2019 Planning and Forecasting Consultation responses on Scenarios, Inputs, Assumptions and Methodology

August 2019

Final Report

Important notice

PURPOSE

The publication of this Final Report concludes the consultation on AEMO's planning and forecasting inputs, scenarios and assumptions for use in its 2019-20 publications for the National Electricity Market (NEM). This report outlines the scenarios to be used by AEMO in 2019-20 publications, informing the Integrated System Plan (ISP) and Electricity Statement of Opportunities (ESOO).

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VERSION CONTROL

Version	Release date	Changes
#1	16/8/2019	Initial publication

Executive summary

The publication of this Final Report concludes the consultation on planning and forecasting inputs, scenarios, and assumptions for use in AEMO's 2019-20 Integrated System Plan (ISP) and Electricity Statement of Opportunities (ESOO) publications for the National Electricity Market (NEM).

This Final Report discusses stakeholder submissions to the 2019 Planning and Forecasting Consultation Paper[1], published on 5 February 2019, and explains the amendments AEMO has made in response.

AEMO began the consultation process by publishing the Consultation Paper to seek stakeholder feedback on the scenarios, inputs, assumptions, methodology, timeline, and consultation process proposed to support AEMO's key publications. A key focus was whether the scenarios outlined provided sufficient breadth and internal consistency to inform decision-making supported through AEMO's planning and forecasting publications.

AEMO invited written submissions until 20 March 2019, and held briefings, workshops, and webinars in February, April, May, and June 2019 to solicit feedback from a broad range of stakeholders including consumer representatives, network service providers, generators, market bodies, and jurisdictions.

AEMO received 25 submissions from stakeholders, and attendance was high at each workshop and briefing. AEMO appreciates the valuable submissions and engagement throughout the process, which have helped refine the key inputs used to assess the future development needs of the energy industry.

Substantial changes from the Consultation Paper, based on stakeholder feedback, include:

- Increasing scenario breadth:
  - Adoption of a fifth scenario that would meet the long-term goal of the Paris Agreement[2].
  - Varying technology cost improvements across scenarios.
- Increasing transparency:
  - Application of a carbon budget approach to emissions abatement, rather than using coal retirement timing variations as an input to drive emission reductions.
  - Inclusion of additional data in consultant reports and published supplementary material.
- Increasing internal consistency:
  - Adjustment to the correlation of distributed energy resource development to be positive with economic and population growth, rather than inversely correlated.
- Refining renewable energy zones (REZ) representation:
  - Addition of new REZs in Queensland, New South Wales, and Victoria.
  - Resource build limits now incorporate generator investment interest.
- Capturing physical symptoms of climate change:
  - Inclusion of rainfall inflow variability, including forecast rainfall change affected by climate change.
  - Inclusion of variations in future extreme temperature rise under different scenarios.

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[1] For a copy of the Consultation Paper, non-confidential submissions, and other related information, see https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation.

[2] The Paris Agreement's aim is to limit global temperature rises to no more than 2 degrees Celsius (^{0}C) and ideally less than 1.5^{0}C.

- Updating key inputs:
  - Equivalent weighted average cost of capital (WACC) and discount rate to apply, in accordance with the Regulatory Investment Test for Transmission (RIT-T).
  - Use of generator-submitted closure years, rather than the broad 50-year asset technical life approach.
  - Expanding the proposed generation alternatives to include thermal, renewable, and storage options such as 4-hour battery storages, offshore wind, and greater pumped hydro storage diversity from six hours to 48 hours in depth.
  - Updates to the Marginal Loss Factors and shadow connection points of new entry generators.

AEMO has published the 2019 Forecasting and Planning Scenarios, Inputs, And Assumptions Report (2019 Scenarios Report)[3] and Inputs and Assumptions Workbook[4] to accompany this Final Report on the consultation process. The 2019 Scenarios Report provides further details on the broad inputs, assumptions, and methodologies to be adopted in AEMO's 2019-20 planning and forecasting publications.

[3] AEMO 2019 Forecasting and Planning Scenarios, Inputs and Assumptions Report, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-20-Forecasting-and-Planning-Scenarios-Inputs-and-Assumptions-Report.pdf

[4] AEMO, 2019 Inputs and Assumptions Workbook, at https://aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

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1. Stakeholder consultation process

AEMO has been consulting on scenarios, inputs, assumptions, and methodologies for use in planning and forecasting activities to support:

- AEMO's 2019 Electricity Statement of Opportunities (ESOO) and 2019-20 Integrated System Plan (ISP) for the National Electricity Market (NEM), and
- 2020 Gas Statement of Opportunities (GSOO) for eastern and south-eastern Australia.

The table below outlines the consultation steps AEMO has undertaken.

Table 1 Consultation timeline

Consultation steps	Dates
Consultation Paper published	5 February 2019
Stakeholder workshop	19 February 2019
Submissions due on Consultation Paper	20 March 2019 (with one late submission 8 May 2019)
Submission summary briefing	3 April 2019
Stakeholder workshop (Sydney)	12 April 2019
Consumer engagement approach and ISP workshop	21 May 2019
ISP scenario and assumptions briefing	3 June 2019
2019 Scenarios, Inputs and Assumptions Final Report	16 August 2019

Written submissions to AEMO's Consultation Paper have been published on AEMO's website with this Final Report[5]. One submission and one submission's supporting materials have not been published due to confidentiality reasons.

The publication of this Final Report, and the 2019 Forecasting and Planning Scenarios, Inputs, and Assumptions Report (2019 Scenarios Report), marks the completion of the consultation and presents AEMO's response to the feedback received.

[5] At https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation and at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

2. Background

AEMO uses detailed models to support its efforts in identifying the short-term, medium-term, and long-term needs for the maintenance of security and reliability in the NEM. AEMO uses a scenario analysis approach to investigate the direction and magnitude of shifts impacting the energy sector, and the economically efficient level of infrastructure necessary to support the future energy needs of consumers.

The energy sector is undergoing transformative change:

- The power supply mix is rapidly evolving as both distributed energy resources (DER) and variable renewable energy (VRE) expand, coupled with the retirement of conventional plant.
- Sector coupling is expanding, as complex co-dependencies between multiple sectors such as gas, heating, electricity and transport, water and hydrogen develop.
- Energy markets and regulatory frameworks are struggling to keep pace with the rate and scale of technological change in some instances.
- Climate change and extreme weather is testing the resilience of the NEM in new ways, which are likely to increase further in the future.
- Consumers are playing new roles in the energy ecosystem, and also gaining new rights to their data.
- The global explosion in data volumes and digitalisation is requiring an increasing need for machine learning and artificial intelligence.

AEMO has prepared the Corporate Plan 2020-23[6] to inform stakeholders of its plan to shape a better energy future for all Australians within this rapidly changing energy landscape.

Consistent with its market obligations and the corporate plan, AEMO produces several publications that inform the decision support function for members, stakeholders, and industry partners, and are coordinated and integrated in AEMO's modelling to provide its forecasting and planning advice:

- **Electricity Statement of Opportunities (ESOO)** – the ESOO provides technical and market data that informs the decision-making processes of market participants, new investors, and jurisdictional bodies as they assess opportunities in the NEM over a 10-year outlook period.
- **Gas Statement of Opportunities (GSOO)** – the GSOO provides AEMO's forecast of annual gas consumption and maximum gas demand, and reports on the adequacy of eastern and south-eastern Australian gas markets to supply forecast demand over a 20-year outlook period.
- **Integrated System Plan (ISP)** – the ISP is a whole-of-system plan that provides an integrated roadmap for the efficient development of the NEM over the next 20 years and beyond. Its primary objective is to maximise value to end consumers by designing the lowest cost secure and reliable energy system capable of meeting any emissions trajectory determined by policy makers at an acceptable level of risk. It fully utilises the opportunities provided from existing technologies and anticipated innovations in DER, large-scale generation, networks, and coupled sectors such as gas and transport.

This report outlines responses to stakeholder submissions on the appropriate scenarios, inputs, assumptions, and methodologies AEMO consulted on to support the above publications.

[6] At https://www.aemo.com.au/About-AEMO/Our-vision-mission-and-values.

It is complemented by AEMO's:

- 2019 Forecasting and Planning Scenarios, Inputs, and Assumptions Report[7].
- 2019 Inputs and Assumptions Workbook[8].
- 2019 Market Modelling Methodology Paper[9].
- 2018 Demand Forecasting Methodology Information Paper[10].

2.1 Purpose of AEMO's consultation

The scenarios, inputs, and assumptions are a critical input to AEMO's scenario analysis approach to developing its forecasts of consumer demand and development needs. These scenarios are fundamental to AEMO's planning and forecasting publications to help inform decision-makers of risks and opportunities.

AEMO has been consulting with all interested stakeholders on the scenarios, inputs, and assumptions, to ensure the forecasting approach appropriately considers the plausible range of futures to support each publication. AEMO aims to maximise data transparency to stakeholders prior to modelling commencing, and has made supplementary materials available to complement the key documentation delivered as part of this consultation. These materials are available on AEMO's website[11].

The Consultation Paper invited stakeholder feedback on any relevant issue related to AEMO's planning and forecasting. It also invited submissions to respond to the following specific questions.

Engagement

Q1 How could AEMO further improve stakeholder engagement and confidence in the results of the 2019-20 ISP and 2019 ESOO?

Scenarios

Q2 Do you agree that the proposed scenarios outlined in this section provide plausible and internally consistent future worlds for use in network planning and forecasting publications? Do they provide sufficient stretch for forecasting and planning publications?

Q3 What additional sensitivities should be explored in the 2019-20 ISP or 2019 ESOO, that could materially impact power system planning?

Inputs and assumptions

Q4 Do the proposed inputs and assumptions provide a reasonable basis for assessing the value and direction of the future energy market transition? If not, please provide suggestions for improvement, particularly with regard to consumer embedded investments, large-scale generation technologies, and network and non-network options to support Australia's future energy system?

Q5 Do you have any other feedback on AEMO's proposed input and assumptions?

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7 At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-20-Forecasting-and-Planning-Scenarios-Inputs-and-Assumptions-Report.pdf.

8 At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-Input-and-Assumptions-workbook.xlsx.

9 At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Market-Modelling-Methodology-Paper.pdf.

10 At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/NEM_ESOO/2018/Electricity-Demand-Forecasting-Methodology-Information-Paper.pdf.

11 AEMO's planning and forecasting input, assumptions and methodology documents are at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

Specific consultation requests

Q6 Do you have specific feedback and data to support AEMO on:

a. The list of candidate generation technologies for assessment?

b. The current and future generation technology costs assumed?

c. Generator fixed O&M costs, noting the inclusion of fixed costs associated with mines?

d. The appropriateness of AEMO's assumptions around various storage technologies?

e. The approach on generator retirements, including appropriate costs to convert existing CCGTs to OCGTs providing a peaking, rather than major energy production role?

Material issues for 2019

Q7 For 2019 planning and forecasting activities, what, if any, material issues should be prioritised ahead of the issues proposed by AEMO?

Q8 What other material HILP events should be considered in assessing resilience?

Q9 What mitigation options could be considered to increase grid resilience, and how should these options be evaluated? Is AEMO's proposed approach reasonable?

System strength and inertia requirements methodologies

Q10 What other factors should be considered in the methodologies or proposed 2019 improvements to determine future inertia or system strength requirements?

3. Summary of issues

AEMO received written feedback from 25 stakeholders (see Table 4 on the next page) during the consultation period. Except for one submission that was confidential, these submissions are available on AEMO's website[12]. AEMO was also informed by additional feedback through workshops and one-on-one discussions. The formal consultation milestones are listed in Table 2 below.

Table 2 Consultation timeline for AEMO's forecasting and planning scenarios, inputs and assumptions

Key milestone	Indicative date
Forecasting and Planning Consultation published	Tuesday 5 February 2019
Stakeholder workshop to address any questions of clarification conducted	Tuesday 19 February 2019
Submissions on Forecasting and Planning Consultation received	Wednesday 20 March 2019
Briefing webinar to summarise submissions	Wednesday 3 April 2019
Stakeholder workshop to explore scenarios and resolve issues conducted	Friday 12 April 2019
Consumer Engagement workshop	Tuesday 21 May 2019
Forecasting and Planning scenarios briefing	Monday 3 June 2019
Final scenario and assumptions report published	Friday 16 August 2019

AEMO would like to thank all who provided feedback throughout this process. Submissions covered a broad range of issues, providing AEMO with valuable perspective on stakeholders' collective view of the various proposed settings from the Consultation Paper. While there was broad coverage of issues, there were also common themes (although not necessarily consensus), as shown in the table below.

Table 3 Key themes emerging from stakeholder submissions

Theme	Frequency	Consensus
The **consultation process** and the efforts being made to increase engagement with stakeholders are positive	High	High
Emissions reduction modelling needs to explicitly incorporate policies and account for stricter trajectories	High	High
The current **scenarios** do not sufficiently capture the range of possible energy futures	High	Medium
The modelling of **generator retirements** needs to account for earlier retirements, and be based on more than technical retirement age	High	Medium
Improvements can be made to the **distributed energy resources** modelling approach	High	Low
A commercial **discount rate** should be used, as opposed to a social discount rate below the WACC	Medium	High
Increase the transparency and dynamism of **Marginal Loss Factor** modelling	Medium	Medium

[12] At https://www.aemo.com.au/Stakeholder-Consultation/Consultations/Reliability-Forecasting-Methodology-Issues-Paper

Theme	Frequency	Consensus
The establishment of more **renewable energy zones** and their modelling	Medium	Low
When modelling benefits, incorporate **ancillary benefits and services**, or establish a market for these services	Low	High
System strength is an important issue, and improvements need to be made in terms of how to incorporate it effectively into the models	Low	Medium
Resilience modelling approach: both HILP and mitigation options	Low	Low

This Final Report contains a detailed summary of these themes and specific issues raised in submissions and at meetings/forums, together with AEMO's considered responses as follows:

- Section 4 outlines material issues related to scenarios and sensitivities
- Section 5 outlines material issues related to inputs and assumptions
- Section 6 outlines material issues related to methodology.

Table 4 List of stakeholders who provided written feedback

Organisations	
AGL Energy (AGL)	Infigen Energy
Ausnet Services	Meridian Energy
Australian Energy Council (AEC)	Origin Energy
Australian Energy Regulator (AER)	Snowy Hydro
Clean Energy Council (CEC)	Stanwell Corporation (Stanwell)
Energy Australia (EA)	Tasmanian Networks (TasNetworks)
Energy Networks Australia (ENA)	Tesla Motors Australia (Tesla)
ENGIE	TransGrid
Ergon Energy	University of Melbourne
ERM Power	Walcha Energy
Ernst & Young	WSP Australia
Hydro Tasmania	*1 additional confidential submission*
Investor Group on Climate Change (IGCC)	

4. Discussion of scenarios and sensitivities

This section:

- Discusses the material issues raised in relation to the scenarios, inputs, and assumptions proposed by AEMO for the 2019 ESOO, 2019-20 ISP, and 2020 GSOO.
- Outlines submissions, AEMO's response, and AEMO's conclusions.

4.1 2019 scenarios to apply in AEMO publications

4.1.1 Issues summary and submissions

The original proposed scenarios for 2019-20 were framed around the rate of transformation of the energy sector, and vary in three key dimensions, as shown in Table 5:

1. Level of distributed energy resources (DER), including electric vehicle uptake.
2. Uptake of utility-scale renewable generation (as the lowest cost and least risk form of new generation to replace retiring thermal generators).
3. Growth of energy demand.

Refer to the Consultation Paper[13] for full details of the scenarios initially proposed.

Table 5 Scenario dimensions as proposed in the Consultation Paper

Scenario	DER uptake	Large-scale renewable generation uptake	Energy demand
Gradual change	Medium	Medium	Medium
Fast change	Medium-high	High	Medium
Slow change	Low	Low	Low
High DER	High	Medium or High	Medium

4.1.2 Scenario breadth and emissions abatement ambition

Emissions abatement ambition

The overwhelming theme that dominated almost all submissions was for AEMO to consider scenarios with stronger ambitions for emission abatement, consistent with the aim of the Paris Agreement to limit global warming to well below 2 degrees Celsius (^{0}C).

Stakeholders also considered that the proposed scenarios did not sufficiently capture the range of possible energy futures affecting the NEM more generally.

[13] At https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation.

Concerns raised included:

- **Infigen Energy**, **the Investor Group on Climate Change (IGCC), the Australian Energy Council (AEC), ERM Power, the University of Melbourne, Hydro Tasmania, TransGrid, ENGIE, Walcha Energy**, **WSP Australia, and AusNet Services** articulated a strong need for the scenarios to address Australia's international commitments to the Paris (COP21) emissions reduction – not just the 26-28% emissions reduction target by 2030, but also the net zero emissions by 2050 target.
- **Infigen Energy** said history shows that there are real measurable costs that can be avoided if future scenarios do not simply assume 'straight line' extrapolation of current trends, but also consider step changes in the grid.
- **AusNet Services** suggested a scenario with early coal retirement should be considered in preference to simply being a sensitivity analysis
- The **IGCC** recommended that the Central scenario (formerly Neutral scenario) be aligned with achieving the objectives of the Paris Agreement and achieving net zero emissions in the sector by 2050 at the latest, noting that all major NEM regions have committed to achieving net zero emissions by 2050. **Infigen Energy** also suggested that the Central scenario represent the "best available extrapolation of current policies and trends". Infigen suggested that AEMO needed to consider a balance between current policies and the transformation required by the Paris Agreement (for which there is bipartisan support). The **AEC** emphasised that the Central scenario should not simply be a 'change nothing' scenario but represent the most likely case.
- **Hydro Tasmania** suggested that a scenario with substantial electrification – particularly of vehicles – would be a plausible scenario that may have a substantial impact on the power system.
- **ENGIE** suggested that a scenario with very low economic performance is needed, to consider the possibility that Australia's recent run of 28 years of continuous economic growth continuing for another 20 years may be optimistic. ENGIE asked AEMO to include a scenario with negative growth in some years as a bookend scenario. This suggestion was supported by the **AEC's** submission.
- **EnergyAustralia** sought clarification on the purpose of the scenarios, suggesting that scenarios should be used to test the impact of different assumptions, not to suggest a likely future outcome. In EnergyAustralia's view, the inherent danger in presenting a middle, business as usual (BAU), or 'central' scenario is that it is likely to be interpreted as having a high level of certainty. EnergyAustralia said decision-making should be tested across scenarios for robustness, and it was unclear why a single case is required. EnergyAustralia also suggested that the high and low scenarios should represent bookends of all the underlying consumption drivers in aggregation, with multiple sensitivities used to test particular assumptions and internally consistent paths
- **Snowy Hydro** suggested the High DER scenario should be separated into two different scenarios.
- The **University of Melbourne** stated "the scenarios considered do not align with the required emissions reductions to achieve commitments made in the Paris Agreement", providing the following figure as part of its submission.

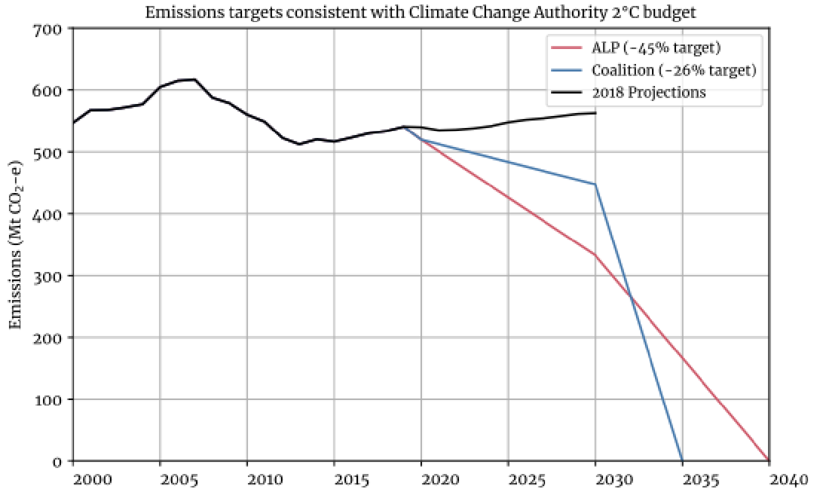

Figure 9: This figure illustrates the latest emissions projection from the Department of the Environment. On current projections, the 10.1Mt emissions budget determined by the CCA would be exhausted in 2031. Trajectories based on the current ALP and Coalition commitments and also consistent with the 10.1Mt budget are also illustrated.

Clarity of narrative

AEMO also received feedback during its February workshop highlighting the critical importance of having scenario narratives that were as clear as possible, to help everyone interpret/assess consistency and understand outcomes.

4.1.3 AEMO's assessment

Scenario breadth and emissions reduction ambition

AEMO has evaluated the breadth of the scenarios it proposed in the Consultation Paper, which differentiated scenarios considering the level of DER uptake, large-scale renewable generation development, and energy demand.

AEMO has incorporated the feedback and is now expanding the scenarios to capture broader changes including faster decarbonisation of the energy sector and the broader economy. This scenario was strongly, and nearly unanimously, requested by commentators. Commentators particularly requested that AEMO model what would be required to at least achieve the breadth of emissions abatement outcomes that could be considered as reasonable.

AEMO convened a workshop on 12 April 2019 with 37 participants from 24 organisations across the whole energy value chain, facilitated by Boston Consulting Group (BCG), to help refine the scenarios, scenario narratives, and associated inputs. At this forum, AEMO introduced a fifth scenario – a Step Change scenario – that incorporated a rapid increase in domestic and international climate commitments and developments to help meet the Paris Agreement aims. The scenario narrative was widely supported by the forum participants , and AEMO has now included this fifth scenario.

Unlike the Fast Change scenario, which places greater emphasis on technology-led developments to address climate change, and the High DER scenario, which places greater emphasis on consumer-led innovation, the Step Change scenario provides a balance of technology development at large scale and consumer-led innovation, and the highest degree of electrification of the transport sector. This type of action will be necessary to help meet the level of decarbonisation in line with the Paris Agreement[14] aims to limit global temperature rises to no more than 2⁰C and ideally less than 1.5⁰C.

[14] At https://unfccc.int/sites/default/files/english_paris_agreement.pdf.

Scenario breadth as a function of demand and economic growth

Two stakeholders requested that AEMO's demand assessments consider negative economic growth. AEMO has engaged Deloitte Access Economics to assist in developing the broader economic settings appropriate for each scenario. While periods of economic recession are possible and potentially even likely across a horizon as long as AEMO's forecasting horizon, AEMO considers it unnecessary to consider the impact of short-term fluctuations in economic growth, given that planning assessments focus on system development needs in the long term. The current scenarios are, in AEMO's view, sufficient to cover the range of long-term potential outcomes. This is supported by Deloitte's independent assessment of AEMO's scenarios.

Scenario analysis as an appropriate method for an actionable ISP

Given the current process underway to make the ISP actionable, and the need to align with the Regulatory Investment Test for Transmission (RIT-T) process, AEMO agrees with stakeholder feedback that it is important to consider the guidance contained in the RIT-T guidelines surrounding scenario analysis[15]:

- *As a principle, be conscious of the current NEM reforms and relevant policy developments, including:*
    - *Electricity pricing reforms.*
    - *The development of new markets and products, such as demand response markets and products that allow consumers to select their own price-reliability preference.*
    - *Policies relating to features of the NEM, such as those concerning carbon emissions, renewable energy, reliability, energy security and other factors. For example, if evidence supports there being a reasonable possibility of policy change (including introducing a new policy or altering/withdrawing a current policy) that could affect the ranking or sign of credible options (or just the ranking, if the identified need was for reliability corrective action), the RIT–T proponent should include a reasonable scenario where this policy change occurs.*
- *Construct scenarios that are genuinely reasonable, in that they comprise of internally consistent parameters so that they can define a reasonable range of plausible states of the world.*

AEMO's assessment of the mix of scenarios has this objective at its core, and it reinforces the need for a fifth scenario to be considered that addresses potential policy change.

4.1.4 AEMO's conclusion

AEMO has adjusted its scenario definitions based on stakeholder feedback. The final scenario narratives are summarised below:

- **The Central scenario represents the current transition of the energy industry** under current policy settings and technology trajectories, with the transition from fossil fuels to renewable generation, generally being led by market forces and supported by current federal and state government policies.
    - The Gradual Change scenario proposed in the February Consultation Paper has been renamed as the Central scenario. It remains the scenario with current policy settings and central estimates of all key drivers. This isn't a "do nothing" scenario, rather a scenario that will investigate expected developments given existing signals.
- **The Slow Change scenario represents a general slow-down of the transition.** It is characterised by slower advancements in technology and reductions in technology costs, low population growth, and low political, commercial, and consumer motivation to make the upfront investments required for significant emissions reduction.

[15] Australian Energy Regulator p.43 of the RIT-T application guidelines, at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf.

- **The High DER scenario represents an even more rapid consumer-led transformation** of the energy sector, representing a highly digital world where technology companies increase the pace of innovation in easy-to-use, highly interactive, and engaging technologies. This scenario includes reduced costs and increased adoption, with automation becoming commonplace, enabling consumers to actively control and manage their energy costs, and consumer-led preferences leading to widespread electrification of the transport sector.
- **The Fast Change scenario represents a rapid technology-led transition**, particularly at grid scale, with advancements in large-scale technology improvements and policy support reducing the economic barriers for an energy market in transition. This includes coordinated national and international action towards achieving emissions reductions leading to manufacturing advancements, automation, and integration of transport into the energy sector.
- **The Step Change scenario represents strong action on climate change** that leads to a step reduction of greenhouse gas emissions. In this scenario, aggressive global decarbonisation leads to faster **technological improvements**, accelerated exit of existing generators, greater electrification of the transport sector with increased infrastructure developments, energy digitalisation, and **consumer-led innovation**.

Details of these scenarios are presented in the 2019 Scenarios Report.

4.2 DER correlation to growth in the scenarios

4.2.1 Issue summary and submissions

The Consultation Paper proposed that DER settings – that is, the level of rooftop photovoltaics (PV), embedded battery storage systems, and electric vehicle (EV) developments – be configured to maximise the degree of stretch affecting grid consumption across scenarios, to the extent plausibly possible. It proposed a purposeful anti-correlation between economic and population growth and consumer preferences for DER, to stress test the needs of the transmission network across scenarios.

The Consultation Paper also considered that the collection of scenarios (including the High DER scenario) would provide the likely reasonable bounds for power system development, and that additional scenarios with alternate settings would not be necessary to test the boundaries of these outcomes.

Stakeholders considered the proposed approach did not appropriately align DER investment and growth, and recommended additional scenarios at least be considered to test the impact of these consumer settings:

- **Stanwell** suggested anti-correlation of DER with economic growth to stretch demand outcomes no longer seemed appropriate, and internally consistent drivers affecting the uptake of DER components should be applied.
- **TasNetworks** identified a need for AEMO to consider increased amounts of DER in the Fast Change scenario, which it considered a more likely outcome and relevant to consider for any subsequent RIT-T examination. TasNetworks also recommended that DER and demand side participation (DSP) could be assigned a resource cost, allowing an optimised level of investment across scenarios, or, if this was impractical, that the level of DER and DSP be varied in response to prices faced by consumers (or a suitable proxy thereof).
- The **Clean Energy Council** suggested AEMO examine both a high and low level of DER growth paths, and supported AEMO's sensible explanation for the inverse relationship between DER and utility-scale renewable energy developments but considered that a scenario with both growing DER and large-scale investments would be valuable.
- **AusNet Services** also suggested that, even though it may be plausible for an inverse relationship to exist between DER and large-scale renewables, state schemes (such as the Solar Homes package and Victorian

Renewable Energy Target [VRET] schemes in Victoria) are likely to result in high uptake of rooftop PV as well as high investment in large-scale renewable generation

- **ERM Power** considered that AEMO had correctly identified that DER growth will continue, and suggested forecast DER uptake would be improved through consideration of the technical settings, costs, and technical restrictions that may face customers within the distribution networks
- **Infigen Energy** considered that a scenario with full electrification of the transport sector is necessary, and the uptake is more likely to be sigmoidal in shape (which Is difficult to forecast from traditional extrapolation models).

4.2.2 AEMO's assessment

AEMO recognises that many factors may impact the speed and scale of DER development. High growth in embedded rooftop PV systems has been observed over a number of years as the cost of PV systems has declined, increasing the affordability of larger systems. This is despite a reduction in subsidies and feed-in tariffs, increasing the payback period for consumers. Battery systems have not (yet) had the same degree of growth as rooftop PV systems; the appetite for this technology will exist when payback times reduce.

AEMO's Consultation Paper proposed an anti-correlated approach, consistent with what was assumed in the 2018 ISP, that reflected a positive relationship between customer hardship and DER investment get greater differences in operational demand on the grid. However, AEMO agrees that this relationship is weak. The more likely drivers of DER investment are economic and population growth, given the higher household disposable income that might be expected under stronger economic conditions, better market designs, new business models, and supportive policies. AEMO therefore welcomes the support from stakeholders to move away from the approach taken in the 2018 ISP, and will now consider a broader range of possible DER outcomes that are more consistent with the scenario narratives.

TasNetworks suggested that DER (and DSP) be provided a resource cost to allow dynamic calculation of the appropriate level of consumer investment in energy solutions. At this time, AEMO does not have the array of data required, including the consideration of potential distribution network limitations in the scope and scale of the ISP models. As such, at this time it is a necessary simplification to provide this setting as an input, presently developed through independent consultants' own top down and bottom up models, and tested through discussion with stakeholders at AEMO's Forecasting Reference Group.

AEMO is currently investigating a range of influences on DER investment as part of the DER Program, as well as collaborations with CSIRO in developing the "GenCost" report (which identifies annual projections of electricity generation technology costs) and with CSIRO on the National Energy Analytics Research (NEAR) program (which applies greater data analytics to discover trends and insights from existing available energy data sets).

AEMO is also actively working with distribution network service providers (DNSPs) to understand the distribution-level impacts of increasing penetrations of DER and the integration costs associated with being able to accommodate the levels projected in the ISP.

AEMO agrees with Stanwell's suggestion that the scenarios need not be configured to deliver maximum stretch of the expected level of electricity consumption.

4.2.3 AEMO's conclusion

AEMO's final scenarios re-align DER growth positively with economic and population growth.

The High DER scenario will continue to represent high DER development, as an alternative to large-scale investment, while the Fast Change and Step Change scenarios will also have greater DER investment than the Central scenario. Details of the specific settings of the relative contributions of DER across the scenarios are in the 2019 Scenarios Report.

4.3 2019 sensitivities to investigate

4.3.1 Issue summary and submissions

The Consultation Paper proposed to use sensitivities beyond the core scenarios to examine the sensitivity of outcomes to:

- Assumptions around pumped hydro energy storage (PHES) potential capacity and costs.
- Variations in the timing of coal-fired generation retirements.
- Variations in the choice of weighted average cost of capital (WACC) and/or the social discount rate.

Stakeholders suggested the following additional sensitivities be considered:

- **ERM Power** suggested that the Fast Change scenario should examine several variants, particularly flatter duration curves, lower maximum demand, and changes to transport fuel and transmission expansion patterns.
- **TransGrid** recommended sensitivities with earlier coal retirements than expected by the market, or for a sudden coal withdrawal. TransGrid also suggested that increased outage rates and/or maintenance costs should be considered across scenarios, reflecting recent performance trends.
- **EnergyAustralia** suggested that the operational modes of battery systems be tested, particularly given the role and effectiveness of Virtual Power Plants (VPPs) is highly speculative at present. EnergyAustralia also recommended that a sensitivity to model the impact of extreme drought conditions through coincident low levels of hydro and wind generation be considered.
- **Walcha Energy** submitted that in planning the future NEM, risks of early closure to Vales Point or another similar major power station in New South Wales be considered.
- **WSP Australia** considered that AEMO should conduct a sensitivity with higher pumped hydro potential (for example, double or triple the currently identified build limits).
- **Hydro Tasmania** suggested that a sensitivity with solar PV and wind generation costs at an equivalent level be considered (rather than solar PV being the cheapest source of energy, as suggested in the Consultation Paper and companion Assumptions Workbook).
- **AGL Energy** suggested that the scenarios seemed somewhat limited in their ability to capture the complexity of the future operation of the NEM, and that expansion may be necessary to include increased variability that may exist in the real world (potentially via more sensitivities)

4.3.2 AEMO's assessment

In any scenario analysis, AEMO considers that it is important that scenarios be defined to adequately capture the spread of potential future worlds while sensitivities are designed to validate the significance of key assumptions within a given future.

The appropriate spread and magnitude of sensitivity analyses must depend therefore on the purpose and scope of the modelling conducted. For the 2019-20 ISP, AEMO will use sensitivities to determine how resilient the development plan is to variations in key assumptions.

AEMO thanks stakeholders for the range of sensitivities suggested. While desirable to run a multitude of sensitivities, it is necessary to rationalise the list and focus on those assumptions considered most material and uncertain given the computational requirements of the ISP. Therefore, where possible, AEMO has varied uncertain assumptions (such as technology costs) across scenarios, and only identified a small number of key sensitivities where it is important to know the materiality of discrete changes in decisions or events that may be announced during the course of the analysis. Other sensitivities may be tested, if time permits.

4.3.3 AEMO's conclusion

AEMO's will use sensitivities appropriately to investigate the key modelling variables, and the relative resilience provided by various development options to determine the preferred developments considering all modelled scenarios.

At a minimum, this may include:

- Delays to the timing of the Snowy 2.0 committed project.
- Early retirements of existing generation.
- Development of the Battery of the Nation project, including the appropriate level of transmission to deliver the capacity to the mainland NEM.
- Alternative levels of state-based renewable energy policies not currently legislated, for example, the Queensland Renewable Energy Target (QRET).

AEMO considers that the range of scenarios assessed may require additional analysis and may add sensitivities as the modelling develops.

5. Discussion of assumptions and inputs

In addition to the specific comments related to the scenarios, DER settings, and appropriate sensitivities, stakeholders raised a number of broader issues around the inputs and methodology in AEMO's proposed planning and forecasting models, particularly for the 2019-20 ISP. These are discussed in the sections below.

5.1 Approach to emissions policy and coal generator retirements

5.1.1 Issue summary and submissions

Traditionally, emission abatement policies and/or targets are treated as key inputs that drive different scenario outcomes. However, emission reduction targets for the stationary energy sector to 2050 are highly uncertain. They depend on future government policies that are not yet known, as well as assumptions around the energy sector's contribution to economy-wide reductions. The pace of decarbonisation is uncertain and subject to change during the modelled period, based on policy changes and other factors such as technology evolution.

AEMO proposed tuning scenarios to cover a range of emission reduction outcomes based on different timings of coal-fired generation retirements, rather than imposing arbitrary stationary energy sector emission reduction targets to 2050. Under this approach, emissions would be an outcome of the changing resource mix.

This approach received little support from stakeholders in the formal submissions, with many voicing strong disagreement. Stakeholders said that the degree of emissions ambition across the scenarios should be transparent, so there could be greater visibility into the dynamics that must be considered when determining the optimal infrastructure required to support the power system under various emission scenarios.

Concerns raised included:

- Inconsistency of adopting emissions reduction as a function of the generation mix outcomes (via it being driven through coal retirement settings), while renewable energy targets are model inputs (raised by the **AEC**).
- A view that modelling must take into account the fundamental changes that could impact the power system, which include credible possible emission reduction policy objectives. The generation mix will change to meet emission reduction requirements, not the other way around, therefore the emission reduction trajectory should be a discrete input to the modelling process (**Infigen Energy, the AEC, ERM Power**).
- Lack of transparency on the overall emissions reduction objectives by tying emissions reduction to coal retirements. Unclear how the timing of these coal retirements would be determined, and on what basis (**Infigen Energy, TasNetworks, Stanwell, the AEC, the IGCC, Origin Energy, Snowy Hydro**).
- The **AEC** suggested AEMO's proposed approach to *"treat emissions as an output of the changing resource mix"* was inconsistently applying policy settings, given the presence of the federal Large-scale Renewable Energy Target (LRET) and other state-based targets as inputs to its forecasts. The AEC did not consider this to be the likely progression of national emissions policy, saying that the generation mix will need to change, and that this should be the outcome of least-cost modelling rather than the reverse. The AEC considered that that AEMO should publish, consult on, and apply explicit emissions trajectories.

- **Infigen Energy** recommended applying an emissions trajectory to each scenario, allowing the model to determine the least-cost combination of technologies to meet demand and other constraints. This would enable AEMO to efficiently consider all technologies, including energy storage, gas (open cycle gas turbine [OCGT] or combined cycle gas turbine [CCGT]), fossil fuel with carbon capture, and storage, and avoid the need to make assumptions about the mechanism by which emissions might be reduced.
- **Snowy Hydro** stated that the closure of only coal-fired generation would be unlikely to give the desired emissions reduction outcome and would be difficult to compare against the policies of Australia's major political parties.
- The **IGCC** stated that a core and fundamental challenge for energy policy is the integration of climate change and energy policy. The Consultation Paper proposed that planning scenarios will not be constrained by emissions targets, and the IGCC considered this would send the wrong signal to investors on how climate change and energy policy will be integrated into electricity market planning in the future. It is not credible to expect investors to act on the assumption that emission constraints will not be a major theme impacting future investment returns for the energy sector.
- **ENGIE** suggested that the modelling may be more flexible if an emissions constraint was modelled to meet a cumulative emissions target by 2030 and another one at 2050. This method would minimise costs of meeting the cumulative emissions target and may determine that earlier reductions in emissions may be more effective. ENGIE suggested AEMO formulate the emission constraint based on cumulative emissions when seeking least-cost solutions.
- **ERM Power** suggested that generator retirements should be considered across a range of factors, rather than being discrete inputs, including revenue adequacy, operating and maintenance costs, and the likelihood of plant refurbishment. ERM said an emission reduction trajectory should be a discrete input to the modelling process, which would then allow the trajectory to be met on a least-cost approach basis.
- **Hydro Tasmania** said the proposed approach to capture emissions reduction variability by changing coal retirements as inputs may not provide flexibility to model various emissions or demand profiles
- **TasNetworks** asked that, when analysing the emissions outcomes of all scenarios and sensitivities, the emissions profiles be compared with the emissions reduction policy of the government of the day. Sensitivities should be conducted if the emissions reduction outcomes do not meet this policy, using a mandated emissions profile as a model input if necessary. The outcomes of such a sensitivity would then inform the public debate as to what additional costs and actions are necessary to achieve a particular emissions reduction profile.
- **EnergyAustralia** requested due consideration of federal and state targets for renewable generation, such as the (former) Federal Labor policy of 50% renewables and 45% emissions reduction targets, and the Victorian Government's VRET. EnergyAustralia said these reflect more likely approaches to emissions reduction in the current political climate than defining an emissions trajectory up front.
- The **University of Melbourne** recommended that scenarios reflect at least a limited emissions approach for the NEM, reflective of the [carbon] budget derived by the Climate Change Authority (CCA) in their electricity sector analysis.

Carbon pricing

Stakeholders suggested that a carbon price may be a reasonable consideration for the 2019 scenarios:

- **Tesla** suggested that it would be instructive for AEMO to explore modelling sensitivities that can transparently quantify the impact that a carbon price will have on the generation mix and future grid requirements. This would provide at least one pathway that can support the investment certainty required for low emission energy technologies, and could complement the inclusion of a risk premium to financing costs to reflect this carbon price risk for fossil-fuel plant, as is evident in the financial markets currently.

- **Hydro Tasmania** suggested that a form of carbon pricing mechanism is a credible future scenario, and that it is important this is covered in the modelled scenarios, because it would provide an indication of the marginal cost of abatement in the electricity sector.
- The **Clean Energy Council** suggested that AEMO explore modelling sensitivities that can transparently quantify the impact that a carbon price will have on the generation mix and future grid requirements.

Emissions reduction – role of other sectors

Stakeholders identified the need to consider the role of other sectors of the economy in assessing the means for broader domestic decarbonisation.

- The **AEC** suggested that interaction with other sectors needs to be considered in the modelling. For example, policies which increase EV penetration will change power system demands and affect generation retirement decisions, and coal-fired generation retirement may increase natural gas and perhaps diesel emissions as replacement plant seeks to fill the gap in dispatchability. The AEC suggested AEMO contemplate a national CO_2 emissions budget for all economic sectors, to consider the cost and effectiveness of electricity sector decarbonisation relative to other sectors in the economy where emissions reductions are harder and more expensive to deliver.
- **Infigen Energy** stated that opportunities for emissions reduction are more readily available in the near term in the electricity sector than in other sectors of Australia's economy. Infigen suggested AEMO could take a lead role in identifying the potential impacts on the electricity sector from this transition, as well as opportunities to improve the efficiency of decarbonisation. Collaboration with the CSIRO or similar bodies would support this aim, drawing together and leveraging the outputs of relevant studies and analysis from across industry and academic stakeholders (as well as AEMO's own internal modelling). For example, AEMO could leverage the output of existing whole of economy models to identify requirements from the electricity sector and provide input key inputs into future modelling exercises.

Coal generator retirements

Stakeholders suggested that AEMO's proposed method of using generator retirement timings as the primary variable for achieving decarbonisation removed a key layer of transparency required to support the objectives of the ISP.

- **TransGrid** emphasised the importance of coal-fired generator retirement timings, and urged AEMO to specify the exact retirement timings for each generator under the scenarios, particularly the scenarios with stronger emissions abatement objectives.
- The **AEC** believed it would be helpful if AEMO set out its assumptions regarding retirement dates.

5.1.2 AEMO's response

Emissions trajectory constraints

There was nearly unanimous concern around AEMO's proposal to avoid directly including future emission trajectories as a scenario input, but rather to use variations in closure of thermal generation and development of renewable generation as a proxy for future policy. It is clear from submissions that the limited degree of transparency on triggers for coal retirements, and the removal of emission abatement trajectories as an exogenous modelling input, has not been broadly accepted by stakeholders.

To address this stakeholder feedback, AEMO has considered an alternate approach which sees the emission abatement and climate change consequences form part of the scenario input but still avoids directly anchoring it to any particular party policy. This approach assigns different global temperature outcomes to each scenario, using Representative Concentration Pathways[16] (RCPs) that broadly align with AEMO's scenario narratives, and translates them to an Australian context. This approach was presented at a stakeholder

[16] Australian Government Department of the Environment and Energy: https://www.environment.gov.au/climate-change/publications/fact-sheet-rcps

workshop on 12 April and was generally accepted. The approach does not link the emissions trajectories to any particular government policy, particularly as these may change over the medium term as Australia's Nationally Determined Contribution (NDC) commitment evolves as part of the five-yearly NDC cycle which is central to the Paris Agreement. For example, the Central scenario will include as a minimum the current NDC of 26% emission reduction by 2030, while other scenarios would provide a broader range of decarbonisation ambitions.

AEMO acknowledges there is a large amount of climate science that provides quantitative support regarding the future climate pathways expected globally with varying levels of emissions abatement, and in turn the level of temperature change that may be expected locally in each future. Each scenario has been allocated an RCP that represent greenhouse gas concentration trajectories that are consistent with the scenario narratives. The RCPs have been developed by climate scientists to describe possible pathways for atmospheric greenhouse gas concentrations, and the associated climate change impacts. Development of "Shared Socio-economic Pathways" (SSP) has broadened the future climate scenarios, providing narratives around global emissions drivers, mitigative capacity, and adaptive capacities that may result in particular RCPs. The RCP/SSP framework is designed to be complementary, and AEMO has considered it appropriate to continue to focus on the RCPs selected, thereby maximising flexibility in scenario specification.

The CCA's 2014 analysis[17] on climate targets and Australia's progress towards medium-term and long-term emissions reduction targets has been considered as a particularly useful guide for determining appropriate Australian and NEM carbon budgets. In considering the role of emissions trajectory constraints in the modelling, AEMO is mindful that there is not a single pathway towards achieving a long-term degree of decarbonisation ambition, and that it is the end goal rather than the pathway itself that should be targeted in AEMO's modelling. That is, AEMO agrees with several stakeholder submissions that multi-year emissions budget constraints would be the preferred mechanism to achieve emissions reductions at lowest system cost and maximum economic efficiency.

AEMO has therefore developed NEM carbon budgets to 2050, broadly consistent with the CCA's 2014 analysis of emissions trajectories (considering global per-capita emissions), and adjusted to be consistent for each scenario, reflecting the level of contribution from the electricity sector. As the NEM is the dominant electricity grid nationally, most decarbonisation action is expected to occur in the NEM regions, and AEMO's calculations scale the NEM contribution by the relative share of national electricity consumption. Emissions trajectories that adhere to the carbon budget constraints will be an output from the modelling for each scenario.

Carbon pricing

Pricing carbon emissions is one method for encouraging market forces to deliver an emissions reduction ambition efficiently. The NEM experienced a period of carbon pricing in 2012 to 2014, and the carbon price legislation was repealed at the beginning of the 2014-15 financial year. Since that time, neither major political party has committed to an explicit carbon price as part of their policy settings. In addition, renewable generation technologies are becoming cost-competitive with conventional new entry generation even without subsidies. As such, AEMO does not apply a price-based mechanism to achieve decarbonisation. Rather, AEMO's approach may apply a volume-based carbon budget to suit each scenario's level of decarbonisation ambition, and the modelling does not, and does not need to, stipulate the actual mechanism for achieving this outcome. Several market structures could be developed to support this objective, and it is beyond AEMO's planning scope to quantify and articulate the impacts of each mechanism.

Emissions reduction – role of other sectors

Decarbonisation is broadly considered more cost-effective in the electricity sector, ahead of other major sectors such as agriculture, transport, industrial processes, and other smaller industries. AEMO's scenarios

[17] Climate Change Authority, Targets and Progress Review, 204, available at http://climatechangeauthority.gov.au/reviews/targets-and-progress-review-3 (Appendix C)

incorporate an increasing role for an electrified transport sector, with the Step Change, High DER, and Fast Change scenarios having stronger EV growth than in the Central scenario, in part due to the decarbonisation objectives of each scenario. As such, decarbonisation of other sectors is inherent in AEMO's emissions reductions from the electricity sector.

Decarbonisation of the gas sector is not explicitly modelled at this stage, but may be considered in future ISPs.

In identifying the overall emissions reduction ambition of the electricity sector, AEMO has considered that full decarbonisation of the sector may pose additional technical challenges, currently the subject of detailed technical studies. Future ISPs may include potential zero emissions scenarios.

Coal generator retirements and revenue sufficiency

AEMO recognises that there has been broad rejection by stakeholders of the proposed approach to vary coal retirements as a means of achieving emissions reduction. Stakeholders voiced concerns that this approach would reduce transparency, increase subjectivity, and move away from an optimised solution. As such, AEMO will not adopt the proposed method, and will instead approach decarbonisation through the application of current government policies (in the Central, Slow Change, and High DER scenarios) and an emission carbon budget (in the Fast Change and Step Change scenarios).

AEMO will apply the expected closure years that have been supplied by generators to AEMO and published in AEMO's Generation Information data package[18]. These dates will be applied as the latest date for retirement in all scenarios except Slow Change, where life extensions will be allowed if modelling indicates it is economic to do so. Economic retirements driven by revenue inadequacy are possible and will be assessed within the modelling (see Section 6.5).

AEMO's recent work with Aurora Energy Research[19] has highlighted that the expected revenues of coal-fired power stations are likely to be broadly sufficient to continue operating to end of technical life, at least in expected futures, however, this may not apply in all future scenarios with different supply mixes. Aurora Energy Research went on to identify specific generators most at risk under certain conditions.

Specific generators that are 'at risk' are difficult to identify, as they are influenced by a number of factors that AEMO's assumptions cannot reasonably include, such as contract positions across the portfolio, condition of assets, and overall company strategy. AEMO's modelling incorporates independent assessments of generator costs and may identify capacity that is operating with utilisation variability – a potential 'lead indicator' of plant at risk in the absence of detailed confidential financial information.

AEMO's revenue sufficiency analysis will then use detailed time-sequential modelling of snapshot years of each scenario to demonstrate the operability of the power system with the forecast future energy mix. As part of AEMO's iterative modelling framework, at-risk generators that are deemed to operate at uneconomic operation levels will be retired within the capacity outlook modelling, and the future energy mix re-simulated to ensure the robustness of the power system. This would be similar to the expected supply mix which may be expected with sufficient (three years') notice of economic closure.

AEMO acknowledges that a number of factors will ultimately influence the financial viability of any given generator and highlighting a particular participant as 'at risk' could potentially be misinterpreted. In publishing its advice, AEMO may aggregate outcomes to avoid any potential misinterpretation of the modelling outcomes.

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[18] AEMO, Generation Information page, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information.

[19] See Aurora Energy Research reports providing an independent third-party assessment of the benefits provided by the 2018 ISP and assessment of the coal closure timings, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan.

5.1.3 AEMO's conclusion

Emission reductions for the Central scenario will be a natural consequence of current government policies and expected closure years for existing thermal generation. In other scenarios, carbon budgets to 2050 will be assumed, consistent with scenario narratives.

Annual emission trajectories will remain an outcome of the modelling, based on these inputs. Details of the carbon budgets are provided in the 2019 Scenarios Report.

For the 2019-20 ISP, AEMO will perform assessments of modelled snapshot years to test the revenue sufficiency and operating conditions of coal-fired power stations to determine whether the timing of retirements across scenarios is appropriate.

5.2 Distributed energy resources

5.2.1 Issue summary and submissions

DER considerations

Several stakeholders have requested that AEMO consider specific technical considerations in forecasting the future uptake of DER:

- **ERM Power** suggested that the forecast uptake of DER would be improved through the consideration of the following technical factors impacting uptake:
  - The ability of the current distribution network to facilitate increasing rollout of DER.
  - Estimates of additional costs to facilitate the increased rollout of DER.
  - The impact of potential changes to network tariff structures on the future rollout of DER.
  - Ongoing maintenance and disposal costs.
  - Potential saturation levels for DER.
  - Potential impacts of increased DER on power system resilience.
- **Ergon Energy** recommended that the DER datasets be transparent to stakeholders and include more granular information regarding the uptake, charge, and discharge profiles, and for the datasets to be provided on the same measurement basis (on a 'sent out' basis), with separation for aggregated (VPP) and disaggregated capacity. Ergon also requested that the aggregate number of installations of various DER categories be provided.
- The **Clean Energy Council** suggested AEMO consider the following additional considerations:
  - The significant growth in smart DER systems and smart appliances.
  - Validating assumptions for EV growth paths.
- **AusNet Services** requested data improvements by providing more context around some DER inputs:
  - Solar penetration forecasts (percentage of dwellings with rooftop PV).
  - Number/average size of batteries.
  - Percentage of total vehicle fleet/percentage of new vehicle sales which are electric.

Virtual Power Plant integration

Two stakeholders provided feedback on the appropriate role of VPPs in the forecasting:

- **TransGrid** suggested that the extent of future VPP deployment and coordination is a significant area of uncertainty, with many organisations currently assessing the potential of these technologies to deliver benefits to consumers, networks, and the wholesale market. TransGrid supports AEMO testing a range of DER and demand response scenarios and recommends AEMO test a range of VPP levels across scenarios.

- **Tesla** noted support for AEMO's intention to include the impact of early VPP trials (with up to 700 megawatts [MW] of VPP-enabled deployments by 2022) across all scenarios. Tesla also encouraged AEMO to specify scenarios for how DER assets operating in aggregate may be scheduled – including the minimum size requirements for scheduling.
- **Stanwell** commented that it is unclear the extent to which DER would be exposed to sufficient signals to facilitate their participation in the market, or whether their operating mode would remain static.
- The **Clean Energy Council** noted that further clarity is required on the management and growth of DER, such as who is assumed to be able to control individual and/or aggregated DER and what is considered an appropriate level of aggregation for DER to participate in markets operated by AEMO.

Electric vehicles

The role of EVs was commented on by two stakeholders:

- **Tesla** suggested that AEMO's current forecasting was significantly underestimating the total amount of electricity charging required from 2019 and onwards. Tesla offered to further engage with AEMO to provide supporting data on specific charging profiles they are observing, to inform AEMO's future modelling of EVs.
- **EnergyAustralia** asked if AEMO could provide more clarity on the impacts of EV charging on maximum demand forecasts, suggesting that with the availability of smart chargers and adjusted retail tariffs it would be unrealistic to assume evening/convenience charging would be the predominant charging profile in the future, and assuming this may create erroneous network investment requirements.

Distribution network consideration

The role of distribution networks in enabling the degree of DER penetration expected was an area of focus for several stakeholders:

- **Stanwell** requested that AEMO's planning integrate the distribution network into transmission planning. This would presumably be a key requirement of any plan that considers large levels of DER, particularly if they are going to be active in the market via VPPs, or at times contribute to congestion levels of the transmission network.
- **ERM Power** suggested that consultation with distribution network services providers could reveal what level of DER could be supported in current existing networks.
- **AusNet Services** acknowledged that the treatment of the "local network" to which DER is connected is unclear. Consideration of locational factors of DER could inform a more accurate prediction of operational characteristics where there may be a conflict between market services (particularly for VPP modelling) and network services at the distribution level. AusNet also suggested that there needs to be consideration in the modelling for the impact of pseudo "synchronous" charging behaviour on the respective local networks to which it is connected, as this is already a known condition that results in abnormal use of the network and consequent asset risks.

5.2.2 AEMO's assessment

To appropriately consider the breadth and depth of forecast DER, AEMO engaged two independent consultants to develop forecasts, from the top down and bottom up, and deliver key insights into the future role for DER in each of AEMO's scenarios. AEMO engaged CSIRO and Energeia to provide these forecasts, supplying the scenario settings that would apply to each of the scenarios (including the appropriate appetite for DER in each scenario, the emissions reduction ambition, the qualitative degree of tariff reform, and guidance on cost structures for DER technologies, consumer retail energy prices, and policy settings appropriate to each scenario). The consultants developed their forecasts of each DER component, considering the capabilities of the distribution network to integrate and allow export from the distribution networks.

AEMO also engaged through two separate workshops with the transport and energy industry to consult on appropriate considerations to improve the quality of the forecasts of EVs by the consultants. Engagement in that workshop supported the consultants' consideration of some of the technical aspects of the datasets they produced.

The consultants' draft forecasts were presented to stakeholders at the 12 April 2019 workshop hosted by BCG, and stakeholders provided perspective on which of the DER uptake trajectories were most appropriate for each scenario. The consultant forecasts were also presented to AEMO's Forecasting Reference Group at several different sessions through the consultation period, and stakeholders had an opportunity to question the outcomes and inputs of the consultants' models in those sessions. This was a useful process, as it identified points of clarification that were added to the consultants' final reports and datasets. These reports and datasets contain much of the information requested in stakeholder submissions.

These datasets have been used by AEMO to develop internally consistent forecasts that reasonably consider the degree of spread that each DER component (rooftop PV, embedded battery storage systems, and EVs) may have on the future energy mix. AEMO has specifically consulted on the approach, considerations, and outcomes of the consultant forecasts, as well as the consolidated outputs affecting the broader demand forecasts. Where necessary to maintain consistency, AEMO has made normalising adjustments to ensure that the relativity between scenarios is not skewed by differing assumptions between consultants on the technical preferences of consumers, particularly regarding battery size and PV system size, for example.

AEMO agrees with TransGrid that the VPP sector in Australia is still in the very early stages of development, particularly with regard to responding to electricity market price signals and stacking various value streams (although greater advancement exists internationally). Given this, AEMO has applied a broad range of possible VPP aggregation trajectories to the scenarios (between 15% and 80% by 2050-51).

Examinations of the distribution system, the capacity for consumer-generated energy exports, and the potential bottlenecks (and costs for addressing these limitations) are important considerations for planning the future power system. AEMO's actively progressing additional programs of work which relate to these issues, and the capacity and role of DER. These include the DER program[20] (including the VPP Demonstrations project[21]) and the Renewable Integration Study[22]. The learning and outcomes of these will be incorporated into the broader ISP evaluation where possible as part of qualitative or quantitative analysis depending on available data developed throughout the ISP.

5.2.3 AEMO's conclusion

The consultants' methodologies and forecasts are now available on AEMO's website[23]. The CSIRO forecasts have been used for the Slow Change, Central, Fast Change, and Step Change scenarios, and Energeia's forecasts have been used for the High DER and Fast Change scenarios, depending on the DER component.

Depending on scenario, forecast uptake of rooftop PV, batteries, and EVs varies significantly.

By 2030 in the NEM:

[20] More information on AEMO's DER program is at http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/DER-program.

[21] More information on AEMO's VPP Demonstrations is at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/DER-program/Virtual-Power-Plant-Demonstrations.

[22] More information on AEMO's renewable integration study is at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Future-Energy-Systems/Renewable-Integration-Study.

[23] AEMO Inputs Assumptions and Methodologies website, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies. CSIRO's report is at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/2019-Projections-for-Small-Scale-Embedded-Technologies-Report-by-CSIRO.pdf. Energeia's report is at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Distributed-Energy-Resources-and-Electric-Vehicle-Forecasts---Report-by-Energeia.pdf.

- Rooftop PV capacity is projected to range from 9.6 gigawatts (GW) to 22.4 GW.
- Embedded battery installations of between 0.8 GW and 15.9 GW are projected.
- EVs are assumed to consume between 600 gigawatt hours (GWh) and 7,710 GWh of electricity.

By 2050 in the NEM:

- Rooftop PV capacity is projected to range from 17.9 GW to 41.3 GW.
- Embedded battery installations of between 1.4 GW and 45.1 GW are projected.
- EVs are assumed to consume between 17,130 GWh and 41,800 GWh of electricity.

AEMO considers the forecasts will provide stakeholders with sufficiently granular information (as requested in several submissions) to support decision-making.

AEMO will consider the implications of DER development limitations due to the distribution network through AEMO's DER program and Renewable Integration Study work. Data limitations may preclude quantitative inclusion in the whole of system planning in the 2019-20 ISP, but could be included in future ISPs.

5.3 Discount rate and the weighted average cost of capital

5.3.1 Issue summary and submissions

Stakeholders provided a broad rejection of the proposed approach outlined in AEMO's Consultation Paper to adopt alternate rates for the WACC and for discounting market benefits in net present value (NPV) assessments (through the use of a social discount rate).

AEMO had proposed using a real, pre-tax rate of 6.25% for the WACC, as provided by GHD in the preliminary work informing the GenCost 2018 report[24]. AEMO similarly proposed the use of a 4% social discount rate for calculating the NPV, the same as the discount rate recommended by the Australian Government Standing Committee on Infrastructure, Transport and Cities for similar purposes.

Stakeholders, particularly network businesses, identified that this approach may be inconsistent with the acceptable approach suitable for a RIT-T:

- **Energy Networks Australia (ENA)** stated that using a different discount rate for NPV assessment in the ISP compared to that required under the RIT-T may lead to inconsistent outcomes, where an investment with a positive NPV that forms part of the optimal ISP network development path may not be found to pass a subsequent RIT-T. ENA suggested that, to avoid inconsistencies between the ISP and RIT-T for the same project, the same discount rate should be used across both analyses. **TransGrid**, **AusNet Services**, and **TasNetworks** submissions echoed ENA's views.
- The **AEC** submitted that a commercial discount rate should be used.
- **EnergyAustralia** submitted that historically renewable projects generally have a lower WACC for generation contracted under a power purchase agreement (PPA), compared to merchant projects, and in the future these WACCs are likely to be higher due to the increased risk resulting from Marginal Loss Factors (MLFs), congestion, and connection risk (for example, do no harm). EnergyAustralia therefore encouraged AEMO to review and confirm these assumptions with appropriate parties.

[24] CSIRO, GenCost 2018: Updated projections of electricity generation technology costs, at https://publications.csiro.au/rpr/download?pid=csiro:EP189502&dsid=DS1.

5.3.2 AEMO's assessment

AEMO accepts the feedback provided by network businesses and other stakeholders. Aligning the key assumptions affecting the valuation of network and generation developments to that of the RIT-T is appropriate.

AEMO considers that there would be less investment capital available in the Slow Change scenario than in other scenarios. This scenario has more nationalistic policies that may reduce international investor interest or capacity to invest in Australia's energy sector. As such, AEMO considers that this scenario should assume higher project financing cost to remain internally consistent.

AEMO will use an equivalent WACC for all development options – including for transmission and the various generation technologies available, consistent with the AER RIT-T guidelines[25]. Each generation technology can be considered as part of the overall generation portfolio funded through available capital investing in the energy market in a technology-neutral manner.

5.3.3 AEMO's conclusion

AEMO will adopt the same commercial discount rate for both the WACC and the calculations of NPVs. These rates will be set at 5.9% in the Central, Fast Change, High DER, and Step Change scenarios, as sourced from ENA's RIT-T handbook[26]. The Slow Change scenario will examine the impact of a higher rate of 7.9%, being a 2-percentage point greater finance cost than other scenarios, consistent with the scenario narrative.

AEMO will continue to apply a technology-agnostic approach by applying the same WACC for each generation technology option.

5.4 Renewable energy zones (REZs)

5.4.1 Issue summary and submissions

REZs are areas in the NEM where clusters of large-scale renewable energy can be efficiently developed, promoting economies of scale in high-resource areas, capturing important benefits from geographic and technological diversity in renewable resources, and recognising critical physical must-have requirements for power system security.

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.
- The proximity to load, and the network losses incurred to transport generated electricity to load centres.
- The critical physical must-have requirements to enable the connection of new resources (particularly inverter-based equipment) and ensure continued power system security.

Stakeholders raised several considerations for AEMO in the submissions:

- **ENA** declared its support for incorporating improvements in modelling of transmission impacts to REZ expansion. ENA considered that the current methodology failed to recognise:
  - Available transmission capacity as dispatch adjusts with market changes (such as new entrants and retirements) with the added complication of interaction between REZs.

[25] AER, RIT-T Application Guidelines – section 3.4.2, available at https://www.aer.gov.au/system/files/AER%20-%20Final%20RIT-T%20application%20guidelines%20-%2014%20December%202018_0.pdf.

[26] RIT-T Handbook: https://www.energynetworks.com.au/sites/default/files/ena_rit-t_handbook_15_march_2019.pdf.

  - The potential for scale efficient transmission solutions to unlock generation capacity.
  - That the lumpiness of transmission investment does not allow for a proportion of transmission build to provide a proportion of its ultimate capacity.
- **TransGrid** suggested that improving the understanding of the value of REZs would be beneficial. Transmission systems in many areas are becoming increasingly congested, and as new connections occur, new and existing renewable generators face growing risks of being constrained at certain times. TransGrid identified though that regulatory frameworks typically require new generation to lead network expansion, creating a 'chicken and the egg' dilemma. TransGrid further noted that new generation projects in high-quality REZs cannot be committed without transmission access, but proactive transmission expansion is not supported, so there is a misalignment of incentives between generation and transmission. Without reasonable supportive frameworks, developments will continue to focus on locations where transmission access already exists, which may not provide for the development of appropriate economies of scale
- **AusNet Services** suggested that accurate identification of REZs is important to ensure low emissions generators can join the power system at the lowest cost. AusNet suggested that a new REZ in Central Northern Victoria, around the Glenrowan and Shepparton terminal stations, should be added to the 2019 REZs given the high level of interest from renewables developers in that zone. AusNet noted that the development of this REZ may lead to alternative interconnector options from Victoria to New South Wales through central Victoria and the new REZ.
- **WSP Australia** suggested that REZ build limits are a critical input and suggested that the previous build limits be re-examined.
- **ERM Power** said a holistic approach is required to assess the potential for each individual REZ to provide benefit to the market. AEMO should provide data in comparing REZs, such as:
  - Expected generator output (expressed in terms of percentage of installed capacity) at the time of summer and winter peak regional demand.
  - Cost of development of deep transmission connection from the REZ to satisfy regional demand requirements.
  - Costs of modifying interconnector routes to facilitate REZ connection, being the cost of deviating from more direct routes.
- **Walcha Energy** also considered that REZ definitions should include benefits of the specific transmission routes that may enable better access to renewable resources. Walcha Energy suggested that some REZ refinements north of the Hunter Valley in New South Wales may provide greater benefits to accessing high-quality resources than the existing REZ representation.

Build limits

AEMO received the following submissions:

- **Hydro Tasmania** noted that the proposed build limits for renewable energy do not seem to reflect the full opportunity. Hydro Tasmania, through the Battery of the Nation investigations, has identified more than 4,000 MW of potential wind development in Tasmania.
- **WSP Australia** suggested that for all regions, even those with apparently poor solar or wind resources, non-zero build limits should be applied, with realistic capacity factors for projects in those locations. The modelling process could then decide whether to include or reject generation with a poor input resource in these regions. WSP Australia also suggested that pumped hydro build limits may be too limiting, as proposed. For example, WSP observed that prospective South Australian pumped hydro project developments in the public domain amount to around 65% more storage capacity in South Australia than the proposed build limits allow.

5.4.2 AEMO's assessment

AEMO thanks stakeholders for the feedback provided. AEMO has incorporated all feedback on REZ locations network expansion options, and potential synergies between interconnector routes and REZ locations. AEMO has incorporated these as development candidates in the modelling process, with deep connection costs reduced if interconnectors pass through REZ locations.

The submissions also identified several data elements, such as more detail on network expansion options, that may be considered in future data releases if the information is available.

In addition to the stakeholder feedback, AEMO has undertaken extensive consultation with transmission network service providers (TNSPs), which considered:

- REZ boundaries, connection locations, and connection interest.
- Detailed network augmentation options and costings for the various options developed for specific REZs.
- Considerations such as easements, sensitive areas, and network replacement timing.
- Synergies between REZ development and interconnector routes.
- Roles of storage/non-network solutions to increase REZ transfer capacity and minimise losses and network costs.

In regard to the 'chicken and egg' dilemma raised by some stakeholders, the ISP primarily identifies the most economically efficient development plan, and it does not directly address funding and regulatory arrangements. AEMO is working closely with a number of other parties, including the Energy Security Board (ESB), on implementation approaches to deliver the ISP build limits

AEMO regularly conducts assessments of generator investment interest through the Generation Information survey. Through this survey, AEMO is provided development progress of generation projects of all technologies throughout the NEM. This information will be used to refine and adjust the technology build limits to be applied in AEMO's ISP modelling.

5.4.3 AEMO's conclusion

The 2019-29 ISP will include the following candidate zones to better reflect generator connection interest and network characteristics:

- **Wide Bay (Queensland).**
- **Wagga Wagga (New South Wales).**
- **Central North Vic (Victoria).**

Other zones have had their boundaries adjusted given feedback from stakeholder submissions, as outlined in the 2019 Scenarios Report, including expanding the Gippsland REZ in Victoria to capture potential offshore wind generation potential.

REZ resource build limits for each renewable generation technology have also been increased, and are now the larger of a) the connection interest in line with AEMO's 8 August 2019 Generation Information collection or b) twice the 2018 ISP REZ resource limits, based on stakeholder feedback.

5.5 Generator technologies to consider, and their build limits

5.5.1 Issue summary and submissions

Candidate technologies

GHD[27] and CSIRO[28]produced projected build costs for a range of new generation technologies. For 2019 modelling, a filtered list of technologies – selected from those provided by GHD and CSIRO, and guided by stakeholder feedback – was proposed in the Consultation Paper, based on technology maturity, resource availability, and energy policy settings.

AEMO received the following submissions:

- **TasNetworks** noted inconsistency between the Consultation Paper and the Assumptions Book with respect to list of technologies to be considered. In particular, carbon capture and storage (CCS) technologies are included in 2019 Inputs and Assumptions Workbook but excluded from the proposed technology list in the Consultation Paper. TasNetworks also noted that costs of synchronous condensers were not listed in the Workbook.
- **TasNetworks** also suggested that biomass generation be excluded from the generation technologies, on the basis that its implementation is likely to be on an opportunistic basis as a by-product of other industries, rather than a technology that could be developed primarily for the purpose of electricity production.
- **EY** asked for the consideration of the following technologies:
  - Reciprocating engines.
  - Solar PV (fixed flat plate).
  - Battery storages with four hours of storage. This was also a recommendation supported by **Tesla's** submission.
- **ERM Power** suggested improved granularity could be achieved with more detailed consideration of OCGT technologies available, including Frame and Aeroderivative types. ERM also noted that the proposed exclusion of reciprocating engines is not preferred, and suggested smaller generator unit sizes be considered. **Hydro Tasmania** also suggested aeroderivative generators be included in the modelling.
- **EnergyAustralia** sought increased clarity on whether battery storages and PHES were available technologies.

5.5.2 AEMO's assessment

Candidate technologies

The number of candidate technology options cannot be unlimited, because in modelling it is essential to define a sensibly bounded solution space that balances the needs for modelling accuracy and speed. The challenge is setting limits to maximise computational efficiency without constraining the optimal solution.

AEMO appreciates the perspectives provided by stakeholders to increase the consideration for smaller, more flexible generation technologies. One of the principal advantages of peaking generation technologies is the ability to ramp up quickly to manage risk and/or capture price. Some technologies also provide greater ancillary services than others.

[27] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/9110715-REP-A-Cost-and-Technical-Parameter-Review---Rev-4-Final.pdf.

[28] At https://publications.csiro.au/rpr/download?pid=csiro:EP189502&dsid=DS1.

Candidate exclusions

Dynamic fluctuations in intra-hourly supply are currently not captured in AEMO's forecasting models, due to modelling being conducted on an hourly basis. The modelling would not be able to distinguish the technical differences between various peaking generation alternatives (such as OCGTs, reciprocating engines, and aero-derivatives) from a supply demand balance perspective. AEMO considers that these alternative technologies would not materially change the fuel or network development requirements.

As such, OCGTs are included in AEMO's capacity outlook models to represent the peaking generation class of generation. Qualitative discussion of merits of alternate technologies will be included in the system security assessment.

Fixed flat plate solar PV systems remain excluded from the assessment, because the energy increase provided by single-axis tracking systems outweighs the cost associated with these systems. It is unreasonable, given AEMO's input data, to expect any additional value would be provided from adding this technology to the candidate technology list.

Candidate inclusions

AEMO has reconsidered the proposed exclusion of various technologies that are unlikely to be developed given the trend in input costs. AEMO now considers that these technologies may be part of the modelling, allowing their development to be within the bounds of the scenario optimisations. These candidate revisions have been based on stakeholder feedback to explicitly demonstrate the merits of specific technology options to the least-cost expansion plan. This includes:

- Supercritical coal-fired generation.
- Offshore wind generation (although only available where development interest resides, off the Gippsland coastline in Victoria).

For the 2019-20 ISP, AEMO will place greater consideration in the operability of the power system and increase the modelling effort toward identifying the need and value for flexibility. In this analysis it is likely that flexible thermal generation will be valuable, complemented by energy shifting and capacity firming storage technologies.

Candidate enhancements

AEMO has considered stakeholder submissions on the role that 4-hour battery storages can play in the planning horizon, and the increased flexibility provided by deeper, modular battery systems. AEMO has determined that the addition of this technology would provide two benefits:

- Increase the flexibility of battery storages to service longer periods of energy shifting (at additional cost).
- Increase the availability of modular storages to locate at any location, without development limitations that may exist for pumped hydro systems.

AEMO has therefore expanded the proposed storage options, to include both 2-hour and 4-hour storage options for battery systems.

AEMO proposes to keep the opportunities for biomass development, but limit the developments, given the technology is most often deployed in combination with other opportunities, as suggested by TasNetworks. This technology, and the technologies added, will be considered using AEMO's refined capacity outlook modelling approach[29], which may exclude technologies from subsequent detailed assessments where no developments have been identified from screening analysis.

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[29] AEMO, Market Modelling Methodology Report, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Market-Modelling-Methodology-Paper.pdf.

5.5.3 AEMO's conclusion

AEMO has adjusted the candidate technologies to be used in the ISP to include supercritical coal, offshore wind, and 4-hour battery storage.

5.6 Storage modelling considerations

5.6.1 Issue summary and submissions

AEMO's Consultation Paper indicated that AEMO's approach in 2019-20 would provide strong consideration of a portfolio of storage depth options, from 2-hour battery storages to 48-hour pumped hydro storages (and large-scale strategic storage projects such as Snowy 2.0 and Battery of the Nation).

AEMO presented pumped hydro storage capacity availability and cost data based on projections developed by Entura, including a method for allocating storage capacity to various storage depths across 6-48 hours. AEMO proposed splitting the identified storage limits to individual storage sizes, to reduce the overall computational size of AEMO's capacity outlook model.

AEMO also outlined that data improvements through collaborations with Snowy Hydro and Hydro Tasmania would be applied in 2019-20 modelling.

Treatment of pumped hydro energy storage

AEMO received the following submissions:

- **Hydro Tasmania** noted that:
  - The Assumptions Workbook shows reduced Tasmanian capacity, both compared to previous years and compared to data provided for the purpose of the new seven pond model. The workbook also includes summer de-rating of a number of Tasmanian hydropower plants, which is inconsistent with the capabilities of Tasmanian system.
  - An allowance had been included for transmission connection to the nearest transmission substation, however, these costs may be a duplicate of those already assumed in the pumped hydro cost model. Hydro Tasmania recommended that AEMO review these assumptions to address this duplication.
  - Tasmania's pumped hydro opportunities have a better round-trip efficiency than AEMO's assumed efficiency of 77.5%, because Tasmania's opportunities tend to have shorter conveyances than other pumped hydro opportunities. The typical round-trip efficiency in Tasmania is approximately 80%, and can be slightly better in some locations.
- **ERM Power** supported the choice of six, 12, 24, and 48 hour storage options for hydro pumped storage facilities. ERM sought additional details to justify the maximum build limits to apply to these different levels of pumped hydro storage on a regional basis
- **WSP Australia** noted that the approach to pre-allocating pumped hydro storage capacity to different nominal storage-duration schemes seemed somewhat arbitrary, which may lead away from optimised solutions. WSP recommended that this be a variable in the modelling.
- **Snowy Hydro** commented that "the [future] power system … will require flexible and dispatchable generation and/or additional interconnector capacity to enable more efficient sharing of generation resources between states. It is also important to note that pumped hydro energy storage is unaffected by water droughts as it recirculates existing water between two reservoirs".

Treatment of battery storages

AEMO received the following submissions (extending beyond the availability of 4-hour batteries discussed in the previous section):

- **Tesla** noted that the technical life of a battery is often based on a guaranteed energy provision warranty from manufacturers. The market is already seeing the shift to 15-year warranties being offered as standard, and battery longevity will likely extend beyond the warranted life, although with declining levels of energy. Tesla suggested that batteries should be treated similarly to ageing coal and gas plants, with increasing levels of full/partial outage rates and expanding de-rate factors prior to retirement.
- **Tesla** also noted that battery deployments to date are already achieving greater than 90% efficiencies (above the proposed value of 81%). Tesla supported AEMO in updating parameters for battery charge and discharge efficiency to at least 90%. **ERM Power** also noted the discrepancy between the round-trip efficiency of batteries and the efficiency of pumped hydro, and recommended that AEMO examine actual outcomes of existing batteries to inform a more accurate evaluation of battery performance.
- **ERM Power** also noted that two significant considerations regarding modelling of battery storage do not appear to be considered in the modelling input assumptions:
  - The yearly costs to maintain the minimum level of storage as the capability of a battery to store energy deteriorates over time.
  - The cost of safe environmental disposal of used batteries at the end of their expected 10-year life.

5.6.2 AEMO's assessment

AEMO appreciates the feedback on specific input assumptions. AEMO's conclusions reflect the incorporation of these assumption changes.

Pumped hydro energy storages

AEMO's source for PHES costs and capacities is Entura's December 2018 report on Pumped Hydro Cost Modelling[30]. This report outlined the cumulative amount of storage available per NEM region for various storage sizes (6-hour, 12-hour, 24-hour, and 48-hour storage). For example, Entura identified 1,200 MW of available 6-hour and 12-hour storage locations in Victoria, 700 MW of 24-hour storage, and 400 MW of 48-hour storage. However, these storage limits were not mutually exclusive. For every megawatt of 48-hour storage developed, there would be one megawatt less storage of smaller depth available.

AEMO outlined in the Consultation Paper, and reaffirmed in workshops, that an improvement for the 2019-20 ISP will be the consideration of a portfolio of storage depths in the modelling. To capture the available storages of each storage depth, AEMO had proposed an approach of applying pre-allocated capacities of each storage capacity. Stakeholders did not consider this an appropriate methodology, and preferred a dynamic method for optimising storage development. Unfortunately, dynamic methods increase computational burden and purport a level of accuracy in the assumptions that is not realistic.

This will be incorporated in the capacity expansion modelling through bespoke constraints. However, to avoid creating unwarranted computational burden, AEMO will instead apply a pre-allocated approach in initially determining the limits applied to all pumped storage depth options in each NEM region, based on storage depth preferences observed in AEMO's ISP PHES Insights modelling[31]. Acknowledging the pre-determined nature of these limits, AEMO will apply further refinements and adjustments to the limits based on modelling outcomes, if these limits prove to be overly constraining.

This approach will allow the least-cost expansion model to identify a suite of storage candidates across the forecast horizon, addressing evolving challenges that are mitigated by alternative storage duration options. AEMO will refine the storage limits where reached by "shifting" capacity from higher duration candidates to smaller duration if identified as a more valuable option by the model.

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[30] Entura, Pumped Hydro Cost Modelling (7 Dec 2018), at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Report-Pumped-Hydro-Cost-Modelling.pdf.

[31] AEMO, ISP Insights: Building power system resilience with pumped hydro energy storage, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf.

For example, based on these limits in Victoria, if the model identifies the need for 1,200 MW of 6-hour storage and only 600 MW for 12-hour storage, AEMO would then explore increasing the 6-hour limit by reallocating capacity from the 12-hour candidates. This approach allows for large duration candidates to be repurposed if, under certain scenarios, shorter duration storage provides for a greater market benefit.

AEMO may consider sensitivities on the available storage capacity limits after the publication of the draft ISP outcomes, if PHES is identified as a key technology solution across the scenarios.

AEMO agrees with the observation by Hydro Tasmania that the costs for PHES as proposed in the Assumptions Book were double-counting connection costs. As such, an explicit connection cost will not be considered for PHES builds, as this is already captured in the total costs provided by Entura.

Battery storages

The technical life of large-scale batteries will be modelled as 15 years, after which the battery will be retired. A greenfield replacement will be available, and, if firm capacity is required, this may continue to be the preferred (re)development option.

Tesla's perspective on the continued usefulness of batteries beyond this warranted period is valuable, however, the capacity outlook models are not capable presently of efficiently incorporating battery degradation. The application of a technical life retirement constraint therefore reasonably ensures that batteries can service the grid reliably, a primary function of this asset type.

The cost of battery disposal is not considered, as cost information on this activity is not within AEMO's datasets. This may understate the full life-cycle cost of the technology. In replacing retired technologies, AEMO assumes a greenfield development, which may overstate the effective cost of replacement. In the absence of better data sets, AEMO considers it reasonable that these two factors may come close to balancing out the total lifecycle costs.

AEMO has clarified that the charge efficiency reported in the Assumptions Workbook was mis-labelled and was intended to represent the round-trip efficiency. This is corrected in the updated Inputs and Assumptions Workbook. Battery candidates will also consider minimum and maximum state of charge and fixed costs.

5.6.3 AEMO's conclusion

To avoid excessive computational burden, AEMO will continue to pre-allocate capacity into various storage depths, as proposed in the Consultation Paper, but retain flexibility to adjust allocation if overly constraining.

Large-scale batteries will be modelled with the assumed technical life of 15 years. At this point, battery replacements may be necessary, at cost, if firm capacity is required to replace the retiring battery. The cost of the replacement will follow the battery technology cost trends, which may be lower than when first installed, although disposal costs are not considered.

5.7 Marginal Loss Factors

MLFs are a feature of the NEM used to adjust the price of electricity in a NEM region, relative to the regional reference node, to recognise the difference between a generator's output and the energy that is actually delivered to consumers.

In its Consultation Paper, AEMO recognised that increasing REZ generation may increase losses and erode MLFs, reducing the value of additional connections at that location. AEMO noted the deterioration of MLFs in recent years in certain areas, and the concern investors have over MLF certainty and the impact on investment returns.

AEMO uses network modelling to estimate the impact of expansions on MLFs, but noted the inability to dynamically characterise the effect of MLFs on REZ developments, because it currently requires iterative analysis between power system modelling and capacity outlook modelling.

5.7.1 Issue summary and submissions

AEMO received the following submissions:

- **Meridian Energy** submitted that large changes in MLFs over time can quickly erode the commercial viability of projects, and that the full forward-looking loss factor methodology should be applied to ensure new investment in the NEM is efficiently allocated.
- **Tesla** suggested that battery storages would provide MLF stabilisation benefits, and assumptions on the benefits of co-located storage should be included in REZ assessments.
- **WSP Australia** questioned whether MLF reform (or more generally loss factor reform) may influence the scale (and associated cost) of economically optimised network augmentation required for proposed REZs. WSP Australia also noted that dynamic MLFs should be considered in the modelling to determine the optimal location, timing, and choice of new utility-scale generation.
- **TasNetworks** and the **CEC** suggested AEMO should systematically review the allocation of shadow connection points for all NEM regions, as the inadvertent incorrect allocation of MLFs could have a material impact on study results. **TasNetworks** also identified several issues included in the Assumptions Workbook, highlighting the need to review some Tasmanian connection points
- **Infigen Energy** suggested there would be significant value to the industry if AEMO, through the ISP, were to consider the long-term trajectory of MLFs associated with various transmission connection points. This is particularly pertinent for REZs – understanding both congestion and loss impacts over time would help make AEMO's studies more robust, and also help inform investment decisions in the market.

5.7.2 AEMO's assessment

AEMO acknowledges the importance of including network losses as a component of the ISP. Throughout the consultation period, AEMO has actively considered how to model dynamic MLFs within the ISP modelling framework, but has not found an appropriate method while maintaining a tractable response time for its models. A nodal model of the physical system to explicitly capture losses would remove the need to forecast MLFs, but would create a problem too large to solve using current techniques. As such, AEMO will not be able to model dynamic loss factors in this 2019-20 ISP. The proposed iterative method represents a commitment to capturing this important financial layer and compensating for model shortfalls.

MLFs are highly dependent on the location of new generation, and any differences between actual new generation and the ISP outlook will cause material differences in MLFs. The ISP will provide an indication of the robustness and potential changes to MLFs for the ISP generation outlook by testing the sensitivity of MLF changes when new generation is added at a given location.

5.7.3 AEMO's conclusion

AEMO appreciates the identification of issues affecting the reported shadow connection points and has corrected these ahead of the 2019-20 ISP.

AEMO will implement the following revisions to the modelling approach:

- **AEMO will use MLFs published in the latest release of the Regional Boundaries and Marginal Loss Factors report as a starting point for the 2019 MLFs to apply.**
- **AEMO will continue to investigate iteratively the interaction that will exist between network losses and generation development drivers affecting generation technologies and locations, and research other ways to capture the effect of losses more dynamically.**
- **The estimated MLF forecasts from the 2018 ISP will further provide useful guidance ahead of the 2019-20 ISP.**
- **Losses will be considered in detail in the power system modelling.**

5.8 ISP publication of data

5.8.1 Issue summary and submissions

AEMO endeavours to be as open and transparent as possible to help improve confidence in, and acceptance and understanding of, the ISP results.

AEMO received the following submissions:

- **University of Melbourne** noted that AEMO has an excellent track record of providing access to electricity market data and is to be commended for this. Future analysis should continue in this tradition and endeavour to make even more of the data (and modelling) open access or open source. In particular, it would be desirable to see the full set of inputs (for example demand traces for particular scenarios) or assumed traces for EV charging made available in future releases.
- **Origin Energy** submitted that AEMO's consultation and stakeholder engagement should extend beyond the input assumptions to also allow consultation on the modelling outputs. This will allow for a sanity check of the results while instilling greater confidence in the overall process and the planning documents that are produced.
- **ENGIE** submitted that AEMO has made a large volume of information and data available, but it is insufficient to enable the reproduction of AEMO processes. As an example, more detailed documentation is needed to describe the demand (maximum demand and energy) development process. ENGIE asked AEMO to provide all the information relevant to the forecasting process and modelling approach. ENGIE also asked AEMO to provide the resource costs for each scenario and sensitivity (total NEM, individual NEM regions, and by modelling year).
- **TasNetworks** noted that stakeholders who choose to use AEMO's data set and model must have confidence that the data and model are accurate and will withstand scrutiny. Given these factors, TasNetworks considers the level of consultation being undertaken by AEMO is appropriate at present and should be seen as the norm in future, as further data and model improvement occurs.
- **AGL** agreed with the views expressed by other stakeholders during the 19 February 2019 workshop, that limitations and constraints to the modelling should be well articulated by AEMO, so there is transparency through clear upfront communication with respect to the modelling. This will help further analysis of results, with proper data limitations expressed and understood.
- **Snowy Hydro** welcomed increased engagement with AEMO through a number of programs on forecasting, modelling, reliability analysis, renewable energy, and other topical items, and encouraged AEMO to expose some of its forecasting components, so commentary can be received from the industry.
- **ERM Power** noted that the modelling and analysis required to produce the ISP is a detailed and multi-staged process. ERM Power said AEMO should detail all outcomes and supporting data from the initial draft modelling process that was used to prepare the initial draft ISP publication, and provide sufficient time for external review of the published information prior to the commencement of works for finalisation of the ISP.
- **Origin Energy** noted that the upcoming ISP should clearly set out the various wholesale market and network cost drivers across the different scenarios, and that AEMO could also present any modelling of the costs of resolving any identified issues through network construction compared to using generation or demand response.

Modelling network constraints

Various stakeholders (**ERM Power, Stanwell, AGL,** and **AusNet Services**) commented on the desirability of network constraint equations being published for each scenario outcome of the ISP.

5.8.2 AEMO's assessment

AEMO recognises the importance of an open and transparent approach in developing its forecasts, so the outcomes are understood and accepted by stakeholders. Increased engagement with the Forecasting Reference Group ahead of the publication of the 2019 ESOO demand forecasts is a clear example of the approach taken to support this goal. The consultation workshops also provided a number of opportunities for stakeholders to review and ask questions about the inputs, methodology, and approach AEMO will take for the 2019-20 ISP.

While AEMO aims for its forecasting processes to be as transparent as possible, occasionally AEMO incorporates confidential information that cannot be published in full, which in some cases limits the release of full modelling inputs. In these cases, AEMO aggregates data to eliminate the possibility of a breach of confidentiality. Moreover, the size and scale of data used in AEMO's modelling processes is expanding beyond the limits of what can be easily published.

AEMO recognises that a balance must exist at times between modelling accuracy (through the use of accurate, confidential data) and modelling transparency.

Regarding network constraints, AEMO will endeavour to publish all transmission constraint equations considered in the time-sequential models. These constraints would be in a similar form to those currently provided as part of the ESOO data package.

5.8.3 AEMO's conclusion

AEMO will continue to publish as much information as possible to support stakeholder decision-making.

AEMO will release a **Draft ISP report in December 2019** to allow for consultation on the draft insights and outcomes. AEMO will also provide preliminary results prior to the Draft Report, outlining the generation expansion outlook for key scenarios. This will be conducted in a workshop (in September/October 2019) prior to formal release of the Draft Report.

Accompanying this report, AEMO has released an **updated Inputs and Assumptions Workbook** that provides details of all key inputs and assumptions to be used in the 2019-20 ISP, and updated methodology documentation for demand forecasting, market modelling, and network planning will be released as soon as practical.

AEMO will publish information, data and analysis that supports the insights reported in the 2019-20 ISP, at both Draft and Final stage. This will include the generation expansion outcomes, network development plans, and costs associated with each. AEMO will continue to publish key inputs (such as demand traces, DER, and renewable generation profiles) as part of the ISP model, subject to any aggregations to protect confidential information.

6. Methodologies and other matters

In addition to the specific comments raised in Sections 4 and 5 above, AEMO also received feedback on the methodology and a number of other matters discussed below.

6.1 Modelling energy system resilience

AEMO identified that a key focus for 2019 would be the consideration of the resilience of the energy system to risks and uncertainties, including high-impact low probability (HILP) events, coal-fired generation retiring earlier than technical life or announced closure timing, and heightened risks that exist due to climate change.

AEMO identified a high-level process to quantify the level of grid resilience in candidate development plans by identifying disruptive events and methods for mitigating these risks. The Consultation Paper concluded that the application of this framework would focus on disruptive events such as extreme weather, renewable energy droughts, and unexpected coal closures.

6.1.1 Issue summary and submissions

AEMO received a significant volume of submissions on this issue:

- **TransGrid** supported AEMO conducting resilience modelling, saying it is important to develop frameworks for assessing how best to manage the risk of new and emerging threats to the system. TransGrid identified threats such as HILP events, unanticipated severe shortages of fuel or water for power generation, and extreme weather that impacts a variety of generating sources (especially wind and solar). TransGrid recommended that AEMO build a greater understanding of HILP events and incorporate HILP threats into risk assessment. Scenario-based planning to explore multiple contingencies can be used to stress test the system and identify gaps in resilience.
- **TransGrid** also suggested that AEMO must first characterise the most important threats, which often vary by region, and recommended that AEMO:
  - Institute policies and practices that can help streamline assessment and decision-making, suggesting this is as important as the infrastructure itself.
  - Harden the grid, including selecting diverse transmission routing for new transmission assets.
  - Diversify generation resources by increasing the number of generation sources and fuel types, and their locations in the NEM, at both the distributed and utility scale.
- **TasNetworks** commented that they continue to develop their own thinking on resilience and will engage with AEMO in the appropriate forum. Resilience to failures such as the Basslink HVDC failures in 2019 and in 2015-16 should be considered.
- The **AEC** assumed AEMO's discussion on resilience was solely focused on HILP events, and expressed concern that this would distort the "bookend" scenarios and the neutral scenario. They reiterated that, in their view, the reliability standard remains appropriate for the scenario assessment needed by the ISP.
- **Snowy Hydro** supported AEMO's consideration of power system resilience, with particular emphasis on transmission investments which are low regret and present high option value to an uncertain future. AEMO's assessment of coal plant retirements highlights the significant increase in the net market benefits of the transmission upgrades for the future NEM as the key enabler of an orderly and secure transition to a low emissions economy. Transmission investment will also support other new projects, in particular the

new REZs across the NEM. Snowy Hydro suggested that the current RIT-T may be unable to fully assess large strategic investments in the NEM because the process may fail to undertake assessments in a timely manner. For instance, it has a lengthy process and can be delayed by individual interests through the dispute process. The timeliness of strategic storage initiatives for the NEM is vital.

- **Stanwell** suggested that ageing network assets be taken into account, as well as an assessment of climate resilience of key transmission infrastructure, and the costs associated with adaptation.
- **EnergyAustralia** considered that it will be key for AEMO to ensure the modelling sufficiently deals with fuel supply adequacy, that is, ensuring there is enough energy to meet demand even with long periods of low wind, low solar, and low water inflows for hydro.
- **TasNetworks** agreed that the long-term impacts of climate change on hydro, wind, and solar generation input data be considered, given the increasing reliance on renewable generation technologies.

6.1.2 AEMO's assessment

AEMO considers that, when assessing the short-term, medium-term, and long-term needs for the maintenance of security and reliability in the NEM, consideration of the system's resiliency to withstand shocks is essential.

These shocks, or disruptive events, are not necessarily low probability events, and may take the form of:

- **Fuel disruptions** – given the interdependencies of gas and electricity, and the fact both demand and supply are now exposed to the vagaries of weather, a resilient NEM cannot be too dependent on any one fuel source (gas, hydro, wind, or solar).
- **Regret costs** – the system needs to be sufficiently flexible to be able to adapt as future uncertainties reveal themselves, without the cost of adaptation resulting in significant regret. For example, pre-emptive investment may be required to reduce the risks of earlier than expected closure of ageing generation.
- **Hazards** – the NEM needs to be able to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and function[32].

This is a complex area, particularly given the cross sectoral interdependencies that need to be considered, including the fuel supply chain, telecommunications, cyber security vulnerabilities resulting from greater reliance on electronics, electrification of other sectors and the increasing severity of extreme weather events.

A growing number of jurisdictions and industry sectors are actively engaged in the process of developing frameworks for assessing how best to manage the risk of these new and emerging threats. However, a standard framework for resilience analysis and an accepted set of resilience metrics/measurements are still unavailable. Risk tolerances need to be understood, risk frameworks established, and quantification techniques evolved.

AEMO continues to work with the BoM, the finance sector, transport sector and independent system operators in other jurisdictions to develop a resilience framework that can appropriately assess and address resilience risk across the power system. Depending on the severity of the risk, and the speed of recovery possible, the most cost-effective mitigation strategy may be to adapt (plan the system differently) or respond (change operational procedures to improve ability to operate through and recover quickly from the disaster.)

Fuel disruptions

The power system is requiring investment in generation, transmission, and storage flexibility to ensure it is resilient to climate change and weather variability. Increasingly, investments must consider the risks to the power system and to the reliability and security of the grid, and the critical role that energy plays for

[32] United Nations Resolution 69/283 Sendai Framework for Disaster Risk Reduction 2015-2030, at https://sustainabledevelopment.un.org/index.php?page=view&type=111&nr=7738&menu=35.

consumers. While HILP events are an important part of any risk assessment, greater focus must be placed on other, more common, risks that will be increasingly likely over the long term, particularly those surrounding weather variability and fuel supply security.

The importance of conducting the ISP under an integrated approach with respect to multiple energy sectors cannot be overstated. The need to explore augmentation solutions to emerging challenges in the electricity and gas sectors requires an integrated approach. This allows for the potential identification of an electrification solution to an emerging gas limitation, and, similarly, gas sector solutions to electricity-based challenges. By coupling these sectors, greater insights and system benefits can be quantified under the ISP scenarios. Further, by assessing the needs and benefits of the electricity system as well as the gas system, and the impact of potential gas supply shortages, the resiliency needs of energy consumers can be better understood.

AEMO's models have been enhanced since the 2018 ISP to ensure greater capture of weather variability, and the relationship between all weather-related energy influences, such as demand, supply availability, resource availability, hydro inflows, and network limitations.

The capacity outlook model now utilises eight historical weather years, known as 'reference years'. These reference years capture the variability of available renewable generation, water inflows affecting hydro availability, and demand profiles. The updated method therefore captures a broader range of weather patterns affecting demand shape and timing of peaks, hydro inflows, and the wind and solar resources affecting both large-scale and small-scale generators (including rooftop PV systems), and considers these risks within the assessment of optimal generation development.

The modelling inherently captures the risks of renewable energy 'droughts' which occasionally are observed, representing extended periods of very low output from renewable generators in a given area, sub-region, or region. The capacity outlook models now capture weather variability through application of multiple weather patterns in the optimisation, using a 'rolling reference years' approach which cycles through the available weather patterns. This improved approach is documented in AEMO's Market Modelling Methodology Paper[33].

Hazards (extreme weather)

The NEM is vulnerable to weather – namely, temperature and extreme temperatures, heatwaves, drought, bushfires, dust, wind and extreme wind, storms, hail, and lightning. Many of these conditions will likely occur much more frequently in future decades, with novel extreme events.

NEM vulnerability includes risks to system performance (such as maintaining reliable supply to meet demand) and system resilience (such as protecting critical infrastructure from failure, providing redundancy for such infrastructure, or providing sound tactical operations for quick recovery)

Climate change is making weather more extreme and harder to forecast, and the current system is not designed, built, or operated to accommodate the extremity and scale of climate-induced weather events, or the influence of weather on major sources of energy production. The power system will need to prepare for increased frequency and scale of extreme weather events, making geographic and technical supply diversity much more desirable to mitigate risks of supply interruption.

In addition, a multi-pronged strategy is required – involving a combination of integrated planning, improved asset design and management, and disaster recovery – to address vulnerabilities.

Challenges exist in developing the climate information required at the appropriate spatial and temporal detail to adequately model these risks in the NEM.

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[33] AEMO, Market Modelling Methodology Paper, at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Market-Modelling-Methodology-Paper.pdf.

To resolve this, AEMO is working closely with CSIRO and the Bureau of Meteorology (BOM) through the Electricity Sector Climate Information (ESCI) project[34] to understand the likely and possible impacts of climate change as they relate to the electricity sector. The project is designed to deliver specific information and data that electricity sector decision-makers need to manage risks to the reliability and resilience of electricity systems from extreme weather events in the context of a changing climate. It will improve information on likely future changes to extreme weather events such as heatwaves, wind, and maximum temperature thresholds, including concurrent and/or compounding events, to inform analysis of long-term climate risk. The project will run over three years, and new climate data will be captured in the AEMO models as it becomes available in that period.

As part of this project, a 'physical risk scenario' has been developed as a narrative to highlight current challenges in managing and planning the NEM. The scenario describes a sequence of extreme weather and climate events that could plausibly occur in Australia in the near future, with a nominal setting in the early 2020s, for use in scenario risk planning. At a minimum, the future system should be designed to ensure there is no deterioration in resilience to these hazards, and ideally, where cost is not prohibitive, the ISP will identify action that can be taken to improve system resiliency.

Regret costs

Investment decisions are necessary, despite uncertainty regarding the likelihood of any given future NEM. In the presence of investment uncertainty, the theory of regret aversion proposes that investors must consider the potential regrets their actions may have over the investment timeframe, and attempt to reduce or eliminate these potential regrets.

Flexibility becomes critical, so decision-makers can adapt without incurring significant costs as the future unfolds and uncertainties reveal themselves. Many investment decisions in the context of energy involve the development (or not) of assets that both have a long development lead time and a long asset life once developed. This amplifies the potential risks that sub-optimal decisions may have on the overall cost to the system and to consumers.

The option value of building in sufficient flexibility in any solution is particularly important in an uncertain decision-making environment, and maximising a solution's adaptability to future challenges will be critical to the planning of the power system. For example, in AEMO's July 2019 ISP Insight – Building Power System Resilience With Pumped Hydro Energy Storage[35], AEMO assessed the value of bringing forward some transmission development, as well as strategic storage, as a potential pre-emptive measure to increase power system resilience against climate change or early, unexpected exits of coal-fired generation.

AEMO's 2019-20 ISP approach to valuing adaptability focuses on maximising transparency with respect to the risks and opportunities of various development pathways:

- Determine the optimal development pathway in each scenario under the veil of perfect foresight, that maximises net market benefits to consumers.
- Identify investment decisions that need to be made now under each optimal development pathway to achieve these benefits.
- Impose these initial investment decisions on each alternative scenario and sensitivity, and re-simulate to determine how the future development pathway would need to change if a different scenario is realised than assumed.
- Calculate the 'regret cost' of making one decision now and having to adapt to a different future to identify the 'least-regret' decisions.

[34] For more information on the ESCI project see https://www.environment.gov.au/climate-change/adaptation.

[35] At https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

Network infrastructure ageing and replacement is not currently modelled within the ISP. The modelling AEMO will conduct, particularly in evolving the generation supplies, will treat the existing network and any optimal network augmentations as available throughout the planning horizon. However, known replacement decisions of major network assets may be included if identified in discussion with NSPs.

6.1.3 AEMO's conclusion

AEMO will consider the resilience that various future development options provide, and the option value of solutions to allow for change in an uncertain decision-making environment. Where possible, solutions that maximise a solution's economic adaptability to future challenges will be critical to the planning of the power system.

While a resilience framework has not yet been determined for the electricity industry that covers all future vulnerabilities, for the 2019-20 ISP, AEMO will apply a methodology that starts to identify the system resilience provided by each solution. By transparently investigating a broad suite of scenarios and sensitivities, AEMO can support informed decision-making to actively mitigate future risks.

AEMO has outlined several sensitivities in the 2019 Scenarios Report that will be examined to inform the degree of resilience that the integrated gas and electricity system may require and the whole-of-system plan may provide. These do not solely focus on HILP events, but on risks that are becoming increasingly likely, due to interdependencies of gas and electricity, and ageing generation assets.

AEMO is incorporating multiple historical weather patterns into its assessments and applying initial CSIRO/BOM data from the energy sector climate information (ESCI) project[36] to capture increases in extreme temperature, hydro inflow variance, and decline in accordance with the climate scenarios. AEMO will publish this information on its Inputs and Assumptions webpage[37] and/or the Inputs and Assumptions Workbook when available.

6.2 Sector coupling

AEMO applies an integrated approach to modelling energy developments, particularly focusing on the interaction between the gas and electricity markets and the influence gas availability may have on electricity developments (and vice versa). The growing interest in hydrogen generation and the integration of an emerging hydrogen economy was outlined in the Consultation Paper as an area of development and research required before it could be incorporated into AEMO's planning and forecasting models. The Consultation Paper proposed that an emerging hydrogen sector not be included in the 2019-20 ISP.

6.2.1 Issue summary and submissions

Hydrogen sector development

Stakeholders noted that:

- **TransGrid** recommended that AEMO consider the development of a hydrogen industry over the medium to long term, noting significant activity in Australia in recent months to investigate and demonstrate the potential role of hydrogen as a clean fuel and export commodity.
- **Snowy Hydro** proposed that AEMO's planning should focus primarily on proven technologies that work in mass markets across the NEM or around the world, saying that if assumptions are made on a technology

[36] The Australian Government is providing funding to improve climate and extreme weather information for the electricity sector. The energy sector climate information (ESCI) project will deliver specific information and data that can support decision making surrounding risks to the reliability and resilience to electricity systems in the context of a changing climate. See https://www.environment.gov.au/climate-change/adaptation.

[37] AEMO Planning and Forecasting inputs, assumptions and methodologies, at https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies.

which is not understood, the risks associated with implementation are high. Snowy Hydro therefore supported AEMO's view that "further research and development is required before hydrogen can be included as an ISP scenario".

- **Hydro Tasmania** suggested that a move to include a hydrogen-export economy is relevant in terms of present planning. Commentary on how international drivers may change the security, reliability, and price of our electricity system should be included.
- **ENGIE** urged AEMO to include hydrogen vehicles and hydrogen production in the EV mix instead of 'betting' only on battery EV technologies, saying that the impact of hydrogen vehicles on the electrical system will be very different to the impacts of battery-powered EVs, and will include different network utilisation and network locations, time of use, and amount of electricity used/stored (hydrogen is a form of energy storage with much higher capacity than EV batteries).

Gas sector coupling

- **EnergyAustralia** suggested that AEMO's range of gas prices were not broad enough to consider the possible influence of the gas sector and the potential for liquefied natural gas (LNG) import terminals to influence domestic prices. EnergyAustralia requested further clarity on the natural gas scenarios in the scenarios, and what developments it includes.

6.2.2 AEMO's assessment

Sector coupling

Increasingly complex co-dependencies between multiple sectors – such as gas, heating, electricity and transport (EVs), water, and hydrogen – will have a significant impact on how best to evolve a power system that meets Australia's future needs.

In particular, gas networks are being disrupted with economic and competition reforms, as well as price impacts from exports and supply tightening in some jurisdictions. These impact the capability of the gas network to deliver affordable gas for heating, industrial processing and power generation.

As outlined in the Consultation Paper and AEMO's Market Modelling Methodology paper, AEMO applies an integrated model to determine the co-optimised development of electricity and gas sector developments, including the consideration of gas production facilities, pipelines, and gas fields. This model is used to ensure an optimal outcome for both gas and electricity sectors, determining the appropriate mix of development of new gas fields and infrastructure along with electricity transmission and generation. This modelling includes gas sector development options investigated in the 2019 GSOO.

In the case of EVs, an integrated electricity and transport model had not yet been developed, but AEMO has also held several cross-sector workshops to test assumptions on uptake, charging, and discharging profiles.

Hydrogen sector development

AEMO has ensured that fuel cell vehicles, such as those which may be hydrogen-fuelled, are captured in the EV forecasts, as suggested by ENGIE.

This ISP will include references to the potential for hydrogen to meet some of the requirements (for example, storage) identified in the ISP. It is too early to integrate more detailed consideration in the modelling. AEMO continues to support and work with the Commonwealth taskforce that is developing advice to support future policy in hydrogen, and decarbonisation of the gas sector more generally. This further research and development is required before hydrogen can be integrated into AEMO's models, or into an ISP scenario.

6.2.3 AEMO's conclusion

AEMO appreciates the potential opportunity that an electrolyser-powered green hydrogen industry may have in Australia, however the data and modelling methods to integrate this are not sufficiently refined to enable inclusion in the 2019-20 ISP.

AEMO's 2019 Inputs and Assumptions Workbook has been amended to include greater clarity on assumptions within the gas sector of AEMO's integrated model, and now outlines the technical capabilities of the existing network and all development options considered in its gas-electricity integrated model.

6.3 Ancillary services

6.3.1 Issue summary and submissions

Stakeholders raised questions around the role ancillary services and future value streams from ancillary service markets may have in the ISP:

- **Tesla** recommended that AEMO provide clarity on the consideration of the total contribution from battery storages across not just energy storage, but flexibility provided, such as ancillary services and system security benefits. Tesla also questioned the extent to which inertia contributions are captured, as batteries may be capable of providing 'virtual inertia'.
- **Stanwell, AGL,** and the **CEC** also suggested that ancillary services need to be considered in any retirement assumptions and replacement decisions, noting the value from generation extends beyond just the energy that is provided.
- **ERM Power** and **Hydro Tasmania** requested the inclusion of alternative peaking technologies to improve model granularity and reflect trends in technology types being developed.

6.3.2 AEMO's assessment

AEMO's optimisation models determining the generation developments for the ISP do not currently have sufficient granularity to consider the co-optimised settlement of energy and ancillary service markets. These markets require strong consideration of dispatch and market dynamics within an intra-hour time-scale. Dynamic fluctuations in intra-hourly supply is currently not captured in AEMO's forecasting models due to modelling being conducted on an hourly basis. AEMO considers that these alternative technologies would not materially change the fuel or network development requirements, and therefore modelling intra-hour for capacity expansion planning does not warrant the added computational burden.

As such, OCGTs are included in AEMO's capacity outlook models to represent the peaking generation class of generation. As the capacity mix changes, the scale of ancillary services required, and the source of these services, will require re-analysis.

6.3.3 AEMO's conclusion

AEMO continues to develop its methodologies to analyse and develop future power system requirements, and will incorporate this information in an iterative approach with generation development modelling. As stated, the current implementation of the ISP models do not allow for the sub-hourly modelling required to consider ancillary services in detail.

6.4 Inertia, system strength, and synchronous condensers

6.4.1 Issue summary and submissions

Stakeholders provided the following feedback:

- **TasNetworks** suggested that, rather than having no representation of inertia or fault level effects in the generation expansion models, some simplified representation of either fault level or inertia be introduced. For example, AEMO could model inertia and system strength on a power station, power scheme, or REZ basis, as opposed to an individual generating unit basis. Such a representation would not be perfect, but it would provide an initial attempt to ensure plainly implausible dispatch outcomes could not be predicted by the capacity outlook models.

- The **CEC** proposed that AEMO provide specific commentary on the South Australian synchronous condensers solution, in particular for managing system security constraints.
- The **CEC** also noted that, under current Rules, AEMO must report on potential inertia and system strength gaps, and indicated it will continue to explore and report on efficient solutions to deliver these system services.
- **ERM Power** commented that system strength and inertia services could be provided by dual-purpose gas turbines or pumped hydro designed to also operate in synchronous condenser mode, as opposed to the current trend for NSPs to provide this as an additional regulated service paid for by consumers. ERM questioned whether markets for the provision of power system support services ultimately deliver these services at lower costs than the current provision of these support services as a regulated network service.

6.4.2 AEMO's assessment

AEMO is exploring the means for reporting on potential inertia and system strength gaps, and will provide information and guidance as required, and in a timely fashion.

AEMO notes that, regarding synchronous condenser operations, ElectraNet has published an Economic Evaluation Report[38] which has specific commentary on this issue. This report was reviewed by AEMO. Additionally, the AER has an open contingent project on their website with further relevant information[39].

6.4.3 AEMO's conclusion

AEMO is continuing to develop its methodologies to ensure, to the extent possible, models are informed of inertia/system strength requirements, to at least reduce the iterative nature of the traditional approach.

In the absence of a more elegant solution, the iterative approach will still be applied, and consideration for which generators may provide these services, or whether other solutions are required, will be included in that iterative approach.

6.5 Revenue sufficiency

6.5.1 Issue summary and submissions

Stakeholders broadly agreed that the proposed consideration of economic retirement due to revenue insufficiency would be a useful addition to the ISP analysis. **AGL Energy**, **AusNet Services**, **Snowy Hydro**, **ERM Power**, **ENGIE**, **Stanwell**, **Energy Australia**, **Hydro Tasmania**, the **CEC**, and the **AEC** all provided submissions regarding the usefulness of this approach.

Several participants pointed out that retirement decisions are influenced by a number of different factors, and not all these factors are included in market models:

- **AGL** highlighted that several factors impact plant closure decision-making – including but not limited to technical end of life, economic viability, fuel availability, jurisdictional retailer of last resort obligations, and the effects of contract markets – not just revenue adequacy: "Most participants operate a portfolio of assets, and utilise these assets on a portfolio basis, rather than as standalone generators. A single generator does not rise and fall on its own limited economics, but on how it fits into a participant's book."

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[38] ElectraNet, 2019, Addressing the System Strength Gap in SA, at https://www.aer.gov.au/system/files/ElectraNet%20-%20System%20Strength%20Economic%20Evaluation%20Report%20-%2018%20February%202018.PDF.

[39] At https://www.aer.gov.au/networks-pipelines/determinations-access-arrangements/contingent-projects/electranet-main-grid-system-strength-contingent-project.

- **AGL** also urged AEMO to consider commercial implications in its modelling and assumptions to form an appropriate basis for the ISP and/or ESOO, for example, considering how customer load can be hedged in a scenario where there are low volumes of in-regional dispatchable generation, and the implications for cap contract revenues.
- **AusNet Services** stressed the underlying importance of the coal retirement trajectory in influencing the ISP development and supported the assessment of revenue sufficiency as well as technical life, safety, and political factors in determining retirement timing.
- **CEC** noted the difficulty in accessing information required to make revenue sufficiency assessments, including details on individual businesses books, contracts, and futures positions, and understanding rehabilitation costs (especially for the Latrobe Valley).
- The **AEC** also noted the importance of considering revenues received from contract and ancillary service markets when assessing future revenue sufficiency.
- **Hydro Tasmania** noted that retirements earlier than end of technical life could be driven by factors including technical and safety issues, as well as financial viability.
- **ENGIE and ERM power** highlighted that generators would vary their unit commitment behaviour over time as required, potentially exploring two-shifting or reducing minimum loads and expressed concerns that maintaining must-run minimum generation levels in the modelling could underestimate revenue potential. They also suggested that the fixed operating and maintenance costs of plant should be allocated on an operating-hours-in-service basis, rather than a $/kW of installed capacity/year, to reflect the fact that fixed costs as a portion of levelised costs of production would increase as capacity factor decreases.
- **Infigen** also noted potential for future coal plant operation changes, including reducing minimum generation and utilising more efficient warm-start technologies.
- **Stanwell Corporation** suggested that AEMO should use the retirement dates provided by generators, as these already take into account forecast revenue adequacy, asset management, portfolio considerations, and other factors.

6.5.2 AEMO's assessment

As outlined in Section 5.1, AEMO acknowledges that earlier coal capacity exit could be triggered by a range of market and policy conditions, not least the competitive dynamics affecting generation operations, portfolio management, and operational flexibility, and the impact the changing generation mix may have on financial markets for financial derivative contracts to hedge risk.

Without significant additional information on the specific commercial arrangements of generators and/or generation portfolios, fuel delivery constraints, or the technical feasibility of changing operating regime of traditionally inflexible plant, revenue sufficiency assessments cannot provide definitive conclusions regarding the optimal closure timings, and should be treated with caution so as not to misinform decision-makers.

Assessing these factors would be a valuable inclusion for the methodology of determining coal retirements. However, due to confidentially concerns, lack of transparency on commercial positions and capital history, and limited available datasets on technical capabilities of individual plant, these elements will not be included in the 2019-20 ISP.

With respect to changes in how fixed operating and maintenance costs should be input, the market modelling does not rely on levelised costs to assess revenue sufficiency, but instead explicitly captures fixed and variable costs within the assessment of generator revenue. If generators are exhibiting declining capacity factors over time, the modelling will automatically assess that the fixed costs, as a proportion of total costs, are increasing. No adjustments are therefore considered to be necessary. However, it is noted that changes in capital expenditure could change over time as plant ages, and this is not currently captured in the modelling.

AEMO intends to consult with industry later this year to better understand what information may be included in future to better assess reliability, maintenance costs, future operating flexibility, and fuel availability, which all impact revenue sufficiency and 'plant at risk'.

6.5.3 AEMO's conclusion

AEMO will work with stakeholders to identify the key sets of data that will be required to improve the quality of retirement decisions for future publications.