, and will continue this approach to develop the ISP.

Questions for consultation

1.1 – The material questions the ISP seeks to address are listed in Section 1.3.1. Are there any other material questions the ISP should address?

1.2 – The scenarios the modelling will use to inform the ISP are outlined in Section 1.4. Recognising the time limitations to produce the first ISP in mid-2018, are these scenarios suitable to address these questions at a high level? Should the scenarios be expanded in more detailed analysis for future ISPs?

1.1 Finkel Review recommendation and scope

In June 2017, the *Independent Review of the Future Security of the National Electricity Market – Blueprint for the Future* (Finkel Review)[14] included a recommendation (5.1) that:

> By mid-2018, the Australian Energy Market Operator, supported by transmission network service providers and relevant stakeholders, should develop an integrated grid plan to facilitate the efficient development and connection of renewable energy zones across the National Electricity Market (NEM).

The Finkel Review further recommended that this integrated plan should:

> - Identify and map prospective renewable energy zones across all NEM regions, including but not limited to wind, solar, pumped hydro, and geothermal resources.
> - Identify transmission network routes to efficiently connect the renewable energy zones to the existing network, including routes for interconnectors that pass through these areas.
> - Include a high-level assessment of the relative economics of different zones, taking into account the quality of the resource, approximate cost of connection, network impacts and other relevant considerations. This will enable the classification of zones according to how prospective they are and inform future decisions about the order in which to develop the transmission network.

[14] Finkel et al., 2017. *Independent Review into the future security of the National Electricity Market*, available at http://www.environment.gov.au/energy/national-electricity-market-review.

- Be released as a publicly available resource to enable investors to make informed decisions about where to plan new renewable generation capacity. Although it may be many years until particular renewable energy zones are connected due to reasons of commercial attractiveness and economic efficiency, an integrated grid plan will send a clear signal to investors about the future of the transmission network. Augmentations in line with the integrated grid plan would be evaluated through the RIT-T process or its successor.

AEMO has begun developing the ISP to deliver a strategic infrastructure development plan which considers a wide spectrum of interconnected infrastructure and energy developments including transmission, generation, gas pipelines, and distributed energy resources, and can facilitate an orderly energy system transition under a range of scenarios.

The purpose of this consultation paper is to seek feedback on the proposed approach to delivering the ISP and preliminary analysis undertaken to date. Feedback will then be incorporated into the detailed modelling to be undertaken in early 2018, before publishing the inaugural ISP in mid-2018.

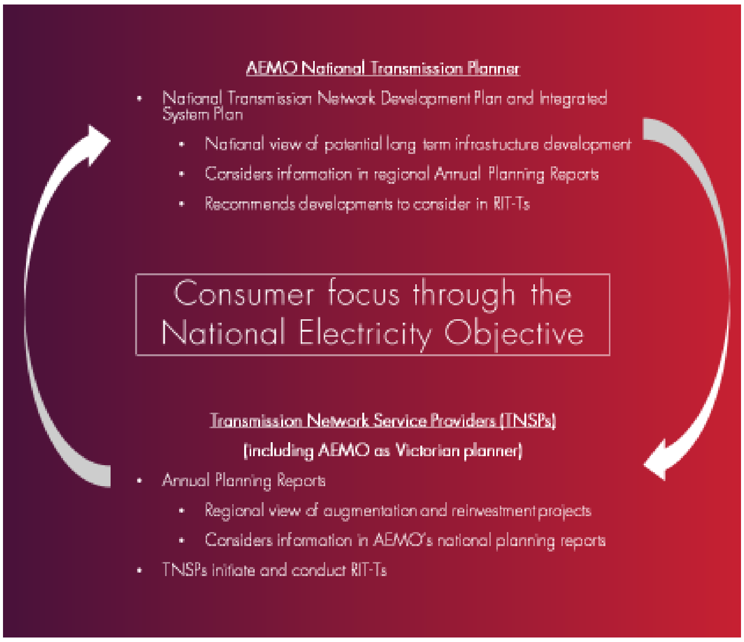
Following the inaugural ISP in June 2018, AEMO intends to list the potential priority projects in each region, in line with the Finkel Review's recommendation 5.2 below:

> “By mid-2019, the Australian Energy Market Operator, in consultation with transmission network service providers and consistent with the integrated grid plan, should develop a list of potential priority projects in each region that governments could support if the market is unable to deliver the investment required to enable the development of renewable energy zones.
>
> The Australian Energy Market Commission should develop a rigorous framework to evaluate the priority projects, including guidance for governments on the combination of circumstances that would warrant a government intervention to facilitate specific transmission investments.

1.2 A more strategic approach to planning the NEM

The current transmission planning approach in the NEM involves a continuous feedback loop of information whereby AEMO publishes an annual National Transmission Development Plan (NTNDP) followed by each Transmission Network Service Provider (TNSP) publishing their Annual Planning Report (APR). In each of these reports, both network and non-network developments must be considered to meet future needs. The information feedback loop is shown in the figure below.

Figure 2 Current transmission planning process in the NEM



Importantly:

- AEMO provides information and analysis to inform an efficient development trajectory at a national level, and can recommend developments for further assessment which best meet the national objectives.
- TNSPs are responsible for initiating and conducting assessments for their regional areas or jurisdiction, through a Regulatory Investment Test for Transmission (RIT-T) for infrastructure developments which are to be rolled into their regulated asset bases.

1.2.1 An enhanced role in national transmission planning

While the ISP will include improvements to deliver the best possible analysis at a national level, the current transmission planning framework and Rules have not changed.

Under this framework, a number of large-scale infrastructure development projects are currently being considered across the NEM, representing billions of dollars of potential investment. These projects are listed in 3.6.

State governments and TNSPs will rightfully have a focus on driving new developments within their regions to ensure the required emission and reliability outcomes for consumers in that jurisdiction at the lowest possible cost. However, by looking at broader opportunities at a national level, it is possible that the same or improved outcomes can be achieved at an even lower cost.

Under the current transmission planning framework, individual TNSPs conduct investment tests in each region. Without a coordinated long-term "national interest" perspective, there is a material risk this could result in uncoordinated development of regional energy infrastructure, which could impose inefficient costs on consumers at times when lowering energy prices is a national priority.

The Finkel Review (Section 5.2) recognised the value of a more strategic approach to transmission planning between regions, and recommendation 5.3 proposed the Council of Australian Governments (COAG) Energy Council, in consultation with the Energy Security Board (ESB), review ways in which AEMO's role in national transmission planning can be enhanced[15].

National coordination of the assessment and approval of major infrastructure development projects would support the National Electricity Objective being delivered, by promoting efficient investment for the long-term interests of consumers with respect to price, quality, safety, reliability, and security of electricity supply.

AEMO will work with the ESB and COAG Energy Council throughout their review of AEMO's role in national transmission planning.

Feedback from stakeholders on this topic is welcome, in submissions to this consultation paper and in other discussions.

1.2.2 Improvements to deliver the best possible analysis

To deliver the best possible analysis for appropriate long-term development, AEMO will adopt an approach similar to that used for developing the NTNDP, but including some important improvements.

The NTNDP, typically published at the end of each calendar year:

- Is an independent assessment of efficient generation and transmission development in the NEM over a 20-year horizon to deliver continued energy security and reliability, at least long-term cost for consumers, while meeting emissions reduction targets.
- Includes a least-cost outlook for NEM generation and transmission development. This projects the most efficient amount of large scale generation required to meet forecast demand, taking into account growth of distributed energy resources.
- Typically identifies the amount of new generation required in each region, but due to historical modelling constraints, has not performed a detailed assessment of the best zones for renewable energy development. This is a vital aspect of the ISP, and AEMO has improved its modelling methodology to facilitate this (discussed below).
- While examining both network and non-network developments to meet future needs for the national power system, has not focused on DER and the new challenges to continued security of the power system to the extent the ISP will.

The ISP will expand on this approach by:

- Identifying and mapping prospective renewable energy zones (REZs) across the NEM, with input from key stakeholders such as renewable generation developers and TNSPs. AEMO engaged consultants DNV-GL to deliver

[15] Finkel et al., 2017. *Independent Review into the future security of the National Electricity Market*, available at http://www.environment.gov.au/energy/national-electricity-market-review.

detailed renewable energy mapping across the NEM to assess the suitability of locations across the NEM for renewable energy development (see Chapter 3).

- Obtaining more granular data, which can enable a consistent assessment of wind and solar generation diversity across the NEM. This is a vital component of assessing the potential benefits of developing REZs.
- Developing methodology improvements to address the challenges of modelling variable generation, the operation of storage technologies, and generation diversity between regions, discussed below.
- Identifying the potential transmission development routes to efficiently connect REZs, and continually deliver a secure and reliable energy supply in the long term.
- Performing detailed economic analysis to identify the most prospective REZs. This involves modelling similar to the NTNDP, but with further analysis of how capturing diverse renewable generation profiles across the NEM may reduce the need for other types of development, thereby minimising the overall cost of the system for consumers.

1.2.3 Improvements to address modelling limitations

Modelling how generation and transmission infrastructure should develop over time is a challenging exercise which reflects a complex set of inputs and assumptions available at a snapshot in time. The energy transition is challenging the validity of previous modelling techniques, and AEMO has made a number of methodology improvements to better reflect the changing dynamics in the NEM, particularly in relation to variable generation and energy storage technologies.

Modelling limitations

Previously, AEMO's long-term modelling had a number of limitations which we intend to address through improvements developed for the ISP:

- Electricity and gas modelling were separated, such that limitations in the supply and transport of gas were not fully considered in modelling the development of the electricity system.
- By using a load block approach in the long-term expansion model, the effects of variability were not fully captured in assessing the development of renewable generation and the other developments required to maintain reliability and security. These impacts were considered in detailed time-sequential modelling, but were not fully integrated with the development of the least-cost expansion plan.
- The challenge of modelling variable generation also limited the ability of the long-term expansion model to value the benefits of increased geographical diversity.
- The load block approach did not account for the limitations of energy storage, particularly the operational limitations of battery storage with relatively low levels of storage capacity.

Improvements developed for ISP modelling

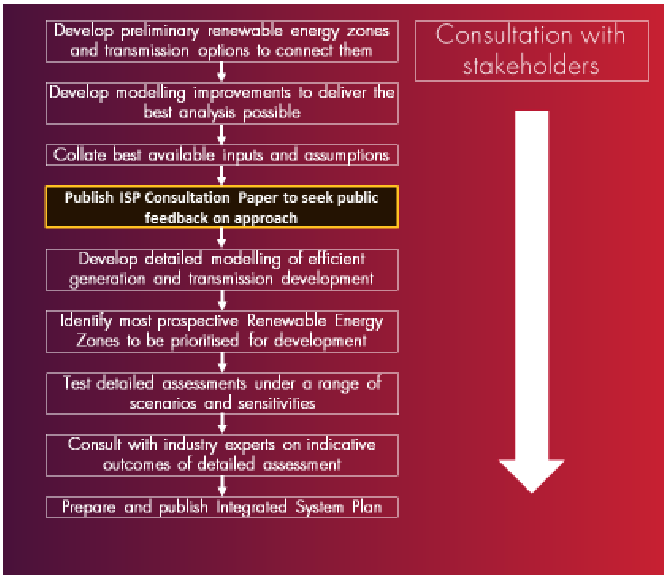
As a result of these limitations, AEMO is making a number of improvements for ISP modelling:

- Moving the long-term expansion model towards an integrated gas and electricity model which captures the linkages between two systems, because any additional gas required for generation will consider the impact on gas reserves and the need for gas pipeline augmentations.
- Incorporating highly detailed expansion plan modelling which uses many more load blocks, linked chronologically to better capture variability, the value of diversity in renewable technologies and locations, and the operational limitations of energy storage.
- Using granular wind and solar traces developed on consistent basis across the NEM to better reflect generation diversity.

1.2.4 Delivering the ISP

Delivering the ISP will involve detailed analysis of the entire energy supply chain in the NEM, assessing transformations occurring in both large-scale and behind-the-meter developments. The figure below provides a helicopter view of the stages involved in delivering the ISP, emphasising the need for extensive stakeholder engagement throughout the process. This is discussed further in 1.5.

Figure 3 Delivering the Integrated System Plan



1.3 Scenarios and sensitivities

Generation and transmission investments have long technical and economic lifetimes. The ISP must therefore account for the material uncertainty facing the industry in the medium to longer-term. For this, the ISP will use scenario analysis to assess how efficient generation and transmission development is impacted by a range of uncertainties.

1.3.1 Material uncertainties and questions to address

In setting the key drivers for scenario analysis, it is important to understand the key questions the ISP is seeking to address. The following key questions have been collated through stakeholder engagement over the past year:

- What is the best way to achieve the policy objectives of affordable, reliable, secure power and meeting emissions targets?
- In pursuing this pathway:
  - What are the least-regret generation and transmission developments which are most robust to different futures?
  - Could large-scale renewable generation in targeted zones provide an efficient solution for future power system development, and what storage and transmission investment would be needed to support such an outcome?
  - What is the optimal balance between a more interconnected NEM, which can reduce the need for local reserves and take advantage of regional diversity, thereby more efficiently sharing resources and services between regions, and a more regionally independent NEM with each region self-sufficient in system security and reliability?
  - To what extent could aggregated load shifting and price-responsive load management, made available through investment into distributed energy resources (DER), reduce the need for large-scale generation and transmission development to replace the existing generation fleet as it reaches end of life, while maintaining power system reliability and security?
- What is the optimal balance between the lowest-cost pathway and having the optionality to ramp up new development if required by circumstances, such as earlier than expected generator retirements, lower than expected DER uptake/orchestration, or higher than expected development of renewable generators?

1.4 Scenario design

At the highest level, transmission augmentation pathways used to be driven mainly by demand growth, but now the needs are driven more by the location and type of new generation investments, as discussed in Chapter 2.

Noting the final question listed in 1.3.1 above, AEMO proposes a scenario design for the ISP which provides:

- A neutral outlook, and

- Two bookend scenarios which explore futures with faster and slower rates of change, affecting the need for and timing of large-scale generation and transmission augmentations.

The proposed scenario settings are shown in Table 1, with proposed sensitivities in 1.4.1. These settings are designed to address the material uncertainties and questions identified above, with a particular focus on the range of possible development pathways for large-scale generation and transmission development.

Table 1 Proposed scenarios for the Integrated System Plan

Key input	Neutral – business as usual	Slow change	Fast change
Demand settings			
Economic growth and population outlook	Neutral	Weak	Strong
Rooftop PV capacity	Neutral	Neutral	Neutral
Battery storage installed capacity	Neutral	Neutral	Neutral
Large-scale demand side participation and distributed storage aggregation	Neutral	Strong	Weak
Electric vehicles	Neutral	Weak	Strong
Policy settings			
Emissions reduction trajectory*	28% 2005 - 2030	28% 2005 - 2030	52% 2005 - 2030
	70% 2016 - 2050	70% 2016 - 2050	90% 2005 - 2050
Government renewables targets	LRET+VRET (to 2025) QRET (to 2020)**	LRET VRET+QRET (to 2020)	LRET VRET+QRET (to 2020)
Energy efficiency	Neutral	Weak	Strong
Supply side settings			
Wind + utility PV	Neutral cost reductions	Slower cost reductions	Rapid cost reductions
Grid scale storage costs	Neutral cost reductions	Neutral cost reductions	Neutral cost reductions
Small scale PV + distributed battery costs	Neutral cost reductions	Neutral cost reductions	Neutral cost reductions
Gas market settings			
Gas demand: LNG export	Neutral	Weak	Strong
Gas demand: Residential/commercial/industry	Neutral	Weak	Strong***
Gas demand: Gas powered generation	Model outcome	Model outcome	Model outcome

* Emissions reduction trajectory assumptions are discussed further in Section 2.1.4 below.
** AEMO notes the recent Queensland election outcome and will determine the most appropriate assumption to apply for the QRET through stakeholder consultation.
*** Underlying growth strong, but increased shift to electricity for heating and industrial processes will moderate any increase.

1.4.1 Sensitivities

Sensitivities are used to assess how specific drivers could impact the Neutral outlook for generation and transmission development.

Proposed sensitivities include, but are not limited to:

- How could the proposed Snowy 2.0 project impact generation and transmission development across the NEM?
- How could a greater uptake and orchestration of DER (behind-the-meter generation and storage, demand response, energy efficiency, and load shifting) impact large-scale generation and transmission development?
- How could proposed additional Bass Strait interconnection, for instance driven by the Battery of the Nation project, impact generation and transmission development across the NEM if it was built sooner than currently projected?

AEMO welcomes feedback on these proposed sensitivities and any other key drivers which should be included in the ISP assessment.

1.5 Inviting stakeholder collaboration and input

AEMO is approaching the development of the ISP collaboratively with TNSPs and other key stakeholders, seeking and encouraging input at all stages. This collaborative process began shortly after the Finkel Review was released, and will continue until the June 2018 ISP is published.

To prepare this consultation paper, AEMO hosted two collaborative workshops with key industry stakeholders to develop a collective understanding of the role and value of REZs (discussed further in Chapter 3):

- A workshop in September 2017 with NEM TNSPs to identify the possible long term transmission development options in the NEM to connect indicative REZs.
- A workshop in November 2017 with a broad range of industry stakeholders (including renewable generation developers, TNSPs, industry bodies, consumer representatives, and research organisations) to seek feedback on the results of renewable energy resource mapping across eastern Australia (outlined in Chapter 3) and to explore the potential value and barriers to development of REZs.

AEMO has also established expert working groups to provide specialised consultation on various inputs to the ISP, including market modelling, transmission planning, and future-proofing energy systems.

The stakeholder engagement undertaken to date has informed the preliminary observations and questions in the remaining chapters of this consultation paper.

AEMO welcomes additional input and feedback throughout the process so the ISP can most effectively meet stakeholders' needs and expectations. Any comments or suggestions can be sent to ISP@aemo.com.au.

2. Drivers of energy infrastructure development

Preliminary messages

- There is a need to coordinate generation and transmission development in future to:
  - Deliver the lowest-cost reliable power system to consumers.
  - Facilitate a smooth long-term transition to re-engineer the power system as the existing coal generation fleet is decommissioned.
  - Effectively capture diverse renewable resources to smooth natural variations in wind and photovoltaic (PV) generation.
- Factors which reduce investment uncertainty, such as clear strategic priorities to develop large-scale renewable generation, can foster generation and transmission coordination.

Questions for consultation

2.1 – What key factors can enable generation and transmission development to be more coordinated in future?

Generation and transmission development is no longer being driven by maximum demand growth, because this is projected to remain flat over the long term. This chapter explores the primary drivers of new supply resources (such as generation, storage, and demand response) and transmission development in future, and why coordinating this development will be a key component of the ISP.

2.1 Primary drivers of energy infrastructure development

While generation and transmission development has traditionally been driven by load growth, and its role to transport energy from coal and gas generation centres to consumers, AEMO now believes it is being driven more substantially by the changing generation mix.

This section investigates the changing drivers of transmission development, specifically:

- Relative cost reductions in generation technology.
- The aging coal generation fleet in the NEM.
- Continually meeting the technical requirements of the power system.
- Emissions reduction policies.
- Geographic diversity of renewable generation.
- Changing consumer behaviour.

2.1.1 New technology cost reductions

Continued innovation in wind and PV generation technologies in particular means they are now recognised as the cheapest form of new bulk energy generation globally[16]. In Australia, wind is already the cheapest form of energy

[16] Lazard, 2017. *Levelised cost of energy 2017*, *available at* https://www.lazard.com/perspective/levelized-cost-of-energy-2017/.

generation, and large-scale PV generation is expected to become cheaper than combined cycle gas-powered generation of electricity (GPG) by 2021[17]. The vast majority of new generation projects in the NEM involve wind or PV generation, which together represent:

- Almost 70% (over 2.5 GW) of new generation projects registered in the NEM since 2012.
- About 82% (representing about 19 GW of capacity) of new generation projects in development (the remainder is mostly GPG projects)[18].

Whereas emissions reduction policies have driven new generation development in recent years, the relative costs of wind and PV generation are now expected to drive new development to add generation capacity as aging plants are decommissioned.

The majority of new generation projects are likely to be remote from the locations where coal generation will retire. This means new transmission development will be required to connect the new projects to the NEM, and the transmission grid will be re-engineered over time to manage new flows of electricity.

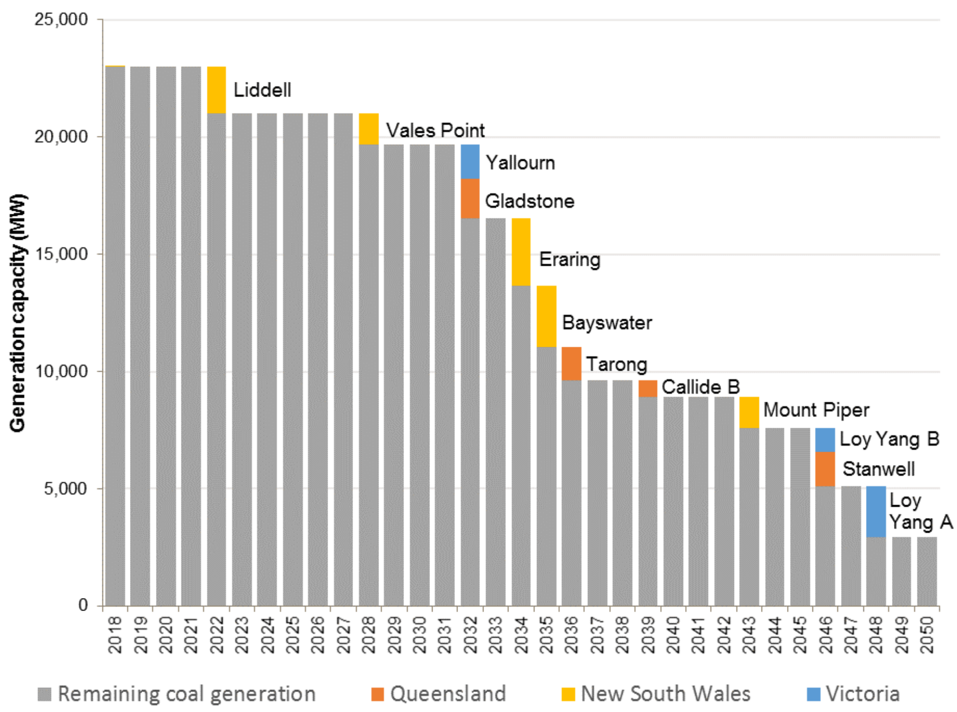
One aspect to resource adequacy is to provide sufficient generation when it is required. The system needs a portfolio of controllable, firm, and flexible resources to effectively deliver a reliable energy supply. This is the basic concept of the reliability obligation in the National Energy Guarantee.

Locating new generation to capture diverse weather patterns, and connecting these sources with transmission development, could reduce the amount of local reserves required to deliver a reliable energy supply and reduce the overall system cost to consumers. This demonstrates how new generation and transmission developments are expected to be interlinked in future.

2.1.2 Aging coal generation fleet

About 70% (16 GW) of existing coal generation (totalling 23 GW) will exceed 50 years from full operation by 2040, indicating that a large proportion of the fleet is approaching the end of its intended operating life[19].

Figure 4 NEM coal generation fleet operating life to 2050, by 50th year from full operation or announced retirement



Source: Australian Energy Council, 2016. Submission to the Parliamentary enquiry, *Retirement of coal fired power station*, available at https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/Coal_fired_power_stations/Submissions.

[17] Bloomberg New Energy Finance, 2017. *New Energy Outlook 2017*, available at https://about.bnef.com/new-energy-outlook/.

[18] As listed on AEMO's generation information page (5 June 2017 update), at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

[19] Figure 4 shows a 62% reduction in generation capacity by 2040 as, although Loy Yang A will have been operating for more than 50 years by then, it already has announced an intention to keep operating until 2048.

The figure above shows the NEM coal generation fleet and the reduction in generation if each plant was to retire at its 50th year of full operation (or its announced retirement year, if this is different).

This trajectory objectively and simply reflects plant age or public announcements. Decisions to retire generation capacity are based on a number of considerations, not all of which can be captured in market modelling. The condition of assets, portfolio optimisation and financial position, rehabilitation costs, and company policies will all influence any commercial decision to withdraw generation. The analysis in the June 2018 ISP may produce a different trajectory, having considered some of these factors.

It may be effective to continue operating some of the existing coal generation fleet beyond 50 years, but a continued influx of wind and PV generation could also impact the revenue sufficiency of coal generation, leading to earlier withdrawal. In either case, the scale, location, and timing of coal generation withdrawals over the coming decades will be key drivers of new generation and transmission development for the foreseeable future.

To deliver continued power system reliability and security, new supply resources and transmission assets will need to be planned and developed well before material amounts of coal generation are withdrawn.

The long lead times involved in such development emphasise the need for coordinated planning to ascertain the likely timing and location of coal generation withdrawals, enabling system planners to determine the most efficient pathway for new generation and transmission development to minimise long-term costs for consumers.

2.1.3 Meeting the technical requirements of the power system

To deliver a reliable and secure energy supply a number of power system technical requirements must be maintained. The provision of these services, as an engineering necessity, is a non-negotiable in all planning scenarios and will be a key driver of generation and transmission development in future.

Existing thermal generation, which is synchronous and centrally dispatched, provides a range of power system services other than bulk energy, such as frequency and voltage management. As synchronous generation retires, and more non-synchronous variable generation is connected, the NEM's technical requirements are expected to evolve with an increasing need for flexible resources and alternative sources of frequency and voltage management.

The operational pre-requisites of the power system are identified at a high level in the table below.

Table 2 Operational pre-requisites and technical attributes of the power system

	Pre-requisite/attribute	Description
Operational pre-requisites	Visibility of the power system	Ability to measure or derive accurate data on energy demand, power system flows, and generation output in real time.
	Predictability of the power system	Ability to forecast upcoming power system conditions and have confidence in how the system will perform.
	Controllability of the power system	Ability to manage generation dispatch and configure power system services to maintain system security and reliability.
Technical attributes	Resource adequacy	There is a sufficient overall portfolio of energy resources to continuously achieve the real-time balancing of supply and demand.
	Frequency management	Ability to set and maintain system frequency within acceptable limits.
	Voltage management	Ability to maintain voltages on the network within acceptable limits.
	Ability to restore system	Ability to restart and restore the system in the unlikely event of a major supply disruption.

The ISP will consider the most efficient evolution of the generation mix and transmission grid in which adequate resources provide the operational and technical requirements to deliver a reliable and secure energy supply.

2.1.4 Emissions reduction policies

While the relative costs of wind and PV generation are increasingly driving new generation development (see 2.1.1), emissions reduction targets can also influence new generation development, or focus it in particular areas of the NEM.

All ISP studies propose to assume the NEM achieves at least a proportionate share (28%) of the COP21 commitment (26 to 28% emissions reduction) by 2030. In the absence of emissions reduction targets beyond 2030, AEMO is proposing to apply an emissions reduction trajectory consistent with the Australian Government's broader commitment to the COP21 Paris agreement to limit global mean temperature rise to 2° Celsius.

The International Energy Agency released a paper in March 2017[20] stating that:

> Limiting the global mean temperature rise to below 2°C with a probability of 66% would require energy-related CO_2 emissions to peak before 2020 and fall by more than 70% from today's levels by 2050.

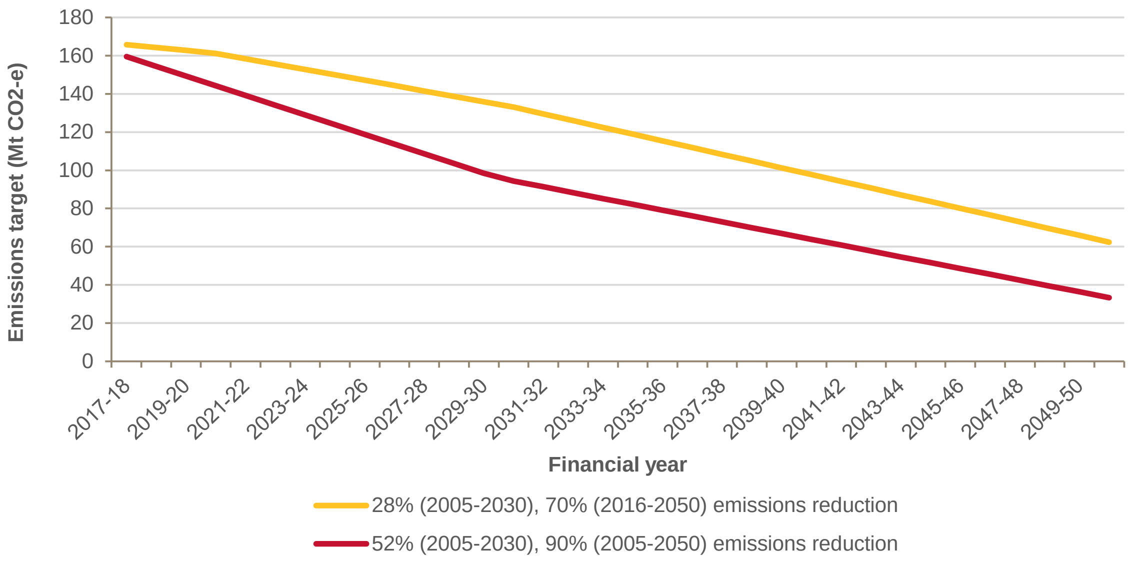
AEMO is proposing to apply an emissions reduction constraint consistent with this trajectory in the ISP.

The proposed Fast Change scenario examines the possible drivers of accelerated investment in generation and transmission development, to understand the impact on the energy system and how soon new developments may be required under the Fast Change assumptions.

This scenario references the CSIRO Low Emissions Technology Roadmap, which found that for the broader energy sector to meet a proportional target of 26-28% emissions reduction by 2030, electricity sector emissions may have to reduce by 52-70% by 2030 and 90% by 2050[21]. AEMO intends to apply an emissions reduction constraint of 52% by 2030 and 90% by 2050 in the Fast Change scenario for the ISP.

Both these trajectories are shown in the figure below.

Figure 5 Proposed NEM emissions reduction trajectories to be examined in ISP scenarios



2.1.5 Geographic diversity of renewable generation

AEMO's analysis (also summarised in the 2016 NTNDP) indicates a range of potential benefits from increased geographic diversity of renewable generation, which interconnectors can capture. These benefits include:

- Smoothing aggregate wind and PV generation across the NEM, reducing the need to dispatch higher marginal cost generation such as GPG at times when the renewable resources within a region are not available.
- Maximising the utilisation of fuel resources. Concentrating too much renewable generation within an area can lead to diminishing return on further generation development.

The development of REZs which are geographically distant will realise benefits relating to lower fuel costs and increased efficiency of capital investment. The improved diversity of this generation mix, and the associated benefits, will continue to grow as geographically distant REZs are established.

[20] International Energy Agency, 2017. *Investment needs for a low carbon energy system*, available at http://www.iea.org/newsroom/news/2017/march/deep-energy-transformation-needed-by-2050-to-limit-rise-in-global-temperature.html.

[21] CSIRO, 2017. *Low emissions technology roadmap*, available at https://www.csiro.au/en/Do-business/Futures/Reports/Low-Emissions-Technology-Roadmap.

Balancing the cost to connect distant areas, including associated network losses, against the benefits relating to the diversity they bring will be essential to creating the most economically efficient solution for consumers.

The following figure illustrates the potential benefits of diversity, by showing the average daily profile of wind and solar generation in different regions, based on historical data.

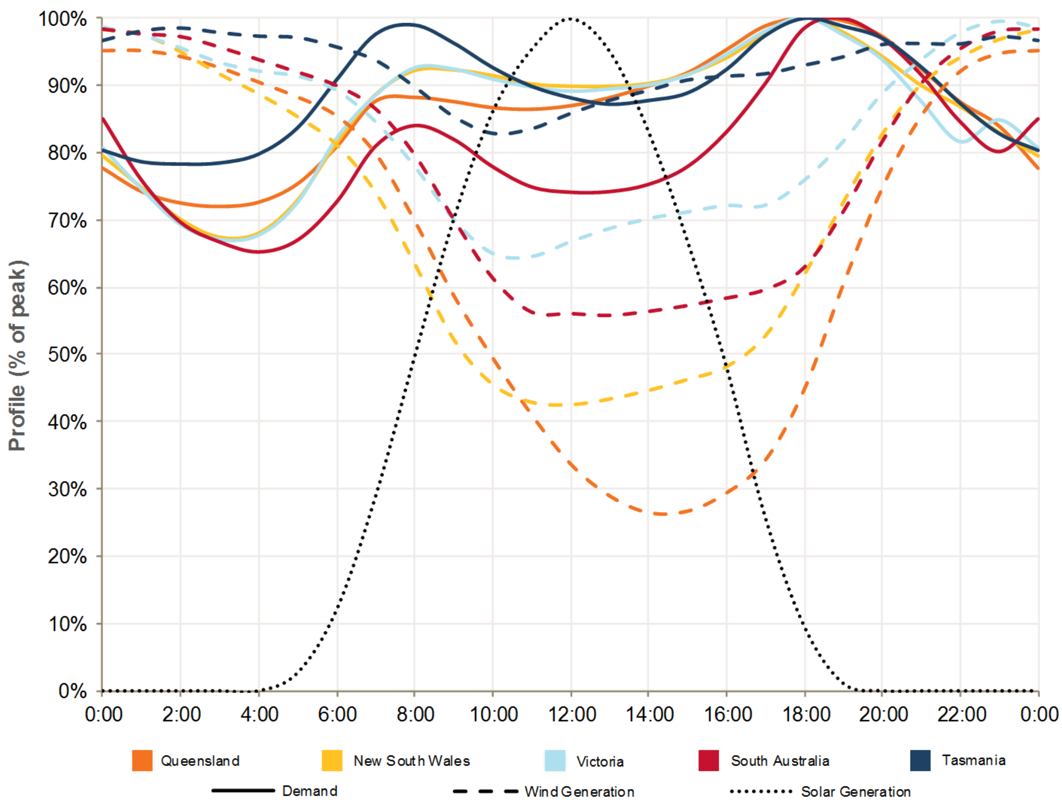
The figure shows average daily profiles as a percentage of peak for:

- Average daily wind profiles for potential wind farm locations in each state, using 10 years of modelled wind data (the same data set as the *Average wind speed at 150 metres* layer on the AREMI website).
- Average daily demand profile for each state for the 2016-17 financial year.
- An indicative daily PV generation profile.

This figure shows the diversity of wind generation between regions, and how negatively correlated wind and solar generation are across each region. This demonstrates the potential benefits of co-locating wind and solar generation projects, taking rooftop PV growth into account, to deliver a smoother generation profile on average.

By showing the average daily profile of wind generation, this chart does not consider the periods where there is very low generation, how long these periods can last, and whether such periods coincide between regions. This is a vital consideration when determining the level of dispatchable capability required to support wind generation and, in the case of energy storage, the optimal energy capacity required.

Figure 6 Average daily profile of wind farm output per region (NEM time)



2.1.6 Changing consumer behaviour

The drivers listed above all relate to a transformation at the large-scale generation and transmission end of the supply chain, but the ISP must also consider the transformation occurring at the consumer end of the energy supply chain, and what impact this transformation could have on requirements for large-scale development.

Material drivers of the transformation in distributed energy resources (DER) include:

- Rooftop PV – AEMO has projected NEM installed capacity to exceed 20 GW by 2040 (from over 6 GW today)[22]. The rate of continued rooftop PV uptake is difficult to project, and forecasts vary. The CSIRO's collaboration with Energy Networks Australia for the *Electricity Network Transformation Roadmap* projected NEM installed capacity to reach 37 GW by 2030[23].
- Energy efficiency or consumers reducing consumption – AEMO has projected[24] that in 2036-37, grid demand could be reduced (compared to forecast underlying demand without these factors) by about 18 TWh due to energy efficiency, and by about 17 TWh due to consumers reducing consumption in response to energy prices. This totals 35 TWh, and compares to projected generation from rooftop PV of about 25 TWh in that year, demonstrating the impact energy efficiency and reducing demand could have on the need for new large-scale infrastructure.
- Active demand management or load shifting – involves achieving more efficient utilisation of all resources in the energy system by incentivising consumers to shift demand either:
  - Away from peak demand periods, when the power system is most utilised.
  - Into periods during the middle of the day in regions with high PV penetration.
- Distributed battery storage – there are no official records of the number of distributed storage systems connected to the NEM, but the SunWiz Battery Market report estimated 6,750 new installations in 2016 and a further 20,000 in 2017[25]. Aggregation software is emerging which can enable multiple systems to be controlled to deliver a specific aggregated response in the energy market, the frequency control markets, or in direct response to a network need.
- Large-scale Demand Side Participation (DSP) – momentum is building around the potential for DSP in Australia, where large-scale (typically industrial or large commercial) consumers actively manage their demand to respond to price signals. Examples include the Reliability and Emergency Reserve Trader framework[26] and AEMO's collaboration with the Australian Renewable Energy Agency (ARENA) to pilot a demand response initiative for the 2017-18 summer[27] (which can also incorporate aggregated distributed demand response).
- Grid connected micro-grids and standalone power systems – micro-grids combine DER to securely meet local demand, either in parallel with the grid or when operating in island mode (not grid-connected).

The Finkel Review noted that:

> “With appropriate communications infrastructure, standards and aggregation mechanisms in place, DER can provide significant opportunities to improve power system security. Rooftop solar photovoltaic and battery storage systems could complement large-scale technologies for providing services such as frequency control, reactive power and voltage control.

The ISP will consider how the extent of DER orchestration – coordinating and optimising the operation of DER to meet the needs of the power system – could impact the need for new large-scale infrastructure developments.

2.2 Coordinating generation and transmission development

In the NEM, there is no overarching control or coordinated planning of generation and transmission. Transmission is built to manage new generation development, which is commercially driven, relying on the market and renewable targets to signal appropriate generation investments to developers (location, timing, scale), and with transmission largely regulated to transport generation to consumers.

Coordination of large-scale renewable generation and transmission development in the NEM will prove challenging, due to differing development incentives.

[22] AEMO, 2017, available at http://forecasting.aemo.com.au/.

[23] CSIRO-ENA, 2017. *Electricity Network Transformation Roadmap*, available at http://www.energynetworks.com.au/electricity-network-transformation-roadmap.

[24] AEMO. *Electricity Forecasting Insights*, June 2017, at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights.

[25] SunWiz, 2017. "Battery installs 'set to triple' in 2017: SunWiz", available at http://www.ecogeneration.com.au/battery-installs-set-to-triple-in-2017-sunwiz/.

[26] AEMO, 2017. *Reliability and emergency reserve trader, available at* https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Emergency-Management/RERT-panel-expressions-of-interest.

[27] AEMO, 2017. "ARENA and AEMO join forces to pilot demand response to manage extreme peaks this summer", available at https://www.aemo.com.au/Media-Centre/ARENA-and-AEMO-join-forces-to-pilot-demand-response-to-manage-extreme-peaks-this-summer.

When assessing new generation projects, developers consider land access and planning approvals, the quality of the renewable resource, and cost point for connection to the transmission grid.

These costs are partly driven by location and proximity to the grid, but also voltage, as the cost of switchgear infrastructure for connection is much higher at higher voltages. The grid is often stronger at the highest voltages and weaker in the lower voltage areas of the grid.

Development costs can drive connections into weaker parts of the grid, requiring grid augmentation which the developers do not fund. For example, the 500 kV transmission system in Victoria is strong, but under-utilised with the exit of coal-fired power generation in the Latrobe Valley, whereas the 220 kV and 66 kV lines in western Victoria – where development interest in wind and solar is strongest – is congested and weaker, and will need augmentation to service new investment.

This can lead to increased cost for transmission augmentation within a region, while large areas of the transmission system become less and less utilised.

There is no first mover advantage or firm access for developers in the NEM who utilise the shared network. If other projects are subsequently developed in the area (creating congestion), the framework relies on the network being augmented to address this congestion, where economic and subject to regulated investment test approvals.

Correspondingly, the regulatory framework allocates all network augmentation costs to consumers, increasing the network costs consumers must bear as new forms of supply are introduced and replace existing supply.

This was acceptable when the lead time for new generation development took many years (as in the case of development of coal-fired power stations). It is more challenging today, however, when solar farms can be developed with very short lead times for approvals and build – often much less time than is needed for regulated approvals and completion of any major transmission upgrades.

Further, TNSPs are generally incentivised to build network infrastructure if it can be incorporated into their regulated asset base (RAB). Uncertainty over the amount of new generation development which will occur in certain regions means assessments through RIT-Ts have so far only led to incremental network augmentations, to manage the risk of under-utilised assets if new generation developments did not materialise to the same extent forecast. This could prove more expensive for consumers than building the network at an appropriate scale in the first place.

The Australian Energy Market Commission (AEMC) identified this under-utilised asset risk when introducing the Scale Efficient Network Extensions (SENE) rule in 2011. The SENE rule sought to provide a framework to capture economies of scale without forcing anyone to bear the risk of under-utilised assets, as it encouraged generation developers to coordinate new projects in particular areas to demonstrate the need for network augmentation. The SENE framework has not yet been utilised.

2.2.1 Times are changing

Since the SENE rule was introduced, there has been continued uncertainty over the future of renewable generation development, but some important factors have changed, which could be the catalyst for coordinated generation and transmission development to capture economies of scale that could reduce overall system costs for consumers. These factors are:

- State government commitments to reverse auction process – this provides certainty over the amount of new renewable generation required within a state over a defined time period. The further certainty provided by a longer-term trajectory for renewable energy penetration, as in Victoria[28] and Queensland[29], enables generation developers and transmission planners to coordinate and identify the most efficient location of new generation and transmission development.
- Greater certainty over the economics of large-scale generation – recent cost reductions have led to wind and large-scale PV generation becoming among the cheapest forms of new bulk energy generation in the NEM, as highlighted in 2.1.1. Continuing cost reductions are projected to emphasise this further, providing greater confidence to project developers and financiers for their investment decisions.
- Greater certainty over the timing of coal generation withdrawals – one of the recommendations from the Finkel Review was for coal generators to provide at least three years notice prior to withdrawal from the NEM. This would provide greater lead times to adequately prepare for major capacity withdrawals and provide market signals for new development required.

[28] Victorian Government, 2017. *Victoria's renewable energy targets*, at https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets.

[29] Queensland Government, 2017. *Powering Queensland Plan: an integrated energy strategy for the state*, available at https://www.dews.qld.gov.au/electricity/powering-queensland-plan.

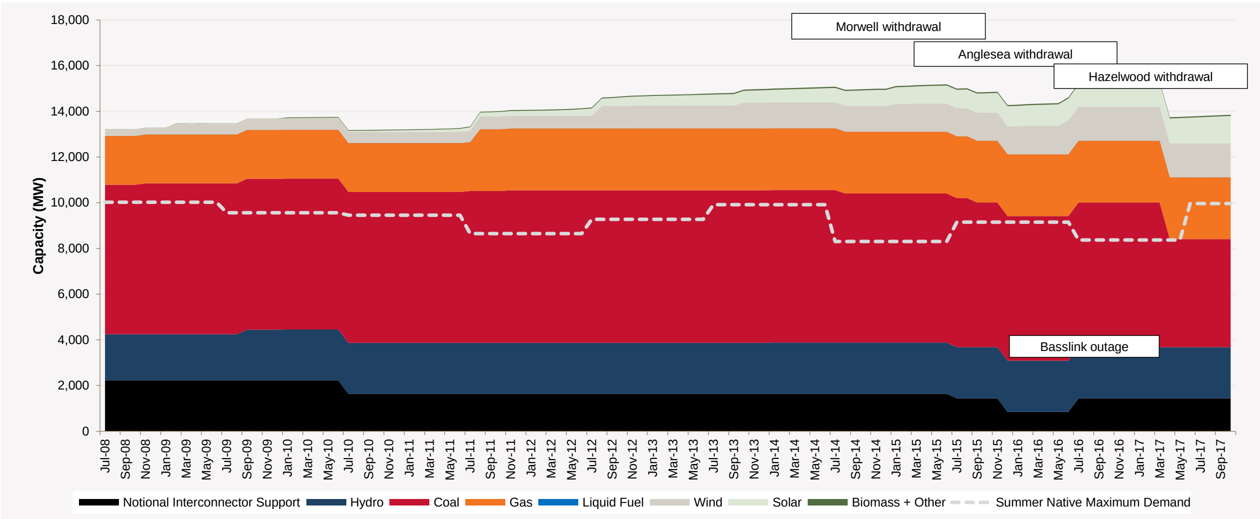
- Reliability challenges – the level of generation reserves in the NEM prior to 2015 has been eroded as generation capacity has retired without replacement by an equivalent level of firm capacity. AEMO's Electricity Statements of Opportunity have highlighted since 2015, a growing need for new generation to maintain a reliable electricity supply in the NEM, and there is a long-term need to appropriately replace around 20 GW of coal generation as it is decommissioned at end of technical life over the coming decades.

The two charts below show the changes in supply capacity and maximum demand in Victoria (Figure 7) and South Australia (Figure 8) individually since 2008. They highlight:

- The changing supply mix over recent years.
- How the level and type of reserves in the system at any time can vary according to changes in both supply and demand.
- That both regions now rely more on variable supply as well as interconnection to meet maximum demand.

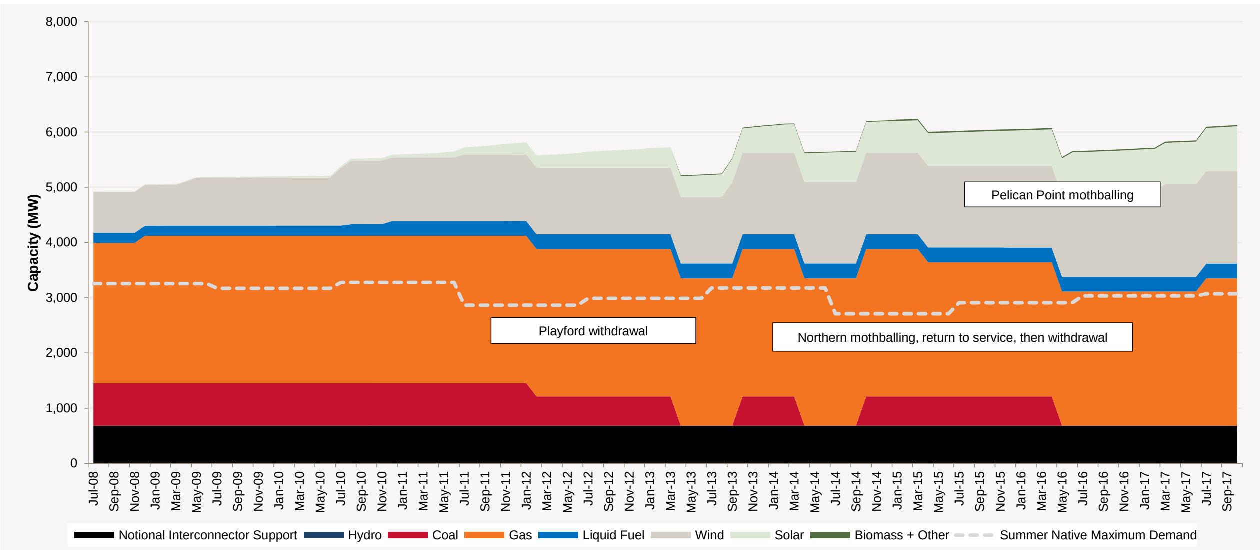
The volume of reserves to respond to unexpected events in each region, or to export if needed, is also now more uncertain.

Figure 7 Registered capacity and maximum demand in Victoria, 2008-17



Native Demand is demand met by local scheduled, semi-scheduled, non-scheduled and exempt generation and by generation imports to the region, excluding the demand of local scheduled loads. Native Demand only includes generation for which AEMO and the Jurisdictional Planning Bodies receive sufficient information.

Figure 8 Registered capacity and maximum demand in South Australia, 2008-17



Variable generation does not inherently contribute the same level of controllable, firm, and flexible generation resources as thermal generation has in the past. Connecting renewable generation which captures diverse weather patterns and temporal diversity can smooth the aggregate wind and PV generation profile across the NEM and contribute more to reliability of consumer supply.

The concept of REZs described in the Finkel Review could take advantage of these key factors to deliver truly coordinated generation and transmission development to benefit consumers.

2.2.2 Renewable Energy Zones (REZs)

The Finkel Review recommendation 5.1 identified a gap in public information about the quality of renewable energy resources across the NEM and their suitability for generation development. Recommendation 5.1 asked AEMO to identify and map the most suitable areas across Eastern Australia for renewable generation development. The intention of making this information publicly available is to enable interested parties, such as investors or governments, to make informed decisions about where to plan new renewable generation capacity.

Chapter 3 outlines the renewable energy resource mapping and the range of potential REZs across eastern Australia which AEMO proposes to further assess in the ISP. Chapter 4 considers the range of potential transmission development options which may be economic and would be needed to connect REZs to the power system.

2.2.3 Lessons from overseas

Overseas examples of successfully coordinating renewable generation and transmission development all exhibit a consistent theme of making strategic policy choices to facilitate large-scale renewable generation at a jurisdictional and policy level. This provides a level of investment certainty which allows various parties to coordinate the development required.

In 2007, the New Zealand electricity commission initiated the "transmission to enable renewables project" (TTER project). This aligned with the New Zealand Energy Strategy (NZES), which sets a target to achieve 90% electricity generation from renewable sources by 2025, from 70% in 2008 (mainly hydro).

The TTER project had three objectives:

- To provide an up-to-date map of potential renewable locations.
- To investigate possible economic transmission development options to support the development of renewable generation.
- To enable participants to better understand how the regulatory framework could be utilised to support the integration of renewables[30].

In 2008, a number of states in the region of the United States of America served by the Mid-Continent Independent System Operator (MISO) adopted Renewable Portfolio Standards (RPSs) which mandated a given level of renewable generation in each region. This drove a need for transmission developments to deliver renewable generation from remote sources to load centres, initially assessed through the *2008 Regional Generation Outlet* study. A series of studies led to the identification of a Multi-Value Portfolio (MVP) of transmission development projects, representing a set of "no regrets" projects, which were approved for development in 2011[31].

Other examples of clear strategic policy choices internationally include:

- Germany – the *Grid Expansion Acceleration Act* established (in 2009) a process to determine how to expand the transmission network to facilitate high levels of renewable energy penetration.
- United Kingdom – the *Transmission Investment for Renewable Generation* mechanism was established to fund projects which connect renewable generation.
- Texas, USA – a directive was passed (in 2005) to establish C*ompetitive Renewable Energy Zones* which would accelerate wind generation and associated transmission development[32].

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[30] New Zealand Electricity Commission, 2008. *Final report on the transmission to enable renewable project (phase 1)*, available at https://www.ea.govt.nz/dmsdocument/16625.

[31] MISO, 2017. *MTEP17 MVP Triennial Review*, available: https://www.misoenergy.org/Library/Repository/Study/Candidate%20MVP%20Analysis/MTEP17%20MVP%20Triennial%20Review%20Report.pdf.

[32] *Independent review into the future security of the National Electricity Market: Blueprint for the future*, available at https://www.environment.gov.au/system/files/resources/1d6b0464-6162-4223-ac08-3395a6b1c7fa/files/electricity-market-review-final-report.pdf.

2.2.4 AEMC market review on coordination of generation and transmission investment

The AEMC is conducting a review into the coordination of generation and transmission investment to determine whether to change the regulatory framework relating to the following topics:

- Transmission charging arrangements.
- Transmission planning arrangements.
- Access arrangements in the NEM.

The AEMC considers these three topics are all interlinked, and plans to address them holistically in an options paper to be released in early 2018.

AEMO and the AEMC collaborated to conduct the industry wide Renewable Energy Zone workshop in November 2017, which explored the value and potential barriers to development of REZs in the NEM. These are discussed further in Chapter 3.

3. Renewable energy zones

Preliminary messages

- Based on preliminary modelling of the renewable energy resources in eastern Australia:
  - Large-scale PV (solar) and wind generation are now among the cheapest forms of new bulk energy generation. Preliminary modelling indicates up to 25-30 GW of new wind and large-scale PV could be built in the NEM by 2037.
  - There are many potential REZs located across eastern Australia, which could accommodate many times the projected additional renewable generation capacity required in the coming decades.
  - The land area required to develop up to 30 GW of new wind and PV generation equates to less than 0.5% of farming land in mainland eastern Australia (New South Wales, Queensland, and Victoria).
  - Many high-scoring wind and solar areas appear to align well with transmission development projects already underway in each region of the NEM.
- Detailed further analysis is required to determine which REZs should be prioritised over others for the ISP.

Questions for consultation

3.1 – Does this analysis capture the full range of potential REZs in eastern Australia?

3.2 – What other factors should be considered in determining how to narrow down the range of potential REZs to those which should be prioritised for development?

3.3 – What are the potential barriers to developing REZs, and how should these be addressed?

Developing new large-scale renewable generation in the right locations will be vital to delivering a reliable and secure energy supply at lowest long-term cost for consumers, as wind and PV generation are now among the cheapest ways to generate new bulk energy in Australia.

AEMO has hosted two industry workshops in recent months to develop a collective understanding of:

- The role and purpose of REZs.
- Characteristics which define a successful REZ.
- Areas which represent potential REZs across the NEM.

This chapter summarises the outcomes of these workshops, highlights some indicative market modelling results, and proposes a number of potential REZs across the NEM which AEMO intends to investigate further in the ISP.

3.1 Role and purpose of REZs

Identifying the best locations to develop large-scale renewable generation is a core component of developing the ISP. Historically, transmission planning has provided only limited guidance on where to locate renewable generation most efficiently for consumers across the NEM. The ISP represents an opportunity to provide more comprehensive analysis to inform such guidance.

There is a lot of potential to connect renewable generation to the existing grid, but there may be a need/opportunity to expand beyond the existing grid.

REZs are areas where clusters of large-scale renewable energy can be developed to promote economies of scale in high-resource areas and capture geographic and technological diversity in renewable resources. Consumer benefits of developing REZs may include:

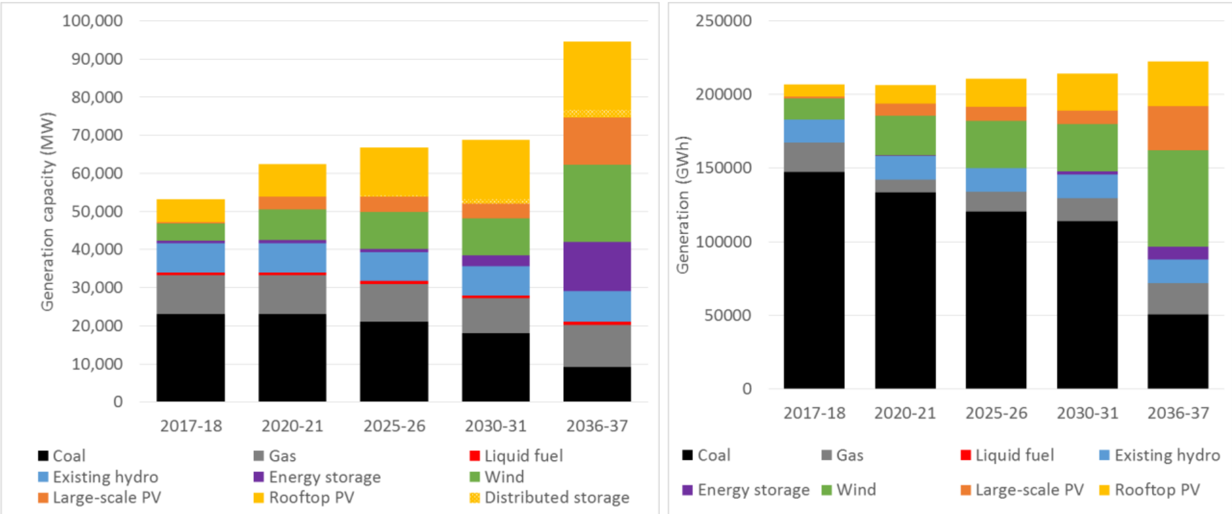
- Facilitating a reliable and secure energy supply at least possible cost to consumers, by:
  - Capturing economies of scale in both generation and transmission development.
  - Capturing diverse weather patterns, across many REZs, to increase the aggregate controllability, firmness, and flexibility of renewable resources.
  - Capturing areas with higher quality resources than connected to existing grid.
- Facilitating timely development of new generation sources to provide optionality for a faster energy transformation if required in future.
- Managing asset stranding risk if development is coordinated at a national level.

3.2 Indicative modelling of the generation mix transformation

AEMO is continuously improving the modelling methodology we apply to forecast generation and transmission developments, and we intend to make further improvements for the ISP, as discussed in 1.2.

The figure below shows preliminary projections of the NEM generation mix transformation, modelled under Neutral scenario assumptions.

Figure 9 Preliminary projections of NEM generation capacity (left) and generation output (right), Neutral scenario



Key points to note from this preliminary analysis include:

- NEM planners must prepare for and manage a rapid transformation of the power system, currently projected in the 2030s but which could occur earlier or later, as ~10 GW of coal generation is projected to retire.
- The economics of wind and large-scale PV are projected to drive combined new generation of up to 25-30 GW by 2037, as existing coal generation retires. Preliminary analysis indicates there is likely to be an increasing benefit for interconnection to smooth the natural variations of wind and PV generation across the NEM.
- Energy storage (either pumped hydro or battery storage) is projected to support variable generation with about 10 GW of maximum output and 20 GWh of storage capacity by 2037, mostly after 2030. AEMO is developing further modelling improvements to identify the most efficient mix of dispatchable capability (including the level of energy storage capacity) and transmission augmentation as the generation mix evolves.

The charts in Figure 9 represent input assumptions at a snapshot in time. Material changes in these assumptions, for instance due to the rapidly evolving cost trajectories of new generation/storage technologies, could strongly influence the generation mix projections. The provision of firm and flexible dispatchable capability in future will depend on the relative cost trajectories of pumped hydro, batteries, solar thermal, and (including fuel costs and limitations) GPG and coal generation. For example, an accelerated cost trajectory for concentrated solar thermal generation could replace a portion of the solar PV and energy storage capacity shown in Figure 9.

AGL's recent announcement of its plans for the Liddell Power Station closure is an example of how a portfolio of resources could contribute to capacity adequacy, energy adequacy, and flexibility as coal generation retires in future[33]. AEMO will provide a detailed assessment of projected reliability incorporating these plans, and whether any further market response is required to maintain reliable supply, in February 2018.

AGL's transparency in announcing both an intention to retire Liddell Power Station with seven years notice, and plans for development to replace Liddell Power Station with five years notice, also enables the rest of the industry to plan appropriately. This aligns with the Finkel Review recommendation 3.2 to require all large generators to provide at least three years' notice prior to closure. Such notice is required to facilitate a smooth transition as further large thermal generators are withdrawn from the NEM in the years ahead.

AEMO welcomes feedback on the high level inputs used in preliminary market modelling, contained in Appendix A.

3.3 Renewable energy resource mapping

The Finkel Review recommended that the assessment of REZs should consider, but not be limited to wind, solar, pumped hydro, and geothermal resources. The following maps indicate the areas underlying renewable energy resource for each of these resources.

Figure 10 Wind (left) and solar (right) resource heat map

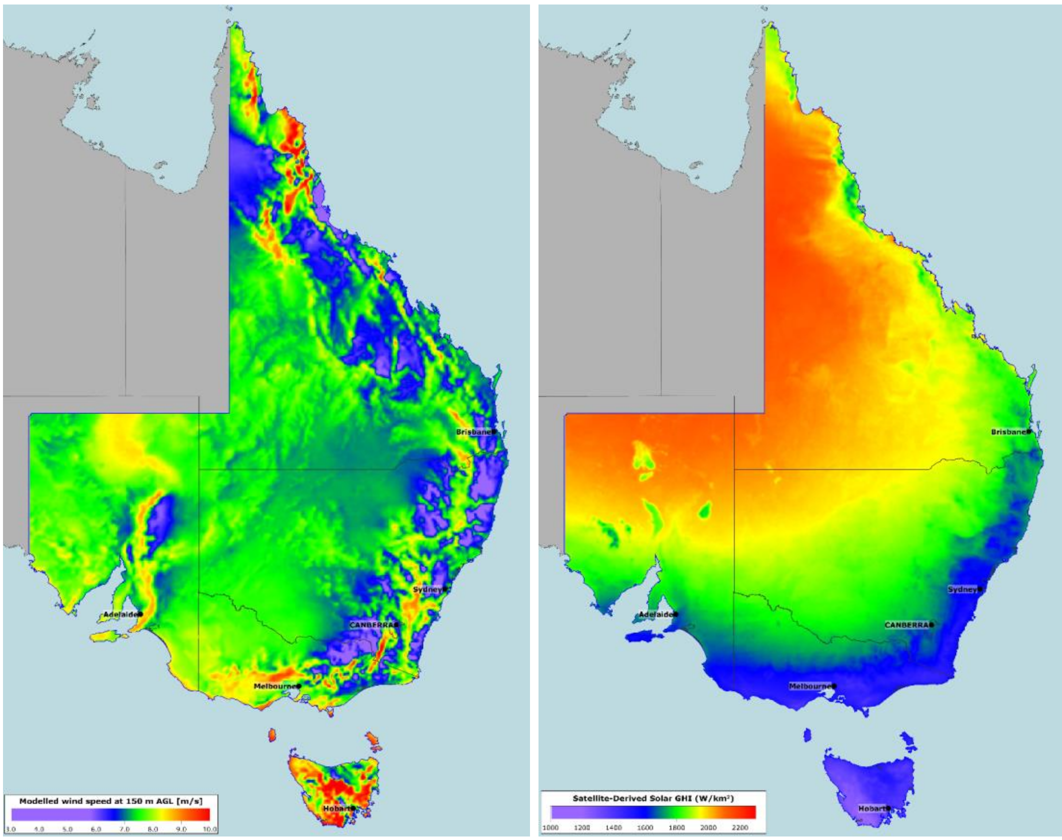


Figure 10 shows wind and solar resources as follows:

- Wind speed in a mesoscale model developed by consultants DNV-GL, but not validated with field measurements.

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[33] AGL, 2017. *AGL announces plans for Liddell Power Station*, available at https://www.agl.com.au/about-agl/media-centre/asx-and-media-releases/2017/december/agl-announces-plans-for-liddell-power-station?utm_source=Direct.

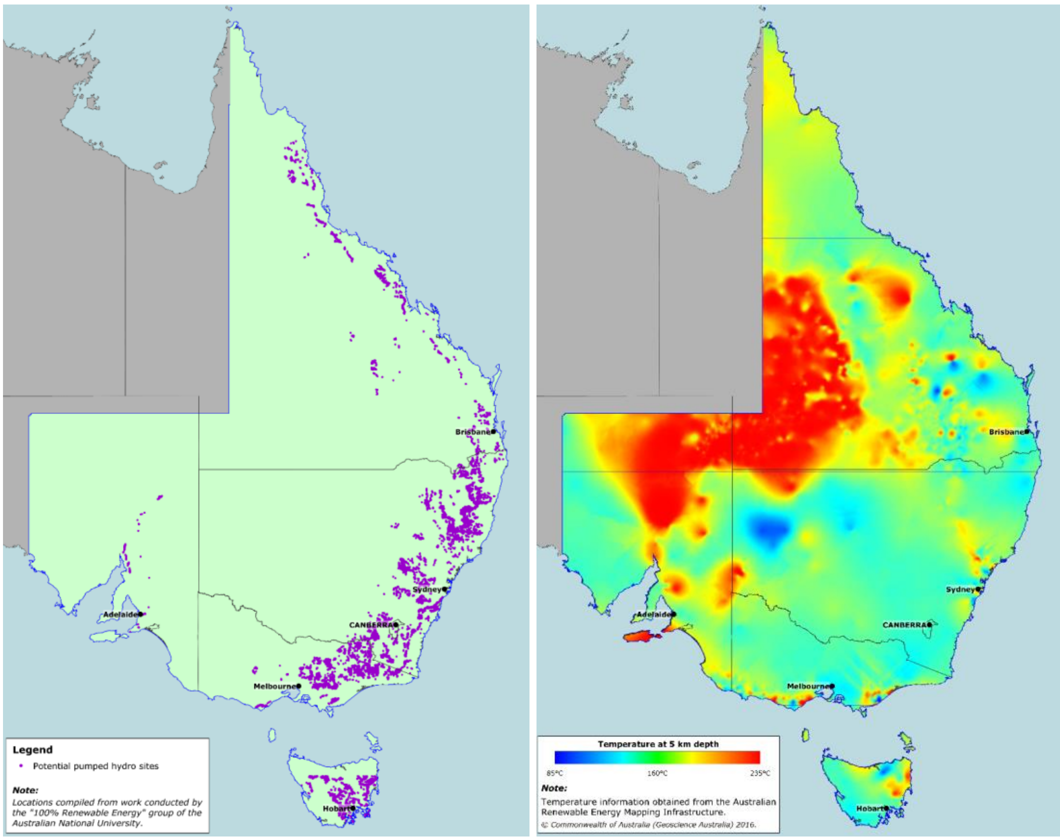
- Solar resources in hourly global horizontal irradiance (GHI) derived from satellite imagery and obtained from the Bureau of Meteorology (BoM).
- Both datasets cover the survey area at a five-kilometre resolution over a 10-year period, and both are available on the AREMI website[34].

Figure 11 represents the resource potential for pumped hydro and geothermal generation:

- The pumped hydro map shows the potential sites identified by Australian National University[35].
- The geothermal map shows the temperature at five-kilometre depth dataset from the AREMI website[36].

It is important to note that if high quality resources are distant from major load centres, development may not be efficient, given the cost of augmenting the network and high transmission losses.

Figure 11 Pumped hydro (left) and geothermal (right) resource maps



3.4 Factors which define a REZ

To help identify potential REZs, AEMO engaged consultants DNV-GL to utilise the renewable energy resource data, and a range of other information, to assess suitability for REZ development at a five-kilometre resolution across eastern Australia.

Suitability for REZ development was assessed through a basic scoring system of constraints, developed in consultation with stakeholders, which generated indicative suitability heat maps.

Many factors define whether an area is suitable for REZ development. This preliminary assessment of potential REZs focused on these factors associated with the renewable energy resource and site characteristics:

- Renewable resource – how good is the wind/solar resource?

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[34] Australian Renewable Energy Mapping Initiative, 2017, available at https://nationalmap.gov.au/renewables/.

[35] ANU, 2017. *Sites for pumped hydro energy storage*, available at http://re100.eng.anu.edu.au/research/phes/.

[36] Australian Renewable Energy Mapping Initiative, 2017, available at https://nationalmap.gov.au/renewables/.

- Land parcel density – representing ease of land procurement.
- Vegetation cover – representing ease of development and impact on other land uses.
- Proximity to road network – representing ease of development.
- Terrain complexity – representing ease of development.
- Population density – representing the potential for objection to REZ development.
- Protected areas – in which development would be prohibited (in National Parks for example).
- Fit to NEM demand – correlation of resource to average NEM demand profile.

The results of this preliminary scoring are shown in the heat maps in 3.5 and 3.6.

Prioritising REZs in the final ISP can only be done following a more detailed assessment of these more complex factors, not yet included in the preliminary scoring:

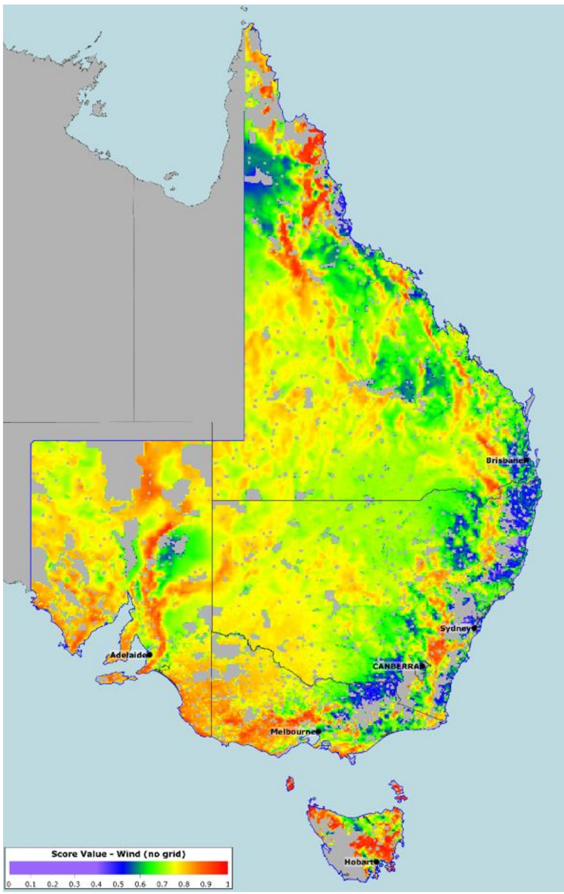
- Cost of network upgrade or extension – what are the relative network costs associated with each potential REZ development?
- Optimising REZ development with transmission reinvestment expenditure – are there opportunities to combine reinvestment expenditure for transmission assets reaching end of life with potential REZs development located near these assets?
- Consideration of transmission losses – renewable generation developers consider both the quality of the renewable resource and the efficiency of the network to transport energy to consumers. Assessing REZs for development should consider whether to prioritise:
  - Remote REZs with excellent resources but suffering greater transmission losses, or
  - REZs with lower quality resources which would suffer lower transmission losses to reach load centres.
- Balancing economies of scale and generation diversity – considering the optimal balance between many small REZs which capture greater diversity, and fewer large REZs which capture economies of scale but less generation diversity.
- Inter-regional generation diversity – to what extent can negatively correlated generation profiles across regions smooth the aggregate NEM-wide wind and PV generation profile?
- Existing generation sources – taking existing generators into account when assessing potential diversity of new REZs.
- Existing network congestion – understanding what transmission development would be required to establish a new REZ near existing NEM infrastructure.
- Potential for new dispatchable capability to share network costs – through proximity to potential pumped hydro sites or the existing gas network.
- Regional economic growth priorities – consider whether state governments have ambitions to develop jobs and growth in particular areas which may prioritise one REZ over another.
- Dynamic load profile – consider how rooftop PV growth will impact optimal generation diversity over time – should wind generation be prioritised?
- Fit to regional demand – assessing the correlation of REZ generation to regional demand profile.
- Solar generation diversity – it is best captured when located along east-west transmission lines rather than lines in a north-south orientation.

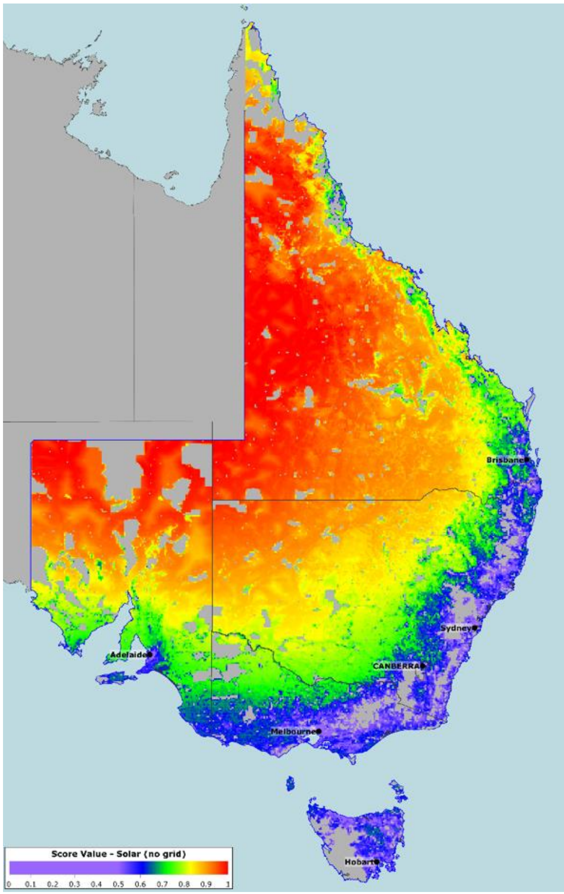
AEMO intends to consider all the factors in both lists above when assessing which areas should be recommended for REZ development in the ISP. AEMO welcomes feedback on these characteristics and whether any further factors should be considered in the assessment.

3.5 Indicative scoring for wind and solar resources

The following maps apply the scoring system described in 3.4 to indicate potential areas for REZs.

Figure 12 Indicative wind (left) and solar (right) scoring





The red areas in the maps indicate potential areas of wind and solar generation, considering the factors addressed in the preliminary assessment (listed in 3.4).

3.6 Indicative high scoring zones for wind and solar resources

The following maps show the highest-scoring areas for both wind and solar resources, when suitability for REZ development was assessed. Both maps include the potential sites for pumped hydro generation from the ANU study.

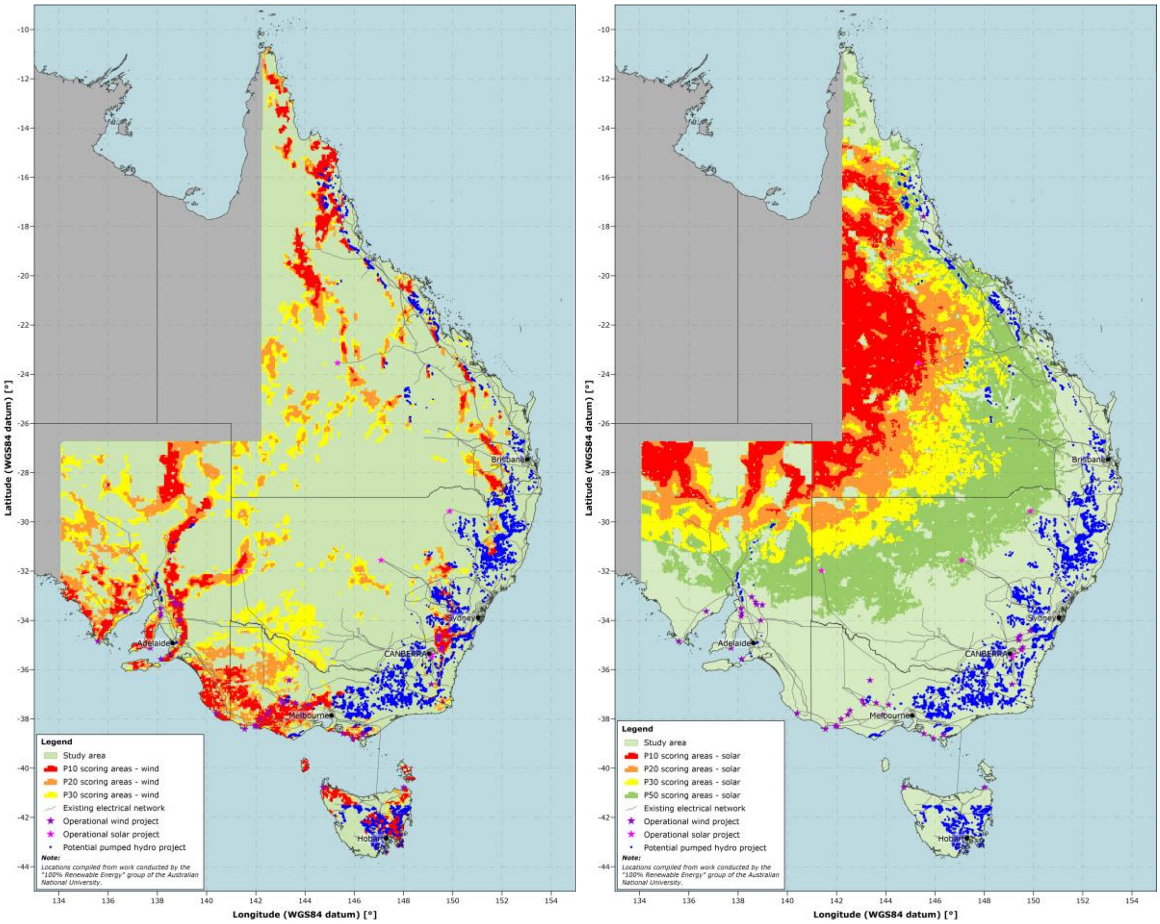
The maps differentiate between P10, P20, P30, and P50 (for solar resources) scoring areas, where P10 represents the top 10% scoring locations in the survey area, P20 represents the top 10 to 20% of scoring areas, and so on.

The maps clearly show that the highest scoring areas occur predominantly:

- In coastal regions for wind resources.
- In central and northern regions for solar resources.

Areas where there is overlap of high-scoring wind and solar resources indicate potential REZs, but this does not preclude areas with only excellent wind or solar resources from being a potential REZ.

Figure 13 Highest scoring areas for both wind (left) and solar resources (right)



Many high scoring wind areas align well with potential pumped hydro sites, and many potential REZs areas appear to align well with transmission development projects already under consideration, including:

- Eyre Peninsula in South Australia, where ElectraNet is undertaking a RIT-T[37].
- The route in ElectraNet's South Australian Energy Transformation RIT-T through South Eastern South Australia to South Western New South Wales[38].
- Western Victoria, where AEMO is undertaking a Western Victoria Renewable Integration RIT-T[39].
- Far North Queensland (Queensland Government's Powering North Queensland Plan[40]).
- Tasmania's Battery of the Nation Project[41].
- New England Renewable Energy Zone in Northern New South Wales[42].
- Potential for co-locating wind generation near the proposed Snowy 2.0 project.

3.6.1 Area required for generation capacity

It is important to consider how much land may be required to install a substantial amount of renewable generation capacity. An indicative calculation is shown in the table below.

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[37] ElectraNet, 2017. *Eyre Peninsula Electricity Supply Options*, available at https://www.electranet.com.au/projects/eyre-peninsula-electricity-supply-options/.

[38] ElectraNet, 2017. *South Australian Energy Transformation*, available at https://www.electranet.com.au/projects/south-australian-energy-transformation/.

[39] AEMO, 2017, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Victorian-transmission-network-service-provider-role/Regulatory-investment-tests-for-transmission.

[40] Queensland Government, 2017. Powering North Queensland Plan, available at https://www.dews.qld.gov.au/__data/assets/pdf_file/0003/1253541/Fact-sheet-Powering-North-Queensland-Plan.pdf.

[41] Hydro Tasmania, 2017. Battery of the Nation, available at https://www.hydro.com.au/energy/battery-nation.

[42] TransGrid, 2017. Renewable Energy Hub, available at https://www.transgrid.com.au/news-views/lets-connect/consultations/current-consultations/Documents/Renewable%20Hub_Knowledge%20Report_TransGrid.pdf.

Table 3 Indicative area required to develop 15 GW of both wind and large-scale PV generation

Resource	Capacity density (MW/km^2)	Example capacity / MW	Area required / km^2	Proportion of top 10% scoring area	Proportion of farm land in NSW, QLD, VIC	Proportion of crop land in NSW, QLD, VIC
Wind	2 - 5	15,000	3,000 - 7,500	~1.1% - 2.7%	~0.13% - 0.39%	~1.8% - 4.6%
Solar	25 - 75	15,000	200 - 600	~0.0% - 0.2%	~0.01% - 0.03%	~0.1% - 0.4%

The area potentially required for large-scale renewable generation is relatively small, compared to:

- The area of land with high quality resources (top 10%) which may be suitable for development.
- The total area of farm land across New South Wales, Queensland, Victoria, and South Australia.

Although the footprint of wind projects is much larger than for solar projects, a sizeable portion of the site area for wind generation can also continue to be available for other purposes, such as crops or grazing.

Solar projects are more likely to be located in arable (crop) farming areas than wind generation, because wind generation is normally located in coastal or ridged areas which are not typically suited for crop farming. Although not as flexible as wind projects with alternative land uses, solar projects utilise a much smaller land area and are unlikely to materially reduce the amount of available arable farming land.

This preliminary, high-level analysis has considered total farm land in the regions, but has not considered the potential level of competition where the best resources for renewable generation may be located in the same areas as prime farm land.

AEMO welcomes feedback on this preliminary analysis.

3.6.2 Potential renewable energy zones

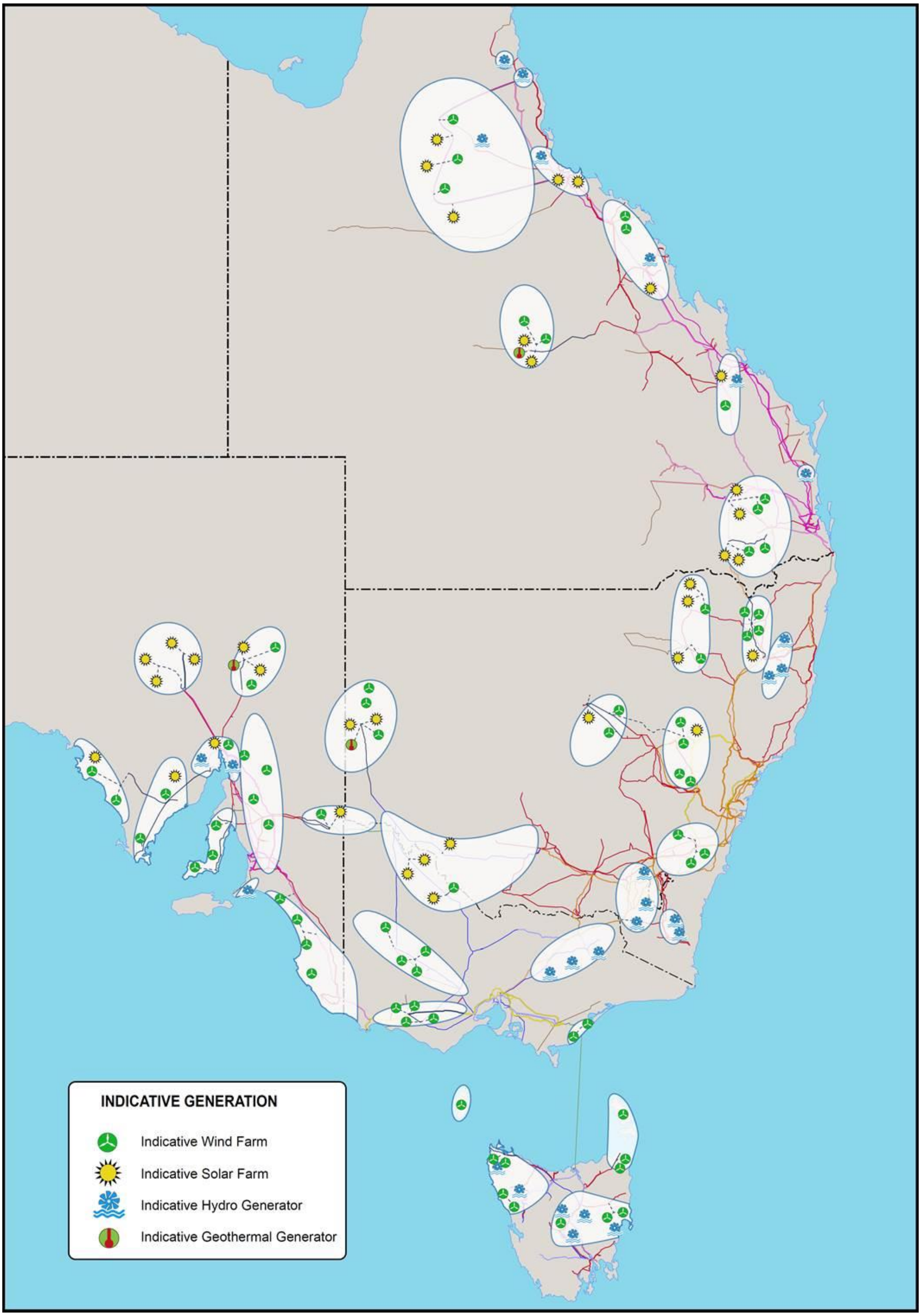
Figure 14 below outlines a number of potential REZs, based on the indicative mapping performed to date.

As highlighted in Table 3 above, further analysis needs to be completed before the ISP can recommend the most suitable REZs to develop.

Factors which could have greatest impact on determining the most suitable REZs to develop include:

- The location of existing renewable generators, and where to locate new renewable projects to best capture generation diversity so that total generation aligns with the consumer demand profile.
- The relative cost of augmenting existing transmission assets to alleviate congested areas or building new transmission to connect brand new areas as REZs.
- Whether local governments have ambitions to develop jobs and growth in particular areas, which may prioritise some REZs over others.

Figure 14 Range of potential Renewable Energy Zones



3.7 Potential barriers to developing REZs

In the REZ workshops held to date, AEMO has asked stakeholders to identify potential barriers to developing REZs. The potential barriers raised are shown in the table below.

Table 4 Potential barriers to REZ development

Potential barrier	Description
Climate and energy policy uncertainty	Continued uncertainty over the long-term emissions reduction trajectory, both economy wide and in the NEM specifically, act as a barrier to new renewable generation commitments which could drive REZ development.
Obtaining project approvals in the face of uncertainty	An outcome of the RIT-T framework is that investment uncertainty tends to restrict new developments to incremental augmentations rather than capturing economies of scale benefits.
Social license and community acceptance	It may be difficult to obtain community acceptance and procure easements for large-scale renewable developments in concentrated areas, particularly close to existing infrastructure.
Lead times to plan and build	The long lead times associated with large-scale transmission developments are misaligned with the shorter lead time of generation development, potential leading to inefficient congestion which could add costs to consumers.
Communicating the value of REZs	Failure to quantify and communicate the complex value of REZs in simple language may hinder gaining consumer acceptance for large-scale developments.
Impact of Distributed Energy Resources (DER) uptake	Greater than expected uptake or orchestration of DER may reduce the need for large-scale generation and transmission developments.
Asset stranding risk	The range of investment uncertainties contribute to an asset stranding risk which may incentivise incremental augmentations. In the long term, however, this may be less efficient for consumers than implementing larger developments which capture greater economies of scale.
Risk sharing in a forward looking framework	Coordinating generation and transmission development will still have to determine who is subject to the risk of under-utilised assets if less than forecast new generation is built. Decreasing investment uncertainty could mitigate this risk.
Cost allocation between regions	Allocating the cost of REZ transmission development within regions, or between neighbouring regions if involving an interconnector augmentation, may not appropriately reflect diversity benefits to consumers across all NEM regions.
State versus national priorities	Each state is incentivised to pursue the best REZs in their region. Coordinated development at a national level through an integrated infrastructure development plan may lead to a more effective and lower cost outcome for consumers.

AEMO will incorporate this feedback into the ISP, and will liaise with the AEMC so relevant feedback is shared with its team running the market review on coordination of generation and transmission investment.

4. Transmission development

Preliminary messages

- Increasing the capacity of interconnection could be pivotal to meeting reliability and security objectives and long-term NEM renewable energy targets. The benefits of increased interconnection would include optimising the use of geographically diverse variable renewable resources, allowing regions to:
  - Export power rather than spilling local generation surplus.
  - Import power when needed to meet demand rather than building additional local generators.
- The benefits of transmission upgrades have to be carefully estimated and compared against their high costs over a range of plausible future conditions which consider the entire supply chain, including behind-the-meter developments.
- Based on AEMO's preliminary ISP modelling:
  - Following the announced closure of Liddell power station in 2022 and changed market conditions, AEMO recommends that Powerlink and TransGrid initiate a RIT-T to increase transfer capacity between Queensland and New South Wales.
  - AEMO recommends that a joint planning study should commence in 2018 to determine the feasibility and preferred option to upgrade the Victoria to New South Wales interconnector.

Questions for consultation

4.1 – Have the right transmission options been identified for consideration in the ISP?

4.2 – How can the coordination of regional transmission planning be improved to implement a strategic long-term outcome?

4.3 – What are the biggest challenges to justifying augmentations which align to an over-arching long-term plan? How can these challenges be met?

4.4 – Is the existing regulatory framework suitable for implementing the ISP?

This chapter presents and seeks feedback on AEMO's proposed approach for identifying emerging transmission development needs in the ISP.

4.1 Transmission planning process

To provide a more focused assessment of the potential for high-quality REZs, AEMO proposes an updated approach to creating a staged transmission plan. The table below shows the proposed stages and our progress so far. We will continue to progress incomplete stages and engage with relevant stakeholders, as the ISP is developed.

Table 5 Transmission planning process

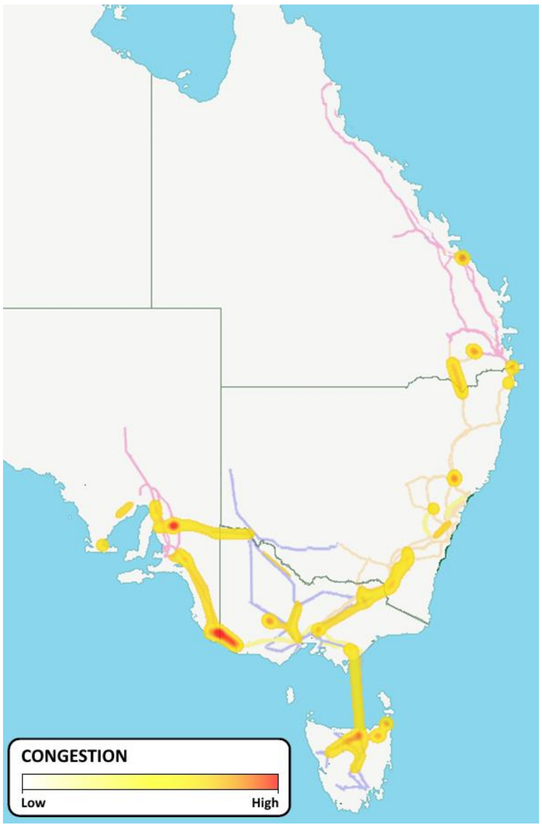
Stage	Progress	See section in this report for more information
Consider drivers of transmission	Mostly complete	Chapter 2
Review current transmission bottlenecks	Complete	Section 4.2
Develop transmission development options	Mostly complete	Section 4.3
Create staged plan	Underway	Section 4.4
Analyse benefits of options	Underway	Section 4.5
Strategic coordinating of nearby options into an over-arching plan	Underway	Section 4.6

4.2 Current transmission bottlenecks

The figure below highlights areas of network congestion[43] during 2016-17. Although some degree of network congestion may be economic, increasing congestion is a signal that upgrades might be justified. The figure shows that the bulk of network congestion[44] in 2016-17 resulted from interconnector transfer limits, signalling a potential benefit of upgrading interconnection.

As the figure shows, this congestion was primarily located between major load centres.

Figure 15 2016-17 transmission congestion heat map



See AEMO's annual NEM constraint report for more information on historical network congestion[45].

[43] Congestion relating to network outages was removed from this analysis.

[44] Network congestion was measured by summarising the marginal value for each constraint equation in each dispatch interval over the period.

[45] AEMO. NEM Constraint Report 2016, available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2017/The-NEM-Constraint-Report-2016.pdf.

System strength requirement

Recent system strength limitations in South Australia are not included in Figure 15, because they were most prevalent after the 2016-17 year.

Sufficient system strength is an essential requirement for any power system, and when weak will materially impact its operation. Higher fault levels, or high currents following a fault, are typically found in a stronger power system, while lower fault levels are representative of a weaker power system.

Low system strength can result in:

- Failure of generators to ride through nearby faults, resulting in multiple generators disconnecting from the system in unison and posing a risk to system security.
- Failure of protection systems, resulting in mal-operation or a failure to operate and posing a risk to life, assets, and system security.

On 6 September 2017, after a series of in-depth power system simulation studies, AEMO determined that a combination of large synchronous generating units must be online in South Australia to maintain a secure operating state[46].

Following a series of directions to maintain system security in South Australia, AEMO declared a Network Support and Control Ancillary Services (NSCAS) gap for system strength[47]. ElectraNet has now committed to meeting this NSCAS gap from 30 March 2018 under the new system strength framework[48].

AEMO expects that this will eliminate the current need to issue directions relating to system strength in South Australia[49], but will not entirely remove system strength limitations in South Australia. AEMO recommends that ElectraNet continues to investigate economic ways to alleviate this limitation under the South Australia Energy Transformation RIT-T[50].

4.3 Transmission development options

AEMO's 2016 NTNDP studies indicated that new or upgraded interconnection to adjacent NEM regions may be economic within the next 10 to 20 years. Following consultation with TNSPs, AEMO proposes to re-evaluate these projections under ISP scenarios, and to focus ISP network studies particularly on determining the economic efficiency of these projects:

- Reinforcing the Queensland transmission backbone to support renewables in the north.
- Staged upgrades of the New South Wales to Queensland interconnector.
- Staged upgrades to the Victoria to New South Wales interconnector.
- Increasing interconnection from South Australia to the eastern states.
- Integrating renewable generation developments in Western Victoria.
- Expanding transmission capacity to the Eyre Peninsula.
- Additional Bass Strait interconnection.
- Maintaining system strength in the NEM.

Most of these developments have been proposed independently. AEMO's 2016 NTNDP examined the overall national benefits of combining some of these proposals, and highlighted the need for coordination and national planning perspectives when assessing these major augmentations. AEMO's preliminary modelling has found that major transmission upgrades are more economic when combined with other major upgrades, creating a more interconnected NEM. Transmission options to connect specific REZs will be developed following feedback on AEMO's preliminary list of REZs (see Figure 14).

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[46] AEMO. *South Australia System Strength Assessment*, September 2017, available at http://www.aemo.com.au/Media-Centre/South-Australia-System-Strength-Assessment.

[47] AEMO. Second Update to the 2016 NTNDP, available at http://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NTNDP/2017/Second_Update_to_the_2016_NTNDP.pdf.

[48] AEMC. Completed rule changes: Managing power system fault levels, available at http://www.aemc.gov.au/Rule-Changes/Managing-powersystem-fault-levels.

[49] AEMO's current method to ensure power system security and a minimum level of system strength is to direct synchronous generators online in accordance with section 116 of the National Electricity Law. If system strength is low, but above the minimum requirement, the output of non-synchronous generators will occasionally be limited to ensure power system security. Synchronous condensers are another existing technology that can provide system strength.

[50] ElectraNet. South Australia Energy Transformation, available at https://www.electranet.com.au/projects/south-australian-energy-transformation/.

While it is unlikely that all of the above options would be needed, AEMO will investigate a wide range of options before narrowing in on the optimal set of solutions which overall best meet the national interest as defined through the National Electricity Objective. The regulatory process is designed so transmission upgrades can only proceed if they deliver overall economic benefits to those who produce, consume, and transport electricity in the NEM, or if the projects are required for reliability corrective action. In addition to affordability, sustainability and reliability are fundamental aspects of transmission planning.

In most instances, a range of credible solutions could serve a similar purpose. AEMO proposes to use an optimised least-cost modelling process to determine the timing and scale of upgrades which might be economic. Following this modelling, AEMO will create a staged plan of economic projects to provide regional transmission planners with a roadmap for coordinated future development. When individual upgrades approach, they will need to be justified through the RIT-T process. These RIT-T assessments will consider both network and non-network options, and the option value of projects which align with the long-term network development needs.

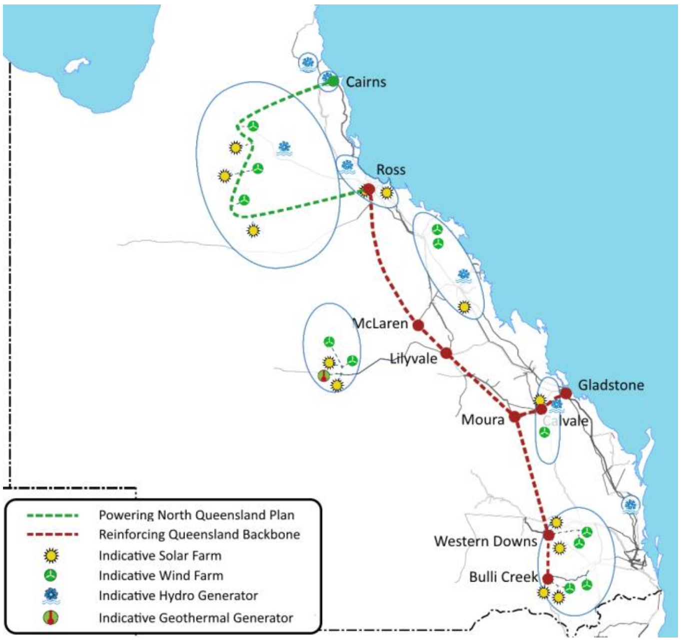
4.3.1 Reinforcing the Queensland transmission backbone

Queensland has good solar resources, and areas of high quality wind and geothermal resources (see Chapter 3). If developed, these resources would add to the diversity of generation in the southern states. However, unlocking the potential of these diverse resources for the rest of the nation may require transmission augmentation from Queensland to southern states.

In June 2017, the Queensland state government announced the Powering North Queensland Plan[51]. This plan looks to extend the grid west of Cairns and Ross to connect high quality renewable energy resources. AEMO notes that this region has access to high quality wind, solar, and geothermal resources. Because this location is geographically distant from existing wind farms, the resources from this area would likely add to the diversity of renewable energy across the NEM.

Figure 16 illustrates the Powering North Queensland Plan, and a possible pathway to upgrade the Queensland transmission backbone. Indicative future generator projects are included on the map based on the availability of resources in the area.

Figure 16 Reinforcing the Queensland transmission backbone



While the Queensland transmission system experienced little congestion over 2016-17 (see Figure 15), a new transmission corridor could be economic if large quantities of variable generation sources were added in the north of the state.

[51] Queensland Government – Department of Energy and Water Supply. Powering North Queensland Plan, available at https://www.dews.qld.gov.au/__data/assets/pdf_file/0003/1253541/Fact-sheet-Powering-North-Queensland-Plan.pdf.

AEMO's studies will seek to determine the threshold of generator connections in North Queensland required to justify this project, and when it might become economic. Due to the long length and high cost, AEMO expects that a new transmission corridor through Queensland is unlikely to be justified within the next 10 years. Alternative options to upgrade the existing transmission corridors will also be considered.

4.3.2 Staged upgrades of the New South Wales to Queensland interconnector

Upgrades to the New South Wales to Queensland interconnector have been assessed previously. Notably, a joint planning study between Powerlink and TransGrid in 2014 concluded that an upgrade was not economically justified. This study did not find an option which was sufficiently robust to deliver benefits across a wide range of credible scenarios, although some upgrades were economic under some scenarios.

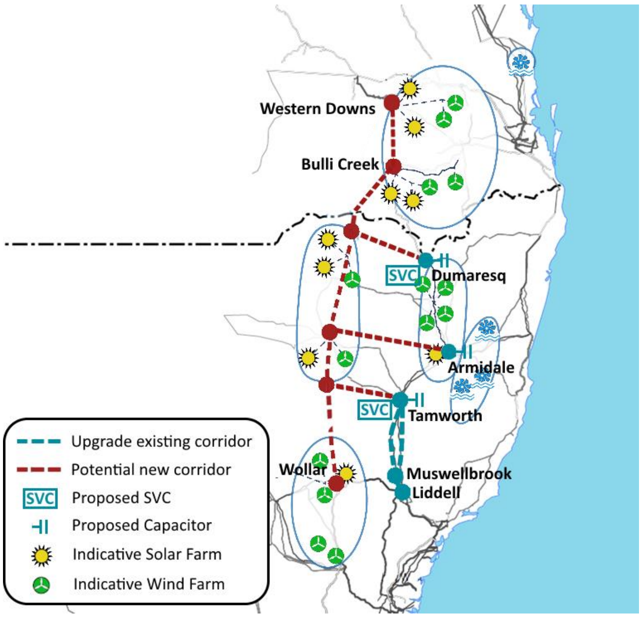
In the 2016 NTNDP, AEMO's studies showed that an upgrade to the New South Wales to Queensland interconnector might be economic in the mid to late 2020s. Due to changed market conditions over the past 12 months and the planned retirement of Liddell power station in 2022, AEMO now considers that an upgrade to the New South Wales to Queensland interconnector is a low-regret decision (see 4.6.2). That is, the upgrade may be needed earlier than previously forecast, and proceeding, even though some scenarios might show inadequate benefits, could insure against the possibility of major generation failure or earlier closure in New South Wales.

Powerlink and TransGrid commented on a New South Wales to Queensland interconnector upgrade in their Transmission Annual Planning Reports (TAPRs). In its final revenue determination, the Australian Energy Regulator (AER) accepted Powerlink's proposal to include the interconnector upgrade as a contingent project for the regulatory period 2017-2022. The AER also accepted TransGrid's proposal to consider the upgrade as a contingent project in their 2018-2023 regulatory period.

AEMO will consider benefits of increased interconnection between New South Wales and Queensland, and recommends that Powerlink and TransGrid initiate a RIT-T to increase interconnector capacity and reduce the likelihood of reserve deficit in either region.

Figure 17 illustrates two projects (labelled as "upgrade existing corridor" and "potential new corridor") to upgrade interconnection between New South Wales and Queensland. These projects could be considered in combination or individually. Indicative future generator projects are included on the map based on the availability of resources in the area.

Figure 17 Options to upgrade the New South Wales to Queensland interconnector



Stage 1 – Upgrade existing corridor

The first stage upgrade being considered for the New South Wales to Queensland interconnector makes use of existing transmission lines by:

- Uprating of Liddell–Muswellbrook (#83).
- Uprating of Muswellbrook–Tamworth (#88).
- Updating of Liddell–Tamworth (#84) 330 kV lines.
- Installing static VAR compensators (SVCs) at Dumaresq and Tamworth substations.
- Installing shunt capacitor banks at Tamworth, Armidale, and Dumaresq substations.

This project is expected to increase the import capacity to New South Wales by 190 MW, and the export capacity to Queensland by approximately 460 MW. This estimated cost of this upgrade is $142 million. This option is considered a first stage because it can be delivered sooner than the option to establish a new corridor. To determine the optimal outcome, these projects should be considered individually and in combination.

Stage 2 – Potential new corridor

After the capacity of the existing lines is fully utilised, a new interconnector path might become economic. The proposed link between Wollar and Western Downs would serve to connect new sources of renewables and increase transfer capacity by 1,040 MW towards Queensland and 840 MW towards New South Wales. The proposed Wollar to Western Downs link could be built at a voltage of 330 kV or 500 kV.

330 kV Wollar to Western Downs Option

The 330 kV link option involves the following components:

- Install Wollar – Bulli Creek – Western Downs 330 kV double circuit lines.
- Establish three 330 kV new switching stations between Wollar and Bulli Creek.
- Install 330 kV single circuit lines from the three new substations to Dumaresq, Armidale, and Tamworth substations.
- Augment existing substations at Wollar, Tamworth, Armidale, Dumaresq, Bulli Creek, and Western Downs.

This option is estimated to cost $1,400 million, and increases the export capacity to Queensland by approximately 930 MW and the import capacity to New South Wales by 840 MW[52].

500 kV Wollar to Western Downs option

The 500 kV link option involves the following components:

- Install Wollar – Bulli Creek – Western Downs 500 kV double circuit lines.
- Establish three new 500/330 kV substations between Wollar and Bulli Creek.
- Install 330 kV single circuit lines from the three new substations to Dumaresq, Armidale, and Tamworth.
- Augment Dumaresq, Armidale, and Tamworth 330 kV substations to accommodate additional 330 kV circuits.
- Augment Bulli Creek substation to establish a 500 kV switchyard and 500/330 kV transformer.
- Augment Bayswater substation to accommodate additional 500 kV transmission line.
- Augment Western Downs substation to convert the existing 275 kV switching station to a 500/275 kV substation to connect 500 kV transmission line.

This option is estimated to cost $1,900 million, and would increase the export capacity to Queensland by approximately 1,040 MW and the import capacity to New South Wales by 840 MW[53].

4.3.3 Staged upgrades to the Victoria to New South Wales interconnector

AEMO's 2016 NTNDP analysis found that an upgrade to the Victoria to New South Wales interconnector could be justified in the mid to late 2020s. Due to the recent closure of Hazelwood Power Station and rapid uptake of renewable energy projects, this upgrade might be justified sooner.

[52] Powerlink and Transgrid. Project Assessment Conclusions Report, 13 November 2014, available at https://www.powerlink.com.au/Network/Network_Planning_and_Development/Documents/QNI_Upgrade_Project_Assessment_Conclusions_Report_March_2014.aspx

[53] ibid.

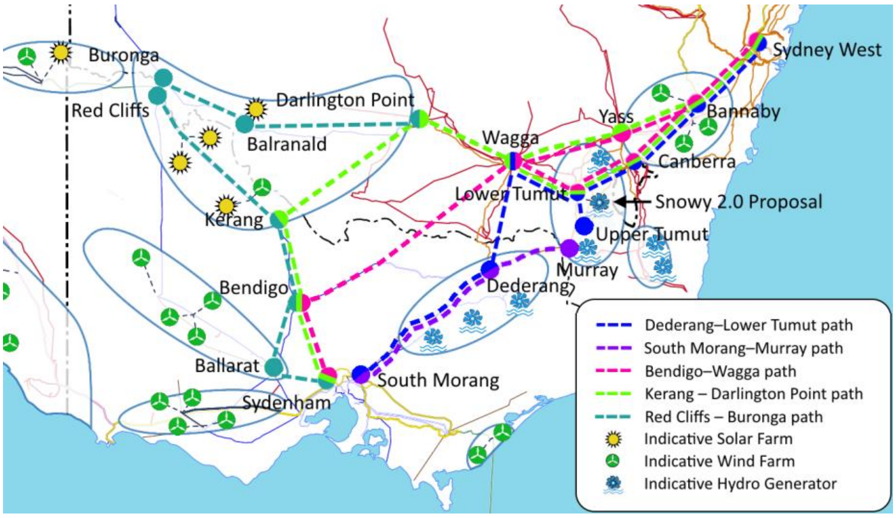
In their transmission annual planning reports, published in June:

- AEMO, under its Victorian TNSP role, found that the benefits of increasing interconnection is likely sufficient to justify augmentations, under both Neutral Demand and Weak Demand scenarios. AEMO committed to commencing a pre-feasibility study within the next 12 months on the need to improve Victoria to New South Wales export capability, considering the preferred options from the Western Victoria Renewable Integration RIT-T and the South Australia Energy Transform RIT-T once they become available.
- TransGrid proposed minor upgrades to the interconnector in the far west, between Buronga in New South Wales and Red Cliffs in Victoria.

Because of the long lead time in building new transmission lines, AEMO recommends that a joint planning study should commence in 2018 to determine the feasibility and preferred option to upgrade the Victoria to New South Wales interconnector.

Figure 18 shows five different options to upgrade the Victoria to New South Wales interconnector. Two options (labelled as “Red Cliffs – Buronga path” and “Dederang – Lower Tumut path”) largely make use of the existing transmission corridors, while the others propose new corridors. AEMO’s ISP assessment will consider upgrades to these five transmission corridors, including upgrades to accommodate the proposed Snowy 2.0 scheme[54]. Indicative future generator projects are included on the map based on the availability of resources in the area.

Figure 18 Five alternative options to upgrade the Victoria to New South Wales interconnector



The five upgrade paths illustrated on the map are discussed in the following sections.

Dederang – Lower Tumut path

Two projects have been identified to upgrade the existing interconnector capacity between Victoria and New South Wales. In combination, these projects are estimated to cost $180 million, and increase capacity by 170 MW towards New South Wales and 400 MW towards Victoria. These projects can be delivered separately or in combination. Any upgrade to the existing path should consider staged upgrades and new transmission corridors.

Upgrade Victoria to New South Wales export capacity

The low capacity option to upgrade the existing link could be a standalone solution, or part of a staged upgrade. This option includes the following work:

- Install a second 500 / 330 kV transformer at South Morang.
- Install a braking resister at Loy Yang or Hazelwood.
- Uprating of Dederang – South Morang 220 kV lines.

[54] Snowy Hydro. Snowy 2.0, available at http://www.snowyhydro.com.au/our-scheme/snowy20/.

- Uprating of Canberra – Upper Tumut 330 kV line.

This option would increase Victoria to New South Wales transfer capability by approximately 170 MW. The approximate cost of this option is $80 million.

Upgrade New South Wales to Victoria import capacity

The medium capacity option to upgrade the existing link could be a standalone solution, or part of a staged upgrade. This option includes the following work:

- Install series compensation (approximately 50%) on Wodonga – Dederang 330 kV line.
- Install a phase angle regulator (1,000 MVA) on the Jindera–Wodonga 330 kV line.
- Uprate Dederang – South Morang 330 kV circuits and series capacitors.
- Install a fourth 330/220 kV 240 MVA transformer at Dederang.
- Install two 150 MVAr 330 kV shunt capacitor banks at Wodonga, Jindera, or Wagga.

This option would increase New South Wales to Victoria transfer capability by approximately 400 MW. The approximate cost of this option is $115 million.

South Morang – Murray path

The proposed South Morang – Murray path can increase the import capacity from New South Wales to Victoria by approximately 1,000 MW. This option includes the following work:

- Install an additional South Morang–Dederang 330 kV single circuit line.
- Install an additional Dederang–Murray single circuit 330 kV line.

This option will be further explored in conjunction with the Snowy 2.0 project.

Kerang – Darlington Point path

The proposed Kerang – Darlington Point path creates a new corridor for high power transfers between Victoria and New South Wales. This option would be most beneficial if large amounts of variable generation connect in Western Victoria. It can be combined with proposed upgrades from South Australia to New South Wales or Victoria (see 4.3.4). This option includes the following work:

- Install a Sydenham – Bendigo – Kerang – Darlington Point – Wagga double circuit 500 kV line.
- Install a Wagga – Bannaby – Lower Tumut – Wagga single circuit 500 kV loop.
- Construct 500 kV substations at Bendigo, Kerang, Darlington Point, Wagga, and Lower Tumut (or expand existing substations to accommodate 500 kV plant).
- Install four 500/220 kV transformers – two at Bendigo and two at Kerang.
- Install six 500/330 kV transformers – two at Darlington Point, two at Wagga, and two at Lower Tumut.
- Install a phase shifting transformer on the Bannaby – Sydney West 330 kV line.
- Install an additional 330/220 kV 240 MVA transformer at Dederang.
- Install additional reactive plant.

This option would increase the Victoria to New South Wales transfer capability by 2,100 MW towards New South Wales and 1,700 MW towards Victoria. The approximate cost of this option is $2,700 million.

Bendigo – Wagga path

The Kerang – Darlington Point option creates a new corridor for high power transfers between Victoria and New South Wales. This option would be beneficial if large amounts of variable generation connects in Western Victoria and if the South Australia to New South Wales (Robertstown to Darlington Point – see 4.3.4) interconnector link does not proceed. The details of this option will continue to be investigated.

Buronga – Red Cliffs Path

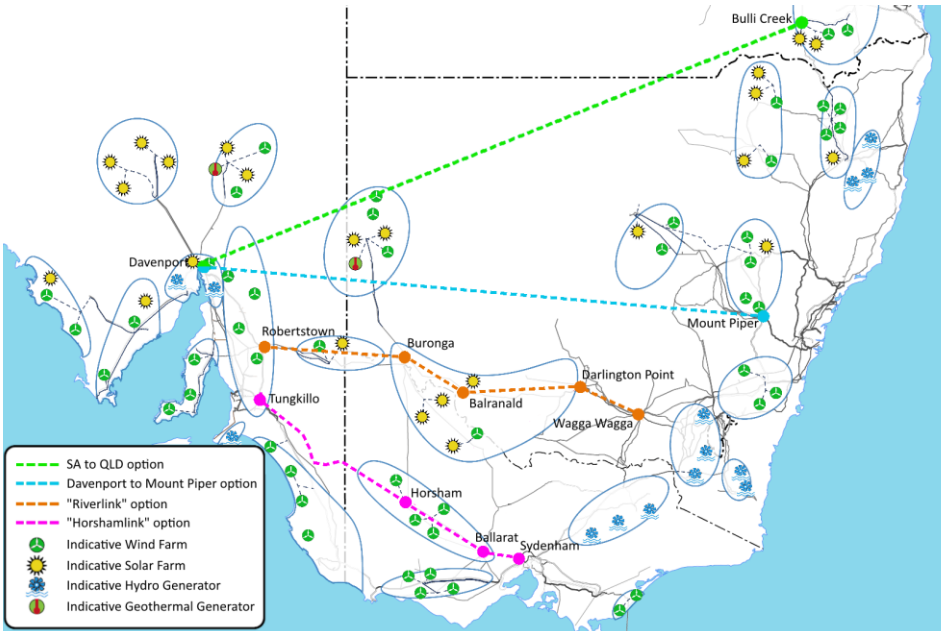
The Buronga – Red Cliffs option focuses primarily on upgrading existing corridors in Western Victoria and South-West New South Wales. This option overlaps with, and supports, the proposed upgrade between South Australia and New

South Wales (Robertstown to Darlington Point). In combination with a connection to South Australia, this option creates a major transmission hub at Buronga and in the vicinity of high quality wind and solar resources. The details of this option will continue to be investigated.

4.3.4 Increasing interconnection from South Australia to the eastern states

In 2013, AEMO and ElectraNet completed a RIT-T to upgrade the capacity of the Victoria to South Australia (Heywood) interconnector from 460 MW to 650 MW. In 2016, AEMO's NTNDP found benefits for an additional interconnector from South Australia to the eastern states. ElectraNet's South Australia Energy Transformation RIT-T is currently assessing four pathways to increase interconnection to South Australia, shown in Figure 19. Indicative future generator projects are included on this map based on the availability of resources in the area.

Figure 19 Four alternative options to increase South Australian interconnection



AEMO is providing input and review to ElectraNet's South Australia Energy Transformation RIT-T, and proposes to review and use the preferred solution indicated by ElectraNet in the ISP. AEMO and ElectraNet are working closely to ensure a coordinated approach between the South Australia Energy Transformation RIT-T and the Western Victoria Renewable Integration RIT-T (see 4.3.8).

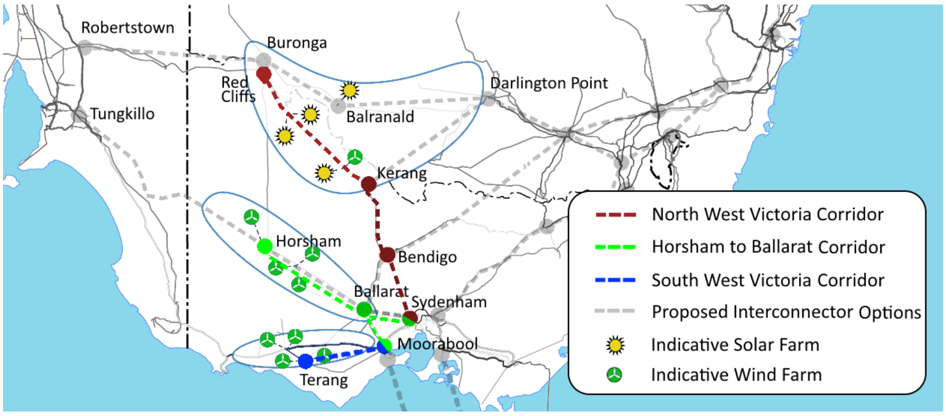
4.3.5 Western Victoria Renewable Integration

Under its Victorian transmission planning function, AEMO is currently assessing options to upgrade the Western Victoria transmission network to accommodate large quantities of renewable generation. Non-network options are being considered within this assessment.

Figure 20 illustrates the primary options currently being considered for upgrades – these upgrades will be considered individually and in combination. Indicative future generator projects are included on the map based on the availability of resources in the area.

This project highlights the need for coordinated inter-regional transmission planning. The transmission options being proposed to connect renewable energy in Western Victoria can have a major impact on the justification for transmission links to South Australia, Tasmania, and New South Wales (see 4.3.8).

Figure 20 Western Victoria Renewable Integration upgrade paths



This project is currently focusing on three transmission corridors:

- North West Victoria Corridor.
- Horsham to Ballarat Corridor.
- South West Victoria Corridor.

North West Victoria Corridor

Upgrades to the North West Victoria corridor focus on increasing transmission capacity for future solar generation projects between Kerang and Red Cliffs, and in south-west New South Wales. In combination with a proposed interconnector path from South Australia to New South Wales, a major transmission hub could be created at Buronga (see 4.3.8).

This option can accommodate up to 1,500 MW of new generation connections, and includes the following work:

- Red Cliffs – Wemen – Kerang 220 kV circuit ($355 million).
- Kerang–Sydenham 500 kV circuit and transformer ($605 million).
- Series compensation and other required works ($17 million).

Horsham to Ballarat Corridor

Upgrades to the Horsham to Ballarat corridor focus on increasing transmission capacity for existing and future wind farms between Ballarat and Horsham. This project could be delivered in combination with a proposed interconnector path from South Australia to Victoria (see 4.3.8).

This option can accommodate the connection of approximately 1,000 MW of new generator connections, largely between Ballarat and Horsham, and includes the following work:

- New Ballarat–Waubra–Ararat transmission circuits at 220 kV or 500 kV (approximately $120 million, 220 kV option).
- New Ararat–Horsham transmission circuits at 220 kV or 500 kV (approximately $85 million, 220 kV option).
- New transmission circuit at 220 kV or 500 kV from Ballarat to either Sydenham or Moorabool (approximately $129 million, 220 kV option).

South West Victoria Corridor

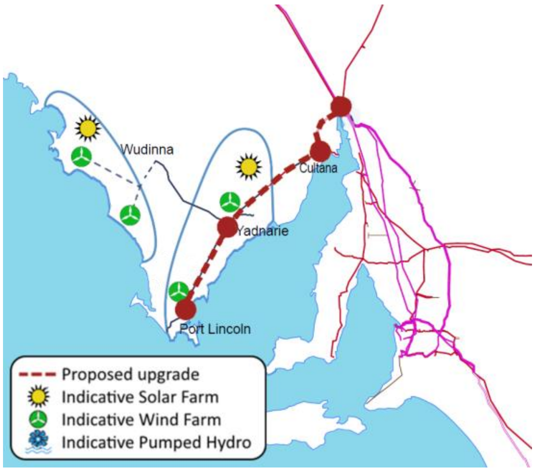
Upgrades to the South West Victoria corridor focus on increasing capacity for future wind farm projects between Moorabool and Terang. This option can accommodate over 500 MW of new generator connections around Terang, and includes the following work:

- 220 kV Moorabool–Terang double circuit (approximately $187 million).

4.3.6 Expanding transmission capacity to the Eyre Peninsula

In November 2017, ElectraNet published an update to its Eyre Peninsula RIT-T, proposing a draft solution to provide supply reliability and connect renewable generator connections in the area. AEMO proposes to use the draft outcome from this assessment in the ISP. AEMO's analysis will consider the benefits of establishing REZs on the Eyre Peninsula. Figure 21 illustrates the location of the proposed upgrade and some indicative generator connections which could follow.

Figure 21 Proposed Eyre Peninsula upgrade



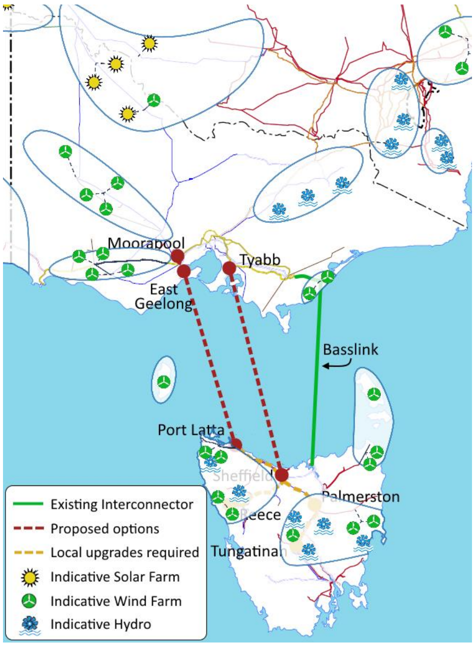
4.3.7 Additional Bass Strait interconnection

In the 2016 NTNDP, AEMO assessed the economic justification for a second Bass Strait interconnector. This assessment found that the new interconnector provided marginally positive net benefits under some scenarios.

Hydro Tasmania are currently working on a proposal to establish Tasmania as the "Battery of the Nation"[55]. AEMO will consider the latest information provided by Hydro Tasmania when assessing potential interconnector projects between Tasmania to Victoria.

Figure 22 highlights some proposed options to establish a second Bass Strait interconnector, and the local upgrades which might be required.

Figure 22 Two alternative Bass Strait interconnector paths



[55] Hydro Tasmania. Battery of the Nation, available at https://www.hydro.com.au/energy/battery-nation.

Upgrades are likely to be required in each region's AC transmission network to connect the interconnector firmly to the state grid. Indicative future generator projects are included on the map based on the availability of resources in the area.

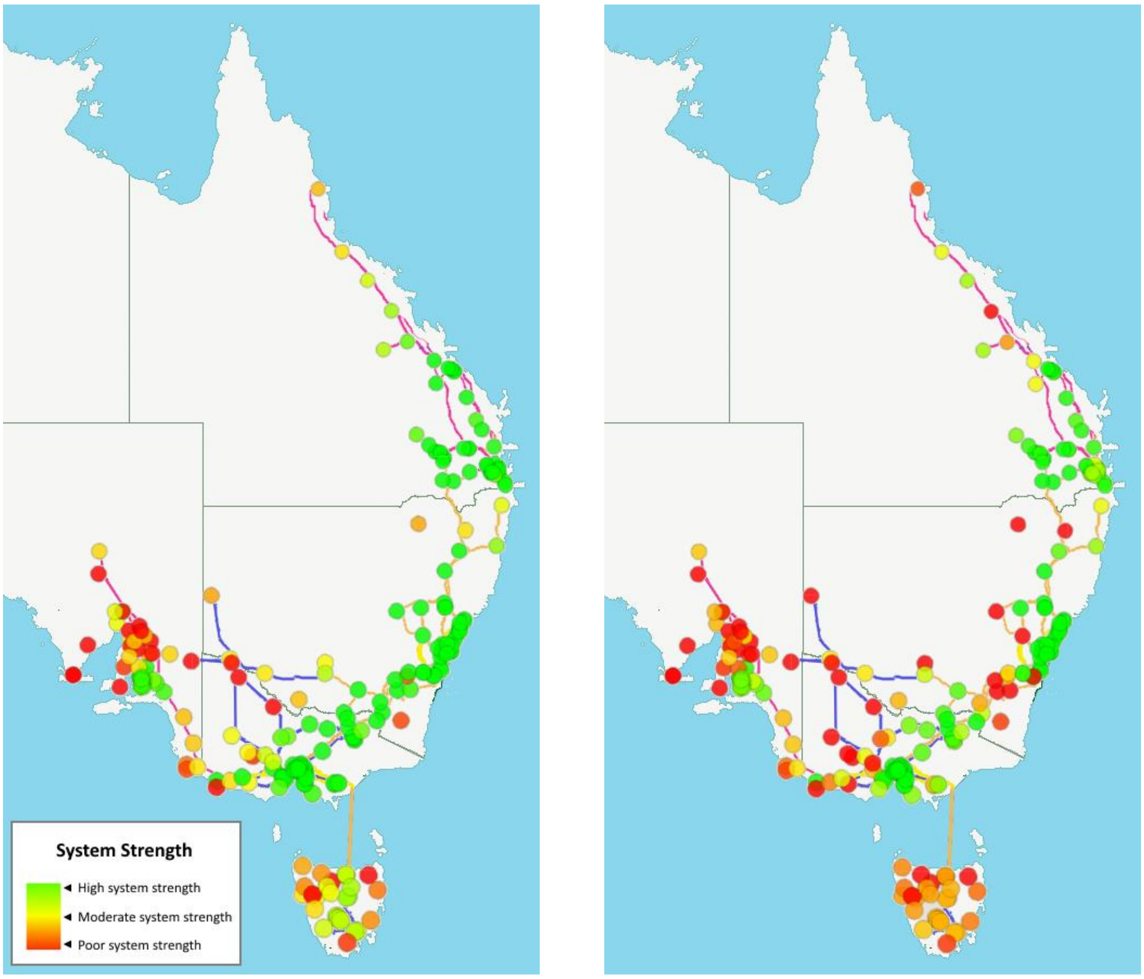
AEMO's 2016 assessments of a second Bass Strait interconnector focused on a 600 MW interconnector estimated to cost $940 million. AEMO is currently consulting with Hydro Tasmania and TasNetworks to determine a range of technically feasible interconnector options. AEMO welcomes feedback on this scale of interconnection that should be considered between Victoria and Tasmania.

4.3.8 Maintaining system strength

The displacement of synchronous generation by non-synchronous generation is projected to greatly reduce system strength (described in 4.2) across the NEM. In the 2016 NTNDP, AEMO performed an assessment of system strength in the NEM as the generation mix changes. The outcome of that assessment is shown in Figure 23 below, and highlights:

- Without remediation, poor system strength is projected to decline further in much of South Australia, western Victoria, and Tasmania.
- Emerging local areas of poor system strength in New South Wales and Queensland, where a high concentration of renewables is anticipated by 2035-36.

Figure 23 2016 NTNDP system strength assessment in 2016-17 (left) and 2035-36 (right)



System strength is a local phenomenon which is driven by local changes, such as installation of non-synchronous generators and displacement of synchronous generators. AEMO intends to update our analysis of system strength based on updated generation projections, and indicate where investment might be required to maintain system strength. Because the location of generator installations over the coming decades is somewhat uncertain, investment to maintain system strength should consider the latest generation information available at the time.

4.4 Coordinated strategic planning

The importance of coordinated inter-regional planning is evident from the current RIT-Ts and feasibility studies underway in and around Victoria:

- The South Australia Energy Transformation RIT-T is considering additional interconnector options from South Australia to the eastern states.
- The Western Victoria Renewable Integration RIT-T is considering major transmission corridor upgrades in Western Victoria.
- Feasibility studies to upgrade the Victoria to New South Wales interconnector are soon to be initiated.
- The "Snowy 2.0" project could add up to 2,000 MW of generating capacity and 350,000 MWh of energy storage near Lower Tumut in the Snowy area.
- The "Battery of the Nation" project is analysing the benefits of additional Bass Strait interconnection.
- The "Star of the South" project, offshore from Victoria's Latrobe Valley, is considering the feasibility of at least 2,000 MW of offshore wind generation capacity.

Under its national planning role, AEMO is working with the relevant jurisdictional planning bodies to facilitate a coordinated approach. However, under the existing regulatory framework, development in each region will continue to be determined by the relevant TNSP as approved by the AER.

Figure 24 shows two solutions where the options considered in these projects are coordinated to deliver an integrated outcome, and one solution where transmission solutions are not coordinated.

Figure 24 Transmission planning coordination in and around Victoria

The top two maps show existing transmission proposals linked together into big "T" or "Y" shapes, which add transmission capacity in new areas with high quality REZs (refer to Chapter 3). The coordination of these projects will deliver a wealth of benefits, in addition to those realised when they are assessed individually. They each offer the potential to open up otherwise untapped rich renewable resources areas for the future in the NEM.

Coordinated planning across regions is essential to deliver the most efficient long-term infrastructure development for consumers. If major infrastructure projects to link regions cannot be initially justified, the option value of linking projects at a later stage should be considered.

The proposed ISP modelling will consider newly identified transmission development proposals in concert with established proposals to create a long-term staged strategic plan.

4.5 Analysing benefits

Under the present regulatory arrangements, it is important that projects in the ISP are individually economically justifiable, so each project can deliver overall benefits to consumers and pass a RIT-T.

Due to the large number of combinations of augmentation options, AEMO is unable to perform an assessment for each individual project within the ISP with the same rigour as a RIT-T. The ISP will aim to use high-level economic assessments to achieve a staged plan for regional transmission planners to follow. Under the current transmission planning framework, individual stages of the ISP will need to be justified through the RIT-T framework.

AEMO's approach for determining a long-term transmission plan uses:

- Capacity outlook model – determines the least-cost long-term generation and interconnection development plan without considering intra-regional network limitations. This model gradually and simultaneously adds new generation and augmented interconnector capacity to the NEM, while retiring existing generation capacities, to solve for the most cost-efficient development trajectory for the NEM.
- Time-sequential model – validates the results from the previous model by carrying out hourly generation dispatch simulations while considering various power system limitations. This model does not make capacity expansion decisions, but highlights network limitations' potential costs
- Network development outlook model – examines the physical transmission network in detail and validates the power system limitations identified from the time-sequential model as well as the feasibility of the capacity outlook model results. Network augmentation options are identified and high level costs are obtained from this model.

AEMO has been working on improving our modelling methodologies – these improvements are discussed further in 1.2. We intend to regularly refine the ISP as new information becomes available.

4.6 Staging a development plan

AEMO's ISP will suggest timings for different components of the long-term transmission development plan. These timings will be driven by:

- Economic justification – primarily, the timing of projects will be driven by the economic model outlined in 4.6.1.
- Bringing forward low-regret upgrades – in some instances, AEMO will look to determine high-impact events which early transmission upgrades can protect against (see 4.6.2). The benefits of bringing forward low-regret upgrades can be captured under existing planning frameworks.

4.6.1 Economic justification

Affordability is of paramount importance when developing a long-term plan. Optimising investment decisions between transmission, generation, energy storage, large-scale DSP and orchestrated DER will be key to achieving an affordable electricity supply.

Major transmission investment decisions are generally made through the RIT-T process. This is an economic transmission investment test which:

- Ensures transmission investment delivers overall economic benefits.
- Allows investment for reliability corrective action.
- Encourages non-network investment.

Investment decisions for generation, energy storage, and large-scale DSP and orchestrated DER are made by market participants based on a wide range of expectations including wholesale prices, forward contracts, supplying load, and opportunities to arbitrage between high and low prices. Ensuring the right price and investment signals exist as the NEM transitions to a high penetration of renewable energy will be important in attracting and retaining sufficient resources with the operational pre-requisites and technical attributes needed to efficiently maintain a secure and reliable power system.

For this to occur, real-time price signals need to reflect the true price of meeting the physical system needs. Accurate price signals provide both producers and consumers with the right incentives for actually providing or receiving these system needs through the market at least cost. These incentives can then flow through to forward financial markets to provide the right planning signals for the quantity, location, and attributes of resources.

A number of reviews and Rule changes are attempting to improve price formation, and are tackling with the issue that some physical attributes have not been valued in the past. For example, the Five Minute Settlement Rule change[56] aims to improve the energy price signal for faster, more flexible response.

The resource mix in the system today, and into the future, is much more heterogeneous than in the past, when most generators provided various degrees of firm capacity, inertia, system strength, and other attributes. The recent system strength[57] and inertia[58] Rule changes recognise that provision of inertia and system strength is not guaranteed as thermal synchronous generation is displaced by non-synchronous generation. These Rule changes place obligations on TNSPs to provide these essential system services, thereby placing a value on them.

These economic factors will be incorporated into AEMO's ISP modelling, analysis, and planning activities to optimise the timing of any transmission augmentation.

4.6.2 Bringing forward low-regret upgrades

A low-regret network upgrade is an upgrade which will eventually be required in most reasonable future scenarios, but might not be needed for some time. Bringing forward low-regret investment decisions can provide the capability to share supply in the event of an unexpected outage. This approach can be included in the RIT-T, but is not generally considered in early stage prefeasibility assessments.

High impact, low probability shocks to the power system can have a serious impact on supply reliability. Examples of such shocks include:

- An expensive power station failure a year or two before its announced closure causes a large power station to close on short notice.
- Gas supply is significantly reduced following an explosion at a major gas supply hub.
- A major transmission link fails requiring repairs which take months.

Transmission augmentations can provide a wide range of market benefits by increasing the capacity to trade energy between regions. AEMO will aim to identify low-regret transmission investments which can be expedited to provide flexibility in the event of a high impact, low probability outage.

4.6.3 Economic assessments of major infrastructure developments

As part of its work in developing the ISP, AEMO will consider the extent to which the current regulatory framework is appropriate for:

- Major infrastructure upgrades (like interconnectors).
- Recognising the significant uncertainties in the electricity industry (such as emissions policy, consumer behaviour, and technological changes).
- Upgrades consistent with an over-arching, technically and economically optimised, long-term plan.

AEMO notes that on 15 December 2017 the AER commenced a review of the RIT-T application guidelines[59], which will explore improvements that:

- The Council of Australian Governments (COAG) Energy Council identified in its RIT–T review.[60]
- Have arisen out of the replacement expenditure rule change.[61]
- Have been identified out of ongoing applications of the RITs.
- Stakeholders identify throughout the AER's review.

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56 AEMC. Five Minute Settlement, available at http://www.aemc.gov.au/Rule-Changes/Five-Minute-Settlement.

57 AEMC. Managing power system fault levels, available at http://www.aemc.gov.au/Rule-Changes/Managing-power-system-fault-levels.

58 AEMC. Managing the rate of change of power system frequency, available at http://www.aemc.gov.au/Rule-Changes/Managing-the-rate-of-change-of-power-system-freque.

59 AER. Review of the application guidelines for the regulatory investment tests for transmission and distribution. Available: https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/review-of-the-application-guidelines-for-the-regulatory-investment-tests-for-transmission-and-distribution.

60 COAG. Review of the Regulatory Investment Test for Transmission (RIT-T). Available: http://www.coagenergycouncil.gov.au/publications/review-regulatory-investment-test-transmission-rit-t.

61 AEMC. Replacement expenditure planning arrangements. Available: http://www.aemc.gov.au/Rule-Changes/Replacement-Expenditure-Planning-Arrangements.

Major infrastructure upgrades and uncertainty

Long-term major transmission upgrades (for example, to establish a new interconnector) can be economically difficult to justify. This is because:

- Major upgrades are likely to be under-utilised in the early years after commissioning. In a cost-benefit assessment, benefits are discounted annually, meaning net losses from under-utilisation in early years become exponentially more difficult to overcome with benefits achieved in later years.
- Uncertainty over the amount and location of new generation, and changing consumer behaviour, makes it challenging for options to deliver benefits across a wide range of credible futures.

In the face of increasing uncertainty about the future, there is an increasing risk on ability to achieve returns. This demonstrates a challenge for justifying major investment and a benefit for incremental or staged upgrades. However, these incremental improvements may not ultimately be the most efficient way to implement these augmentations.

Under the existing regulatory arrangements, where the jurisdictional TNSP develops the economic project justifications, interconnectors have the added process difficulty of multiple parties, potentially working under different regulatory arrangements, needing to work together to progress solutions. While this is not insurmountable, it tends to slow down the process at a time where the rate of change in the industry is increasing.

Upgrades consistent with an over-arching long-term plan

Under the current regulatory framework, a long-term transmission plan is only useful if it can be broken down into individually economic stages – stages which can each pass the RIT-T.

The final ISP will aim to develop a staged transmission investment plan for TNSPs to follow, starting with:

- Low-regret upgrades which will be required under a broad range of future scenarios.
- Augmentations which are likely to be required under some scenarios within the next 10 years.

AEMO welcomes stakeholder views and will work with stakeholders to examine whether the existing regulatory frameworks are appropriate for implementing the ISP.

APPENDIX A. Summary of high level proposed market modelling inputs and assumptions

This appendix provides a high level summary of some key assumptions AEMO is proposing to adopt in its market modelling for the mid-2018 ISP, and incorporates the *NTNDP inputs* as required by rule 5.20 of the Rules.

Demand

Relatively little demand growth is expected, with increases in consumption due to population growth absorbed by rooftop PV growth, more energy efficient appliances, and consumer response to energy prices.

Figure 25 Regional operational energy demand (Neutral case)

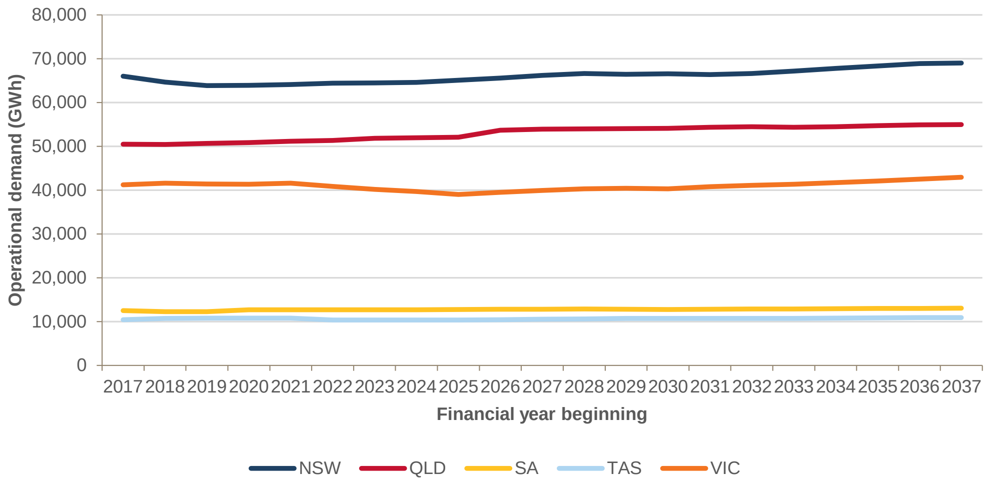
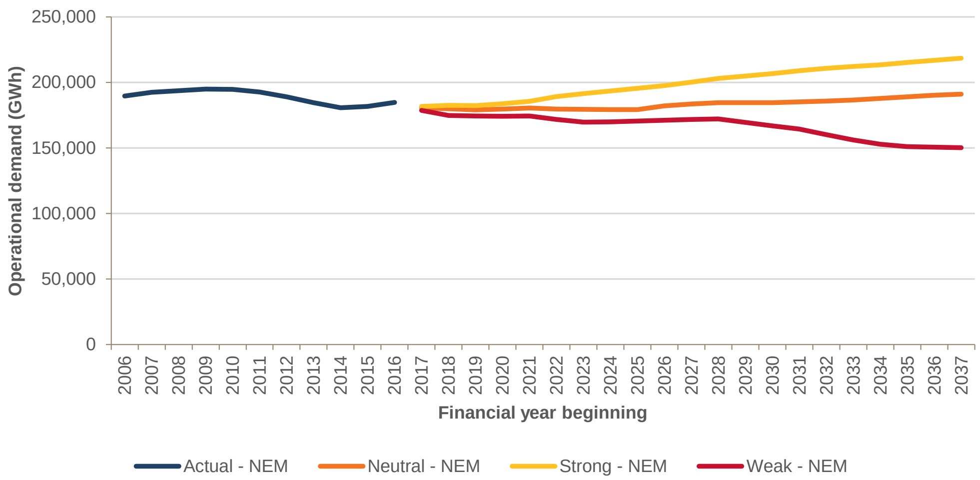


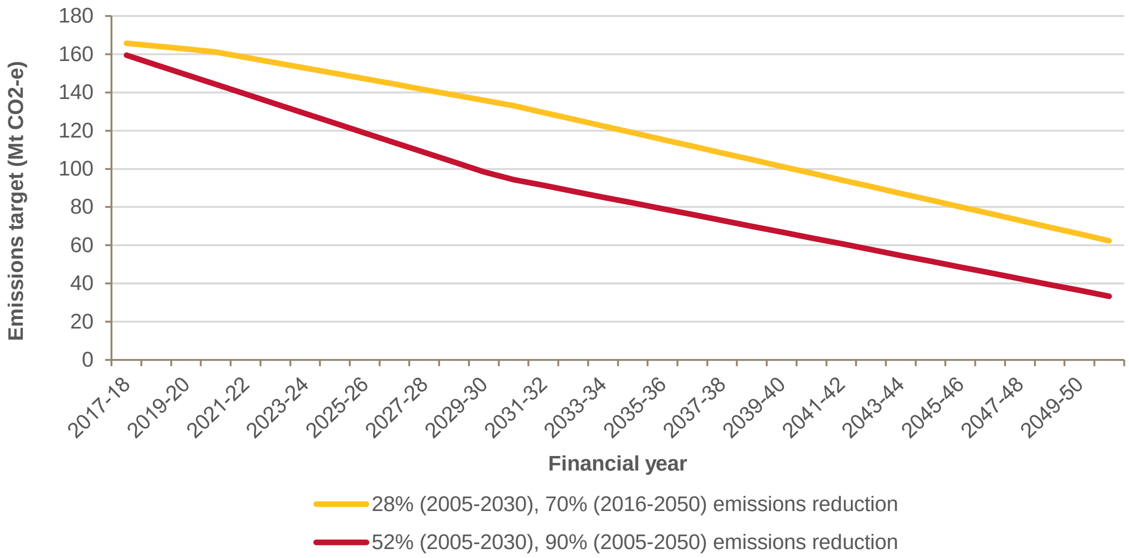
Figure 26 NEM operational energy demand scenarios



Emissions trajectories

The ISP will not model a carbon price, but rather emissions reduction trajectories across different scenarios. The emissions reduction trajectories proposed for the ISP scenarios are explained in 2.1.4.

Figure 27 Proposed emissions reduction trajectories to 2050 for the ISP

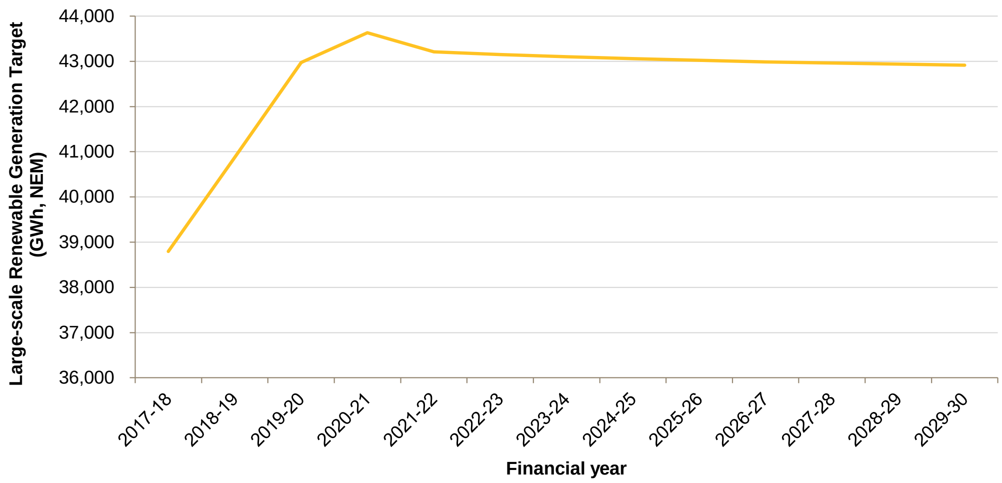


Renewable energy targets

The federal Large-scale Renewable Energy Target (LRET), a primary driver of new generation in previous studies, becomes relatively inactive after peaking in 2020-21. State-based targets and federal emissions targets influence further emissions reductions thereafter.

Large-scale Renewable Energy Target (LRET)

Figure 28 Large-scale renewable energy target applicable to 2030



Victorian Renewable Energy Target (VRET)

The VRET Victorian renewable energy target mandating 25% renewable generation by 2020, 40% by 2040, driven by capacity auction. [62]

[62] Victorian Government, 2017. *Victoria's renewable energy targets*. https://www.energy.vic.gov.au/renewable-energy/victorias-renewable-energy-targets.

Queensland Renewable Energy Target

The Queensland Government recently confirmed its commitment to a 50% renewable energy target by 2030[63].

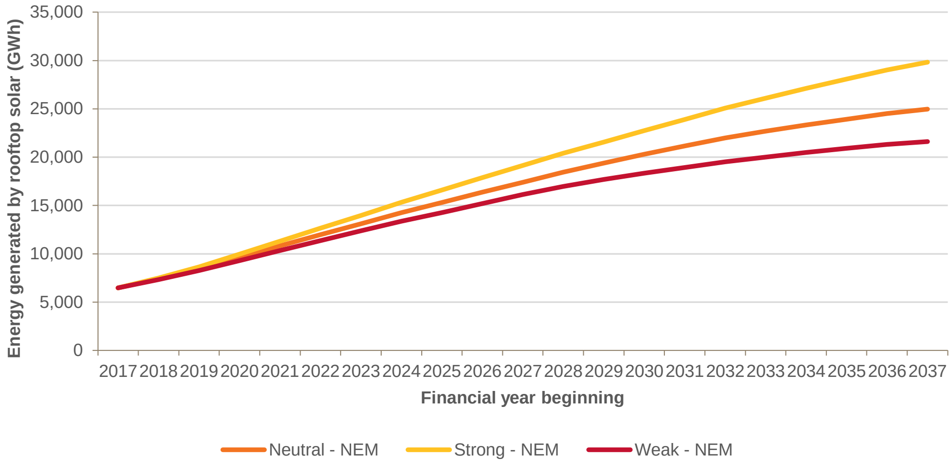
South Australia RenewablesSA initiative

The South Australian Government launched its *RenewablesSA* initiative to support the further growth of South Australia's renewable energy industry with a target of 50% renewable generation production by 2025[64].

Rooftop PV growth

Increasing rooftop PV penetration projected in AEMO's 2017 *Electricity Forecasting Insights*[65].

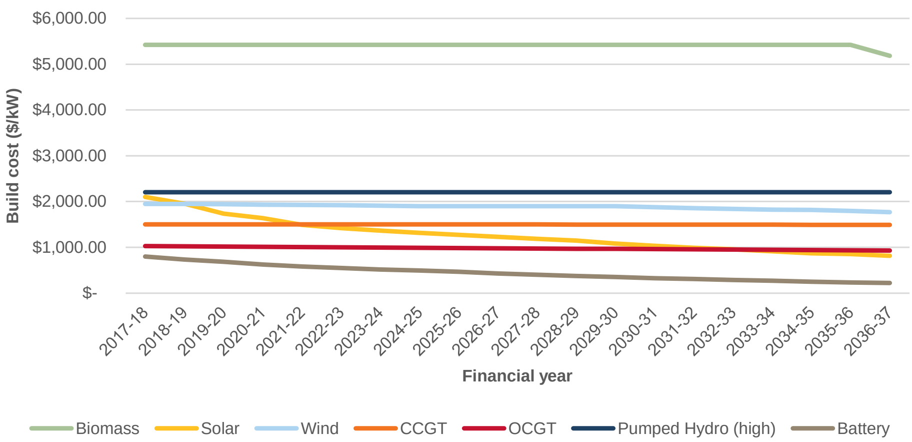
Figure 29 Energy generated by rooftop PV under weak, strong, and neutral growth scenarios



Technology costs

Cost to build new generation developed by CSIRO GALLM and detailed in *Electricity generation technology cost projections: 2017-2050*[66]. Connection costs developed by AEMO and applied at NEM zone resolution.

Figure 30 Build cost by technology (Neutral case, $/kW)



63 Queensland Government, 2017. *Powering Queensland Plan: an integrated energy strategy for the state*, available at https://www.dews.qld.gov.au/electricity/powering-queensland-plan.

64 South Australian Government, 2017. *RenewablesSA*, available at http://www.renewablessa.sa.gov.au/.

65 AEMO, 2017. *Electricity Forecasting Insights*, available at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Electricity-Forecasting-Insights.

66 Hayward, J.A. and Graham, P.W. 2017, *Electricity generation technology cost projections: 2017-2050*, CSIRO, Australia.

Storage technologies

Household and utility-scale batteries are currently modelled with 2kWh/kW energy to power ratio only, and 90% or 80% round-trip efficiency respectively. AEMO intends to test more energy to power ratios of energy storage in the ISP.

AEMO is proposing to model a projected level of aggregation among distributed storage systems which would operate to meet system peaks (rather than household drivers). Two household battery installation trajectories (neutral and strong) and two aggregation trajectories are proposed (45% and 90%), which represent an increasing proportion of new distributed storage systems which are aggregated and optimised to meet system needs, reaching 45% and 90% of new system installations by 2050.

Figure 31 45% aggregation with neutral growth

Gas prices

Gas prices are projected to remain high over the planning horizon.

Figure 32 Regional gas prices for gas-powered generation in time-sequential modelling (Neutral case)

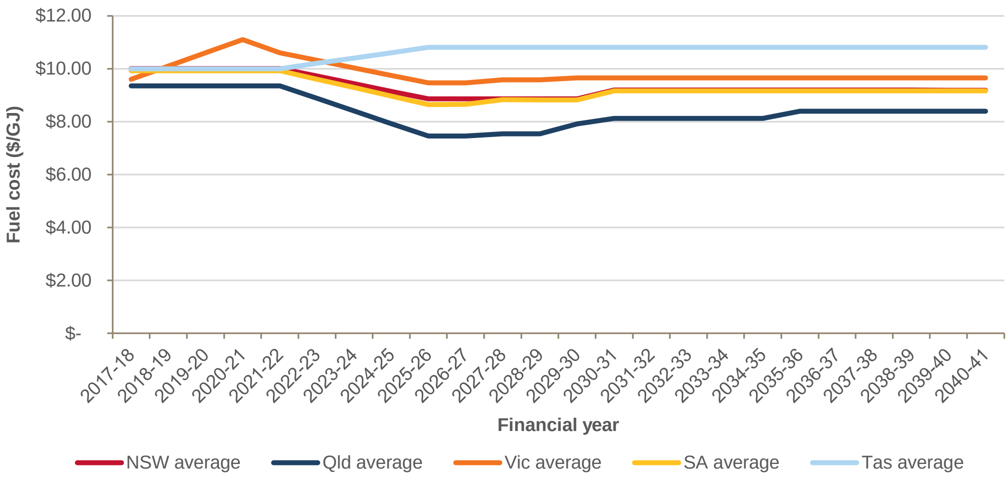
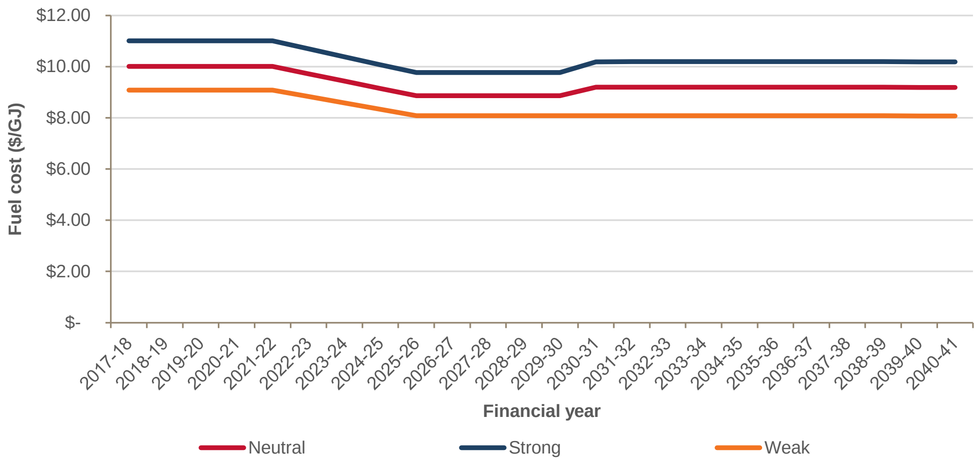


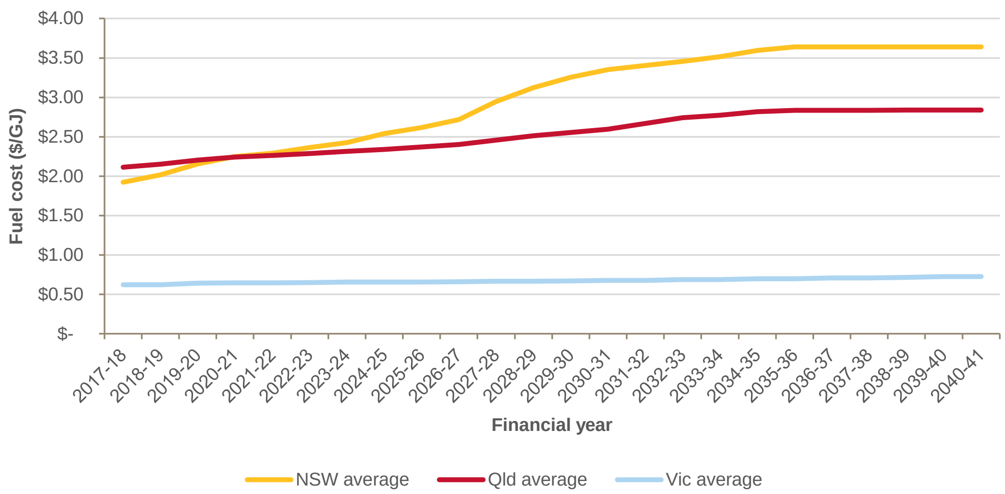
Figure 33 Weak, strong, and neutral gas price scenarios for gas-powered generation (New South Wales)



Coal prices

Coal prices are projected to increase over the planning horizon.

Figure 34 Average coal prices in Queensland, New South Wales, and Victoria (Neutral case)



Transmission augmentations

AEMO proposes considering the following transmission augmentation options:

- Six Queensland – New South Wales options considered, from 0/86 MW to 1037/841 MW increased north and south capacity respectively.
- Seven Victoria – New South Wales options considered, from 170/0 MW to 2,300/1,700 MW increased north and south capacity respectively.
- One or two additional 600 MW HVDC links between Tasmania and Victoria.
- Further interconnection to South Australia via a 500/800 MW west/east capacity link between Buronga, New South Wales and Robertstown, South Australia included from 2021-22 in lieu of ElectraNet RIT-T currently underway.

South Australia – Queensland may be considered as a sensitivity.

Heat rates

Heat rates unchanged since the 2016 NTNDP[67].

Generation location

AEMO's interactive map[68] provides the location of existing generators.

[67] http://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/National-Transmission-Network-Development-Plan/NTNDP-database

[68] AEMO. *Interactive* map, available at http://www.aemo.com.au/aemo/apps/visualisations/map.html.