Transgrid

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Meeting system strength requirements in NSW

System Strength PADR Supplementary Report

Region: New South Wales

Date of issue: 17 October 2024

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Introduction

Transgrid, as the System Strength Service Provider (SSSP) for NSW, is responsible for ensuring sufficient system strength services are available to maintain power system stability in NSW. We are applying the Regulatory Investment Test for Transmission (RIT-T) to network and non-network options that meet our National Electricity Rule (NER) obligations, specifically:

1. Clause 11.143.15 to address a system strength Shortfall in the transmission network at Newcastle and Sydney West, forecasted to arise from 1 July 2025 and continue until 1 December 2025; and
2. Clause S5.1.14 to deliver system strength services to the NSW power system to meet standards set by AEMO from 2 December 2025, including for the safe and secure operation of the power system (minimum level) and to facilitate the stable voltage waveform ('efficient' level) of new inverter-based resources (IBR).

Transgrid published the second stage of the system strength RIT-T, the Project Assessment Draft Report (PADR) on 17 June 2024 which assessed over 100 network and non-network solutions to identify several 'portfolio options' that are designed to meet our system strength obligations and maximise the present value of net economic benefit to the NEM.

There have been several developments since the PADR modelling was finalised that may have an impact on the composition of the preferred portfolio of system strength solutions. This Supplementary Report has therefore been prepared to investigate the anticipated impacts of these developments and to consult on them ahead of development of the Project Assessment Conclusions Report (PACR).

Developments since completion of the PADR modelling

There have been three key developments since the completion of the PADR modelling which may have an impact on the composition of the preferred option. Specifically:

- on 22 May 2024, the NSW Government and Origin Energy agreed to delay retirement of Eraring Power Station by two years from 19 August 2025 to 19 August 2027;[1]
- on 17 May 2024, EnergyCo announced a revised timetable for the completion of the New England Renewable Energy Zone (REZ) Network Infrastructure Project, with a delay of approximately two years to June 2031 (stage 1) and June 2033 (stage 2).[2] This delay will impact AEMO's future forecasts of the quantity, timing and location of new inverter-based resource (IBR); and
- on 26 June 2024, AEMO's Final 2024 Integrated System Plan (ISP) was published. AEMO's IBR forecasts drive Transgrid's obligations to maintain stable voltage waveforms. These IBR forecasts are updated annually in December, via AEMO's System Strength Report. The Final 2024 ISP included a sensitivity which tested a delay to the timing of the New England Renewable REZ Infrastructure Project.

[1] https://www.originenergy.com.au/about/investors-media/origin-and-nsw-government-agree-to-delay-closure-of-eraring-power-station/, accessed 15 August 2024.

[2] AEMO NEM Transmission Augmentation Information August 2024. https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/transmission-augmentation-information/nem-transmission-augmentation-information-august-2024.xlsx?la=en, accessed 12 September 2024.

Purpose of this report

Unlike the various sensitivity tests investigated as part of the PADR which focused on key changes to inputs and assumptions that *could* happen in the future,[3] developments that have already occurred will be reflected in our core PACR modelling, the final stage of the RIT-T assessment.[4]

This Supplementary Report has therefore been prepared to investigate the anticipated impacts of these developments on the optimal portfolio of system strength solutions in NSW and to consult on them ahead of the PACR being prepared. We have modelled these developments through two sensitivities:

- **Sensitivity 1:** Revised retirement date of Eraring Power Station;
- **Sensitivity 2:** Inverter-based resource forecasts within AEMO's Final 2024 ISP, including revised timing for the New England REZ.

We have run these two separate sensitivities to isolate the impact of key developments on the composition of the optimal portfolio of system strength solutions. For the PACR, all inputs and assumptions will be updated together to reflect AEMO's most recent Inputs, Assumptions and Scenarios Report (IASR), outcomes of the 2024 ISP and the best available information at the time.

In addition to these developments, this Supplementary Report also explores the costs and benefits of bringing forward the procurement of synchronous condensers to enhance the robustness of our portfolio of system strength solutions to unexpected events and supply chain risks and to increase competition between non-network solutions. This sensitivity is modelled and presented from a theoretical viewpoint, to be further explored through the PACR.

In this sensitivity, four synchronous condensers which were identified in the PADR as being required between 2029/30 and 2031/32 were each brought forward by one year. This is presented as:

- **Sensitivity 3:** Increasing the robustness of the portfolio of system strength solutions by bringing forward the commissioning of synchronous condensers.

All modelling undertaken for this Supplementary Report applied the same modelling methodologies and inputs, assumptions and scenario as used for the PADR, with the obvious exception of the key assumptions that have been explicitly varied, and commented on, as part of each sensitivity. We therefore have not repeated the discussion of these modelling approaches in this report, and we encourage you to

[3] Specifically, section 9.7 of the PADR presented the results of separate sensitivities that investigated how portfolio option 1 could change if the following are assumed: (1) a range of 'self-remediation' sensitivities for both NSW REZs and modelled BESS to test the implications of a reduction in the amount of system strength we actually need to procure; (2) grid-forming BESS being able to provide more 'stable voltage waveform' support than Transgrid currently expects; (3) alternate Value of Emissions Reductions (VER, consistent with those determined by Energy Ministers and published by the AER in March 2024); and (4) assuming a one-year delay to contracting with all grid-forming BESS (or conversions to become grid-forming), given they represent a relatively novel solution and have a range of timing uncertainties, and a hydro unit that has proposed to upgrade their plant to enable it to operate in both generation and synchronous condenser modes.

[4] While we referred to this Supplementary Report as an additional 'RIT-T re-opening trigger consultation document' in the PADR, its focus has changed slightly to instead be on updates to key assumptions that are expected to be broadly incorporated in the PACR considering developments that have occurred since the PADR modelling was finalised. This report does not propose any additional re-opening triggers to those included in the PADR and we do not consider any of the developments discussed in this report are relevant to the consideration of re-opening triggers, given they have already occurred, or in the case of bringing forward the commissioning of some synchronous condensers, reflect a planning consideration, as opposed to a potential external development that could impact the identification of the preferred option.

refer to the PADR and the accompanying Baringa Market Modelling Report on the portfolio optimisation and wholesale market modelling undertaken for more detail.[5]

Submissions and next steps

Transgrid welcomes written submissions on the materials contained in this Supplementary Report. Submissions are due on 15 November 2024.

Submissions should be emailed to our Regulation team via regulatory.consultation@transgrid.com.au.[6] In the subject field, please reference 'Meeting system strength requirements in NSW RIT-T PADR Supplementary Report'.

At the conclusion of the consultation process, all submissions received will be published on our website. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement.

The next formal stage of this RIT-T is the publication of a PACR. The PACR will address all submissions received to this report (as well as the PADR), including any issues raised in relation to the proposed preferred option. We anticipate publication of a PACR in the first half of 2025.

[5] Both of these reports can be accessed via: https://www.transgrid.com.au/projects-innovation/meeting-system-strength-requirements-in-nsw

[6] Transgrid is bound by the Privacy Act 1988 (Cth). In making submissions in response to this consultation process, Transgrid will collect and hold your personal information such as your name, email address, employer and phone number for the purpose of receiving and following up on your submissions. If you do not wish for your submission to be made public, please clearly specify this at the time of lodgement. See Privacy Notice within the Disclaimer for more details.

Sensitivity 1: Revised retirement date of Eraring Power Station

On 22 May 2024, following the conclusion of our PADR market modelling, the NSW Government and Origin Energy agreed to delay the retirement of the Eraring Power Station by two years, from 19 August 2025 to 19 August 2027.[7]

We have investigated how the composition of the PADR portfolio option 1 changes from 2 December 2025 [8] as a result of the two-year delay to the assumed retirement date for the Eraring Power Station.

The modelling identifies that the delay to Eraring's retirement increases the amount of system strength available from normal energy market dispatch during the period to August 2027. Results show similar numbers of coal and hydro 're-dispatch' hours, but lower number of gas 're-dispatch' hours to meet system strength requirements, compared to the PADR portfolio option 1.

The results show there is no change to the optimal build path of synchronous condensers or synchronous machine upgrades to allow synchronous condenser mode, and only a slight change to the required timing of new grid-forming battery capacity as a result of the delayed retirement of the Eraring Power Station.

Impact on the preferred portfolio of system strength solutions

This sensitivity models the impact of Eraring Power Station's extension on the optimal portfolio of system strength solutions. The extension of Eraring Power Station to 19 August 2027 was the only assumption that varied in this analysis compared to that in the core PADR assessment.

Compared to portfolio option 1 (i.e. the core portfolio option published in the PADR), the Eraring Power Station retirement delay sensitivity:

- increases the amount of system strength available from normal energy market dispatch in NSW prior to Eraring's retirement, as a result more coal units online during most periods of the year;
- shows similar amounts of additional 're-dispatch' hours of coal and hydro generators to meet system strength requirements, but less hours of gas 're-dispatch';
- does not change the number and timing of synchronous condensers. This is due to the revised Eraring retirement date (start of 2027/28) remaining prior to the earliest assumed date that synchronous condensers are able to be commissioned (in 2028/29);
- does not change the amount and timing of synchronous machine upgrades to allow synchronous condenser mode; but
- accelerates the need for 400 MW of grid-forming battery capacity from 2028/29 to 2025/26 and 250 MW from 2029/30 to 2028/29. The portfolio then reflects the same quantity of grid-forming batteries beyond that date.

[7] https://www.originenergy.com.au/about/investors-media/origin-and-nsw-government-agree-to-delay-closure-of-eraring-power-station/, accessed 15 August 2024.

[8] The Shortfall period, being 1 July to 1 December 2025 is not the focus of this sensitivity, as AEMO's modelling, rather than Transgrid's, will determine the size of the Shortfall. Transgrid expects that AEMO will reassess and update its Shortfall declaration (for 1 July to 1 December 2025) in the December 2024 System Strength Report. The implications of any AEMO re-assessment will feed into Transgrid's assessment for the PACR.

Figure 1 compares the expected normal electricity market operating hours and ‘re-dispatch’ hours of synchronous machines in PADR’s portfolio option 1 with this sensitivity modelling the delay to the retirement of Eraring Power Station.

Figure 1. Operation when co-optimised for system strength (lines), compared with expected normal electricity market operation (shaded areas) in the delayed Eraring Power Station retirement date sensitivity and in the PADR’s portfolio option 1

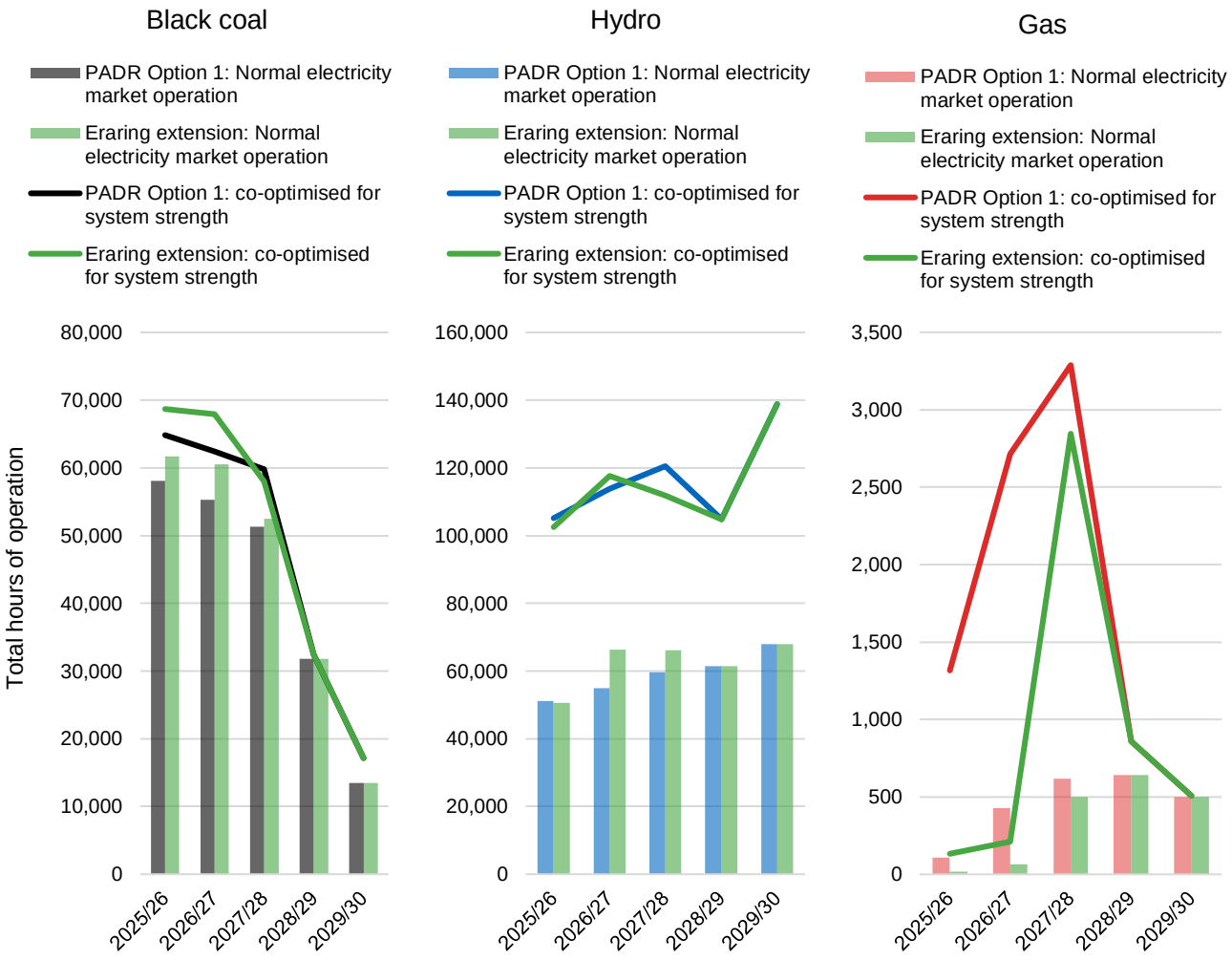


Table 1 shows how the composition of synchronous condensers, synchronous machine modifications and grid-forming batteries in the PADR portfolio option 1 varies with the revised Eraring Power Station retirement date assumption.

Table 1. Comparison between the composition of the PADR portfolio option 1 and the revised Eraring Power Station retirement date sensitivity

Synchronous condensers – cumulative number of units (each providing 1,150MVA$_{fault\ current}$)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	–	–	–	8	10	13	14	14	26
Delayed Eraring retirement	–	–	–	8	10	13	14	14	26

Upgrades to synchronous machine to allow synchronous condenser mode (existing and new units) – cumulative capacity (MW)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	–	50	550	550	550	550	550	550	550
Delayed Eraring retirement	–	50	550	550	550	550	550	550	550

Grid-forming BESS – cumulative capacity (MW)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	750	2,600	2,600	3,500	4,800	4,800	4,800	4,800	4,800
Delayed Eraring retirement	1,150	3,000	3,000	3,750	4,800	4,800	4,800	4,800	4,800

The increase in grid-forming battery capacity between 2025/26 and 2028/29 is driven by the change in synchronous machines dispatch outcomes under the Eraring Power Station retirement delay sensitivity. Our modelling shows that Eraring Power Station's operation offsets the dispatch of other synchronous units across NSW during some periods of the year. Since synchronous generators provide system strength whenever they are dispatched, the reduction in dispatch of other synchronous units leads to reduced system strength levels in the areas surrounding these generators during periods when they are offline.

Our modelling identifies that, in response, bringing forward the delivery of additional grid-forming battery capacity to support the stable voltage waveform of new IBR leads to the greatest net market benefit. Noting the increased requirement for grid-forming batteries in the early years, Transgrid will carefully assess the delivery timeframe of grid-forming battery solutions through the PACR modelling process, to ensure our optimal portfolio of solutions is robust and realistic.

The revised retirement date for the Eraring Power Station in August 2027 remains prior to the earliest commissioning date of synchronous condensers in our model. As such, the build path of synchronous condensers does not change. Once Eraring Power Station retires, we see similar unfilled gaps in system strength at Armidale, Newcastle, Sydney West, Wellington and Darlington Point in 2027/28, as identified within the PADR.

We have not undertaken the full cost-benefit assessment of this portfolio as the objective of the analysis was to identify how the composition of the preferred portfolio option changes because of the delayed retirement of Eraring Power Station. However, the updated retirement date for Eraring Power Station will be reflected in both the portfolio optimisation and cost-benefit assessment of the PACR.

Through the PACR, we intend to explore a sensitivity where Eraring Power Station's retirement is delayed further, to no later than April 2029, as per the latest permanent deregistration date within the agreement between the NSW Government and Origin Energy.[9]

[9] NSW Department of Climate Change, Energy, the Environment and Water, May 2024, Fact Sheet, Agreement between the state of NSW and Origin on its plans for Eraring power station, https://www.energy.nsw.gov.au/sites/default/files/2024-05/NSW-202405-Public-summary-of-Generator-Engagement-Project-Agreement.pdf

Sensitivity 2: Inverter-based resource forecasts within AEMO's Final 2024 ISP, including revised timing for the New England REZ

AEMO's System Strength Report, updated annually in December, provides a 10-year forecast of IBRs which drive Transgrid's system strength requirements. Transgrid intends to update its PACR modelling to reflect the IBR forecasts to be contained with AEMO's upcoming December 2024 System Strength Report, as well as best available information.

Since AEMO's recently published 2024 Integrated System Plan contains more up to date IBR forecasts than were used to model our obligations in the PADR (sourced from the December 2023 System Strength Report), this sensitivity assesses the impact of these new IBR forecasts on our optimal portfolio of system strength solutions.

AEMO's latest 2024 ISP IBR forecasts, within the sensitivity on the delayed commissioning of the New England REZ, projects additional IBR growth surrounding Central West Orana REZ and the Southwest REZ between 2028/29 to 2030/31, and a commensurate decrease in IBR surrounding the New England REZ.

This results in variations to the optimal portfolio of system strength solutions compared to the PADR's portfolio option 1, including one additional synchronous condenser in Transgrid's transmission backbone from 2028/29 and 7 additional synchronous condensers within the Central West Orana REZ (stage 2) and the New England REZ by 2032/33.

While this sensitivity identifies solutions required to remediate the Central West Orana (stage 2) and New England REZs, as we did for portfolio option 1 in the PADR, Transgrid is actively working with EnergyCo to determine the most appropriate party to provide system strength remediation for these REZs.[10]

The modelling suggests that an additional 3,300 MW of grid-forming battery capacity is required from 2027/28 to service system strength requirements across NSW, including within the Central West Orana REZ (stage 2) and New England REZ. Noting these results, Transgrid will carefully assess the optimal location of grid-forming batteries for system strength provision through our PACR modelling process; i.e. within these REZs versus within Transgrid's transmission backbone. We will also closely assess delivery timeframes of the required grid-forming battery solutions to ensure our optimal portfolio of solutions is robust and realistic.

Updates to IBR forecasts within AEMO's Final 2024 Integrated System Plan

Transgrid, as the SSSP for NSW, has obligations under the NER to forward procure sufficient system strength to support the stable connection and operation of new IBRs in NSW, as forecasted by AEMO through its annual System Strength Report.

AEMO will next publish its IBR forecasts in December 2024. We intend to use the latest IBR forecasts which will be published by AEMO in December 2024, as well as best available information, to drive our system strength requirements for the PACR modelling. Since AEMO's recently published 2024 Integrated System Plan contains more up to date IBR forecasts than were modelled in the PADR (driven from the 2023 System Strength Report[11]), this Sensitivity assesses the impact of these new IBR forecasts on our optimal portfolio of system strength solutions.

[10] EnergyCo has previously determined that the Network Operator for stage 1 of the Central West Orana REZ, ACEREZ, is responsible for providing system strength remediation for the first 5.84GW of IBRs within the REZ.
[11] AEMO, 2023 System Strength Report, December 2023.

Following AEMO's commencement of market modelling for the final ISP 2024, EnergyCo revised the expected commissioning dates of New England REZ Infrastructure Project (a two-year delay to previous assumptions). This delay was not able to be captured within AEMO's already-commenced modelling of the Optimal Development Path[12] for the 2024 ISP. Ordinarily, analysis for this Supplementary Report would use the IBR forecasts derived from the Optimal Development Path, however delays to the New England REZ will have a material impact on the timing and quantum of IBRs deployed throughout NSW, and consequently, the location and timing of system strength solutions required.

As such, we have used the 'Step Change & New England REZ delay' sensitivity (Candidate Development Path 9) which was also published within the 2024 ISP, to drive our stable voltage waveform requirements for this Sensitivity (Sensitivity 2). This provides the best available view of how the anticipated updates in the forthcoming December 2024 System Strength Report may change the composition of the portfolio of system strength solutions within the PACR analysis.

Comparison to the IBR forecast in AEMO's 2023 System Strength Report

Figure 2 and Figure 3 below compare the IBR forecast provided within:

- AEMO's 2023 System Strength Report, used to drive Transgrid's obligations in the PADR (in green);
- the Final 2024 ISP Optimal Development Path, where the delay to New England REZ was not captured (light green); and
- the 'Step Change & New England REZ delay' sensitivity (CDP9) within the Final 2024 ISP (in blue).

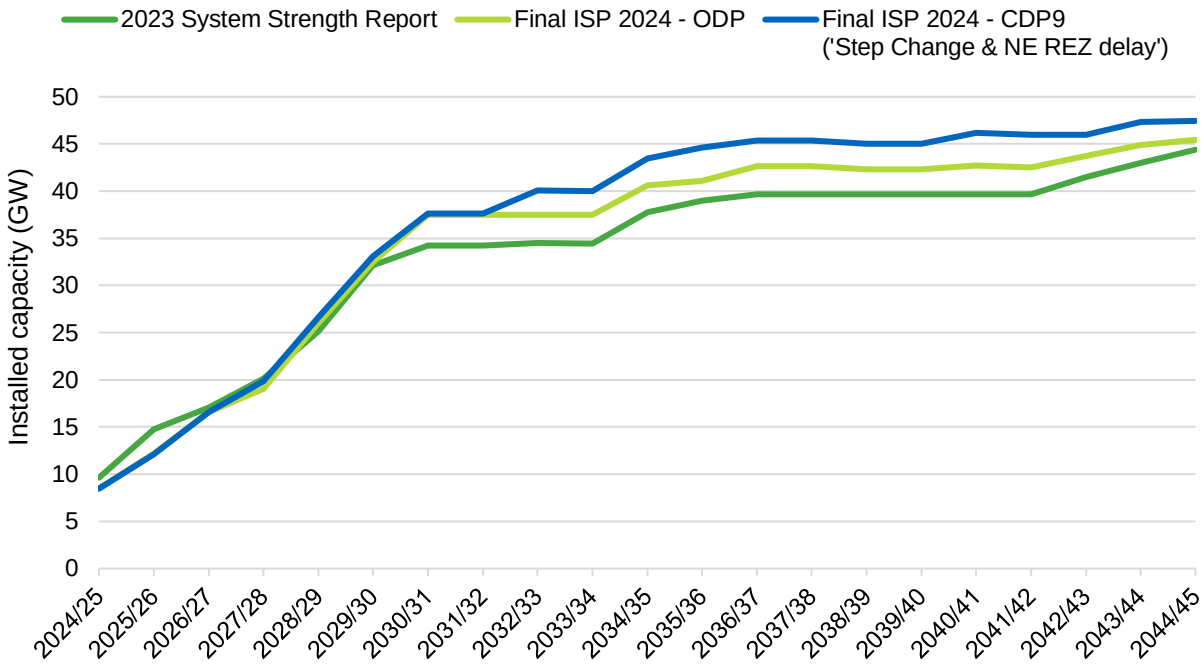
Comparing the IBR outlook from the 2024 ISP forecasts to AEMO's 2023 System Security Report, there is a generally similar trend in IBR uptake with a slight increase in capacity, particularly from 2030/31 onwards.

Comparing the IBR forecast from the 'Step Change & New England REZ delay' sensitivity to the Optimal Development Path, there is additional IBR capacity entering NSW, particularly from 2030/31. Between 2028/29 and 2030/31, IBR capacity enters surrounding Wellington, Darlington Point and Buronga system strength nodes to substitute IBR capacity displaced due to the delay in the New England REZ, to meet demand as coal generators progressively exit the market and to achieve the NSW Electricity Infrastructure Roadmap target by 2030.

Once the New England REZ Network Infrastructure Project (Flow Path Option 1 and REZ Extension) is delivered in 2032/33 in the New England REZ delay sensitivity, further IBR capacity is forecast to enter the New England REZ and utilise the newly available resources and transmission capacity.

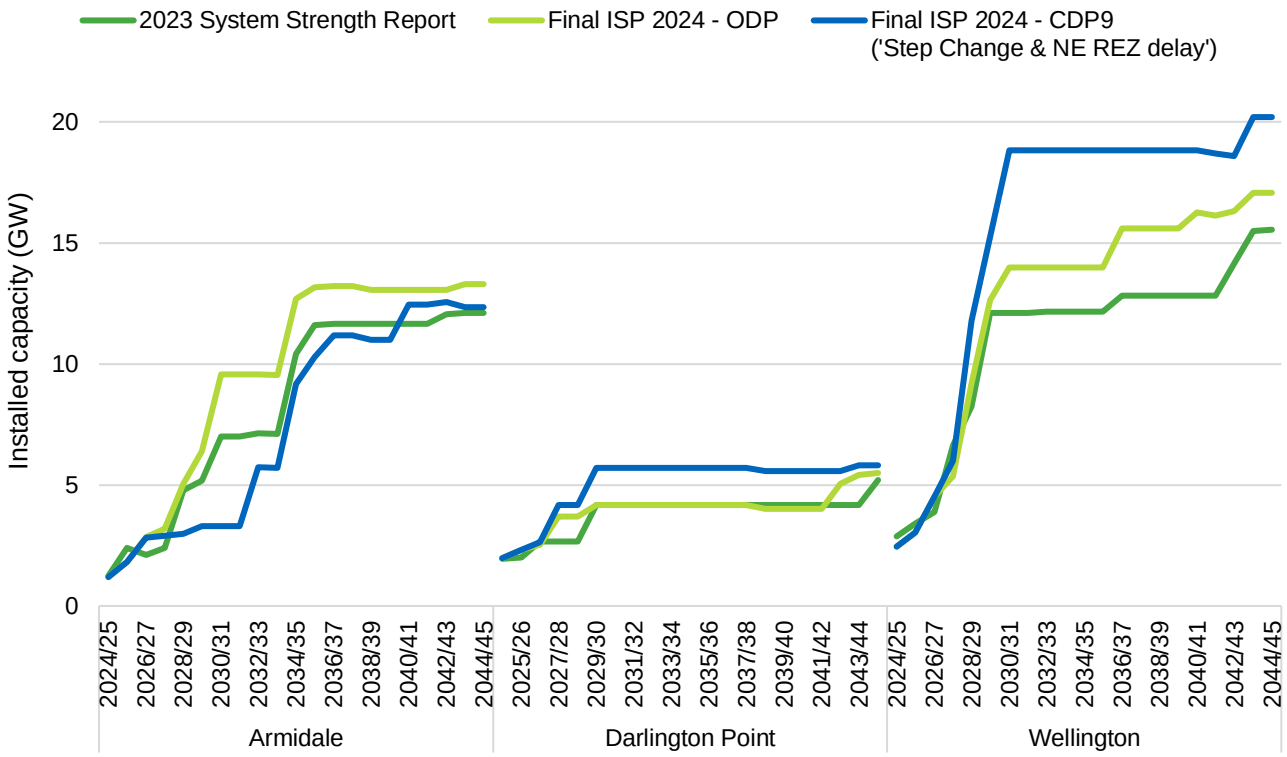
[12] The Optimal Development Path within the 2024 Integrated System Plan is denoted as Candidate Development Path 14 (CDP14).

Figure 2. Total NSW IBR forecasts from the 2023 System Strength Report and the Final 2024 ISP



The IBR capacity outlook surrounding the Armidale (New England REZ), Darlington Point (Southwest NSW REZ) and Wellington (Central West Orana REZ) system strength nodes can be compared in Figure 3.

Figure 3. AEMO IBR forecast comparison at Armidale, Darlington Point and Wellington system strength nodes



Impact on the preferred portfolio of system strength solutions

In line with the PADR portfolio option 1, this sensitivity assumes that Transgrid is responsible for procuring system strength to support all future IBRs in NSW, including within stage 2 of Central West Orana REZ and New England REZ. The only exception to this, consistent with the PADR portfolio option 1, is that ACEREZ, the Network Operator of stage 1 of the Central West Orana REZ is responsible for procuring system strength for the initial 5.84 GW of IBR within that REZ.

Transgrid is actively working with EnergyCo to determine whether Transgrid or a future REZ Network Operator will be the most appropriate party to provide system strength remediation for stage 2 of the Central West Orana REZ and the New England REZ. Transgrid will seek to resolve this question prior to commencing market modelling for the PACR.

Compared to the PADR portfolio option 1, which applies the IBR forecasts from the December 2023 System Strength Report, adopting the IBR forecasts from the Final 2024 ISP 'Step Change & New England REZ delay' sensitivity results in a significant increase in required synchronous condenser build, due to both the overall increase and change in location of forecast IBR capacity in NSW. Notably:

- from 2028/29 (the earliest year synchronous condensers are able to be commissioned in our model), one additional synchronous condenser is required in Transgrid's transmission backbone; and
- between 2028/29 and 2031/32, six additional synchronous condensers are required in Central West Orana REZ (stage 2) and New England REZ relative to portfolio option 1.

In addition, compared to the PADR portfolio option 1, the optimal portfolio contains:

- the same amount of synchronous machine upgrades to allow synchronous condenser mode; and
- the need for an additional 3,300 MW of grid-forming battery capacity in 2027/28, which reduces to 1,800 MW more than portfolio option 1 from 2029/30 for the remainder of the assessment period.

Table 2 shows how the composition of the PADR portfolio option 1 varies with IBR forecasts under the 2024 ISP 'Step Change & New England REZ delay' sensitivity.

Table 2. The composition of the PADR portfolio option 1 and this Sensitivity, which adopts IBR forecasts from the 'Step Change & New England REZ delay' sensitivity from AEMO's Final 2024 ISP

Transgrid network synchronous condensers * Cumulative number of units (each providing 1,150MVA$_{fault\ current}$)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	–	–	–	6	7	8	8	8	12
2024 ISP Step Change & New England REZ delay sensitivity	–	–	–	7	8	9	9	9	10

REZ synchronous condensers * For Central West Orana REZ (stage 2) & New England REZ. Cumulative number of units (each providing 1,150MVA$_{fault\ current}$)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	–	–	–	2	3	5	6	6	14
2024 ISP Step Change & New England REZ delay sensitivity	–	–	–	4	7	12	12	13	21

** Note that the total number of synchronous condensers required in NSW as identified through this RIT-T is the sum of the Transgrid network synchronous condensers and the REZ synchronous condensers.*

Upgrades to synchronous machine to allow synchronous condenser mode (existing and new units) – cumulative capacity (MW)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	–	50	550	550	550	550	550	550	550
2024 ISP Step Change & New England REZ delay sensitivity	–	50	550	550	550	550	550	550	550

Grid-forming BESS – cumulative capacity (MW)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
PADR Portfolio option 1	750	2,600	2,600	3,500	4,800	4,800	4,800	4,800	4,800
2024 ISP Step Change & New England REZ delay sensitivity	750	2,550	5,900	5,900	6,600	6,600	6,600	6,600	6,600

The increase in synchronous condensers and grid-forming battery capacity required across the horizon is principally driven by the large increase in IBRs in the Central-West Orana REZ (stage 2) and the Southwest REZ in AEMO's Final 2024 ISP 'Step Change & New England REZ delay' sensitivity. This increases the requirement for stable voltage waveform support (i.e., the efficient level system strength requirement) surrounding the Wellington and Darlington Point nodes, with a reduction in requirements surrounding the Armidale, Newcastle and Sydney West nodes.

Notably by 2030/31, there is one additional synchronous condenser in Transgrid's transmission backbone and seven additional synchronous condensers in Central West Orana REZ (stage 2) and New England REZ to support the change in location and an additional 3.7 GW in capacity of total IBR compared to PADR portfolio option 1.

The following tables present the composition of synchronous condensers in the optimal portfolio of solutions when comparing this Sensitivity (Table 3) with portfolio option 1 published within the PADR (Table 4).

Table 3. The composition of synchronous condensers in the optimal portfolio of solutions from this Report's Sensitivity 2, adopting AEMO's Final 2024 ISP IBR forecasts ('Step Change & New England REZ delay' sensitivity)

Synchronous condensers – cumulative number of units (each providing 1,150MVA$_{fault\ current}$)							
Financial year	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
Armidale	-	1	1	1	1	1	1
Tamworth	-	-	1	1	1	1	1
Liddell	-	-	-	-	-	-	1
Newcastle	-	1	1	1	1	1	1
Sydney West	-	1	1	2	2	2	2
Wellington	-	2	2	2	2	2	2
Wagga Wagga	-	-	-	-	-	-	-
Darlington Point	-	1	1	1	1	1	1
Dinawan	-	1	1	1	1	1	1
Transgrid synchronous condensers	**-**	**7**	**8**	**9**	**9**	**9**	**10**
New England REZ	-	-	-	-	-	1	7
Central West Orana REZ (stage 2)	-	4	7	12	12	12	14
REZ synchronous condenser	**-**	**4**	**7**	**12**	**12**	**13**	**21**

Table 4. The composition of synchronous condensers in the optimal portfolio of solutions in the PADR's portfolio option 1 (with IBR forecasts driven from the 2023 System Strength Report)

Synchronous condensers – cumulative number of units (each providing 1,150MVA$_{fault\ current}$)							
Financial year	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
Armidale	-	1	1	1	1	1	1
Tamworth	-	1	1	2	2	2	2
Liddell	-	-	-	-	-	-	2
Newcastle	-	1	1	1	1	1	1
Sydney West	-	1	1	1	1	1	1
Wellington	-	1	1	1	1	1	1
Wagga Wagga	-	-	1	1	1	1	1
Darlington Point	-	1	1	1	1	1	2
Dinawan	-	-	-	-	-	-	1
Transgrid synchronous condensers	**-**	**6**	**7**	**8**	**8**	**8**	**12**
New England REZ	-	-	-	2	3	3	7
Central West Orana REZ (stage 2)	-	2	3	3	3	3	7
REZ synchronous condensers	**-**	**2**	**3**	**5**	**6**	**6**	**14**

Note that the earliest commissioning date of synchronous condensers in this sensitivity is 2028/29, in line with the PADR portfolio option 1. As such, the outcome shows similar unfilled shortfalls of system strength at Armidale, Newcastle, Sydney West, Wellington and Darlington Point nodes in 2027/28.

There is an accelerated need for 3,300 MW of grid-forming battery capacity throughout NSW (including within REZs) by 2027/28 to contribute towards meeting the increased efficient level requirements (and synchronous condensers cannot be commissioned by that time due to procurement and commissioning lead times assumptions). Noting these results, Transgrid will carefully assess the delivery timeframe of

grid-forming battery solutions through the PACR modelling process, to ensure our optimal portfolio of solutions is robust and realistic.

The objective of this analysis is to identify how the composition of the preferred portfolio option (portfolio option 1) changes with updated IBR forecasts, which is determined within the 'Long-Term' portfolio optimisation functionality of the market modelling. As such, the half-hourly market modelling required to undertake the full cost-benefit assessment has not been performed for this Supplementary Report.

We expect to use latest IBR forecasts published in the AEMO's December 2024 System Strength Report, plus additional available information, to drive our efficient level system strength requirements in the PACR, for both the portfolio optimisation process and in the cost-benefit assessment.

Prior to commencing modelling, we will be working with EnergyCo to determine whether Transgrid or a future REZ Network Operator will be the most appropriate party to provide system strength remediation for future IBRs within stage 2 of the Central West Orana REZ and the New England REZ.

Sensitivity 3: Increasing the robustness of the portfolio of system strength solutions by bringing forward the commissioning of synchronous condensers

Sensitivity 3 explores the costs and benefits of bringing forward the procurement of synchronous condensers to enhance the ability of our portfolio of system strength solutions to manage unexpected events, supply chain constraints and to increase competition between non-network solutions. This sensitivity is modelled and presented from a theoretical viewpoint only.

Importantly, this sensitivity does not explore procuring synchronous condensers prior to the RIT-T being complete and the AER's approval of a Contingent Project Application (CPA), as was tested in the PADR portfolio option 2. Instead, it explores the commissioning of synchronous condensers earlier than the optimal date as identified through the portfolio formation of PADR portfolio option 1 (with procurement following the standard CPA process).

In this sensitivity, four synchronous condensers which were identified in the PADR portfolio option 1 as being required between 2029/30 and 2031/32 were each brought forward by one year.

Results show that bringing forward the commissioning of these four synchronous condensers reduce, by only $1 million, the net market benefits compared to the PADR portfolio option 1 (which had $11,312 million positive net benefits). This reduction is primarily driven by the time value of money, i.e. the additional capital and operating costs to bring forward the synchronous condensers, offset by the reduction in synchronous generation costs and associated emissions.

While bringing forward the commissioning of four synchronous condensers reduces quantified net market benefits by $1 million over the 20-year modelling period (equivalent to a 0.01% reduction), there are also unquantified benefits to the energy system. These include:

- increasing competition between synchronous generators potentially resulting in lower contracting costs with non-network synchronous generators, as a result of a reduced need for synchronous machine redispatch to fill gaps in system strength;
- enhancing resilience of the electricity system against the risks of earlier-than-expected retirement of coal generators and multiple coinciding planned or unplanned outages of generators; and
- mitigating risks associated with the potential for:
    - delayed entry of new grid-forming battery capacity;
    - delayed or unsuccessful modifications to synchronous machines to operate in synchronous condenser mode;
    - delayed or unsuccessful contracting with non-network synchronous generators; and
    - delayed procurement of synchronous condensers due to increasing global demand and supply chain constraints.

Through the PACR modelling process, we intend to further explore expediting synchronous condensers, and other non-network options where appropriate, to identify a balanced and pragmatic portfolio that both maximises net market benefits and mitigates the risk of future uncertainties, in turn bringing greater benefits for consumers.

We are interested in stakeholder views regarding bringing forward the commissioning of some synchronous condensers, and other non-network options where appropriate, as part of the ultimately preferred option identified in the PACR, in light of the potential benefits outlined in this report.

Future uncertainties and their potential impact on meeting system strength requirements

In line with the Australian Energy Regulator (AER) RIT-T guidelines and the AEMO ISP methodology, the PADR modelling uses a deterministic set of assumptions, aligned with the ISP Step Change scenario, that does not account for unexpected future events. The modelling has 'perfect foresight' of future market conditions and variables are known by the model with certainty, and as such optimises to build solutions 'just-in-time'. As a result, there is a risk that our modelling does not capture the full range of potential outcomes that could result from uncertain future conditions.

The risks associated with the timely deployment of system strength solutions are asymmetric in both magnitude and certainty. That is, the costs of late deployment (or rather 'just-in-time' deployment where unexpected events occur) are disproportionately large and uncertain in nature compared to the relatively small and known additional cost of deploying solutions earlier.

The AEMC also identified this asymmetric risk in the final system strength rule determination, concluding:[13]

> *"Following analysis undertaken through this rule change process, the Commission considers that a slight over-procurement of the service to support connecting IBR is likely to provide greater benefits for consumers than under-procurement. This is because due to the particular characteristics of system strength, the market impacts of having a unit less of the required amount of system strength is more significant than the cost of having an extra unit procured earlier than is needed"*

Examples of future situations which lead to lower levels of system strength than anticipated could include:

- unexpected or accelerated retirement of synchronous generators;
- multiple coinciding forced or planned outage events of synchronous units and/or transmission lines and equipment outages (i.e. above which is currently considered in the modelled set of inputs and assumptions); [14]
- unexpected delays in the procurement of synchronous condensers due to supply chains tightening as global demand increases;
- delays to, or unsuccessful commissioning of (or contracting with) non-network system strength solutions;
- delays or unsuccessful modifications / upgrades of synchronous units to allow synchronous condenser mode or grid-following batteries upgrades to grid-forming capability; and
- delays to transmission augmentations and upgrades which otherwise would have helped to decrease network impedance and increase fault current levels.

[13] AEMC, 2021, Final Rule: Efficient management of system strength on the power system, page vii, https://www.aemc.gov.au/rule-changes/efficient-management-system-strength-power-system

[14] An example of this resulted in a recent system strength security direction by AEMO to maintain the power system in a stable operating state. On 15 November 2023, for the first time, AEMO issued a market intervention to manage power system security in NSW. At this time, there were five coal units offline for simultaneous planned and unplanned outages with a sixth unit scheduled to soon commence an outage. The remaining six synchronous generating units online in NSW would have been inadequate to maintain a secure operating state. AEMO intervened, directing a seventh NSW synchronous generating unit to delay maintenance and remain online to maintain power system security in NSW. Source: AEMO Quarterly Energy Dynamics Report Q4 2023, p50, https://aemo.com.au/-/media/files/major-publications/qed/2023/quarterly-energy-dynamics-q4-2023.pdf

Bringing forward the commissioning of synchronous condensers

This sensitivity is modelled and presented from a theoretical viewpoint, to explore potential costs and benefits of increasing the robustness of the portfolio of system strength solutions.

The PADR analysis found that portfolio option 1 involved eight synchronous condensers as soon as they could be commissioned in 2028/29[15], with an additional six synchronous condensers required by 2031/32.

For the purposes of this Supplementary Report, we have investigated a theoretical sensitivity where the commissioning of four synchronous condensers were brought forward by one year. Compared to the PADR portfolio option 1, this means that the commissioning of:

- two synchronous condensers were brought forward one year, from 2029/30 to 2028/29;
- one synchronous condenser was brought forward one year, from 2030/31 to 2029/30; and
- one synchronous condenser was brought forward one year, from 2031/32 to 2030/31.

Importantly, this sensitivity does not explore accelerating synchronous condensers prior to the RIT-T being complete and the AER's approval of a Contingent Project Application (CPA). Instead, it explores the commissioning of synchronous condensers earlier than the optimal date as identified through the portfolio formation of PADR portfolio option 1 (with procurement following the standard CPA process).

Table 5 shows the synchronous condenser build pathway of the PADR's portfolio option 1 and this Report's expedited synchronous condenser sensitivity, to demonstrate how the composition changed.

Table 5. Annual cumulative number of synchronous condensers in PADR portfolio option 1 and this Report's Sensitivity 3 ('expedited' portfolio option 1)

Synchronous condensers – cumulative number of units (each providing 1,150MVAfault current)									
Financial year	**2025/26**	**2026/27**	**2027/28**	**2028/29**	**2029/30**	**2030/31**	**2031/32**	**2032/33**	**2044/45**
Portfolio option 1	–	–	–	8	10	13	14	14	26
Expedited portfolio option 1	–	–	–	10	11	14	14	14	26

Importantly, this is a theoretical exercise to assess the quantified costs and benefits of bringing forward the commissioning of synchronous condensers, in light of unquantified additional benefits. Through the PACR modelling process, we intend to further explore bringing forward the commissioning of synchronous condensers, as well as other non-network options as appropriate, to identify a balanced and pragmatic portfolio that both maximises net market benefits (within a margin of error) and mitigates the risk of future uncertainties.

This sensitivity does not involve portfolio optimisation and, instead, simply involves a manual adjustment to the timing of synchronous condensers commissioned in the PADR's optimal portfolio of solutions (portfolio option 1). The timing and quantity of upgrades to synchronous machines to allow synchronous condenser mode and deployment of grid-forming batteries remains the same.

[15] 2028/29 was the earliest date assumed in the PADR for the commissioning of synchronous condensers, following the standard regulatory process.

Impact on the estimated net market benefits

The purpose of this additional sensitivity is to understand whether the incremental costs involved (i.e., the time value of money of capital and operating costs to 'bring forward' the synchronous condensers) are materially higher than the quantifiable benefits of bringing forward this procurement.

The benefits estimated below are limited to the associated reduction in generator fuel costs and emissions quantified via the wholesale market modelling. Importantly, they do not include the benefit of enhancing the robustness of the portfolio of system strength solutions nor the potential for lower contracting costs resulting from greater competition between non-network synchronous generator proponents.

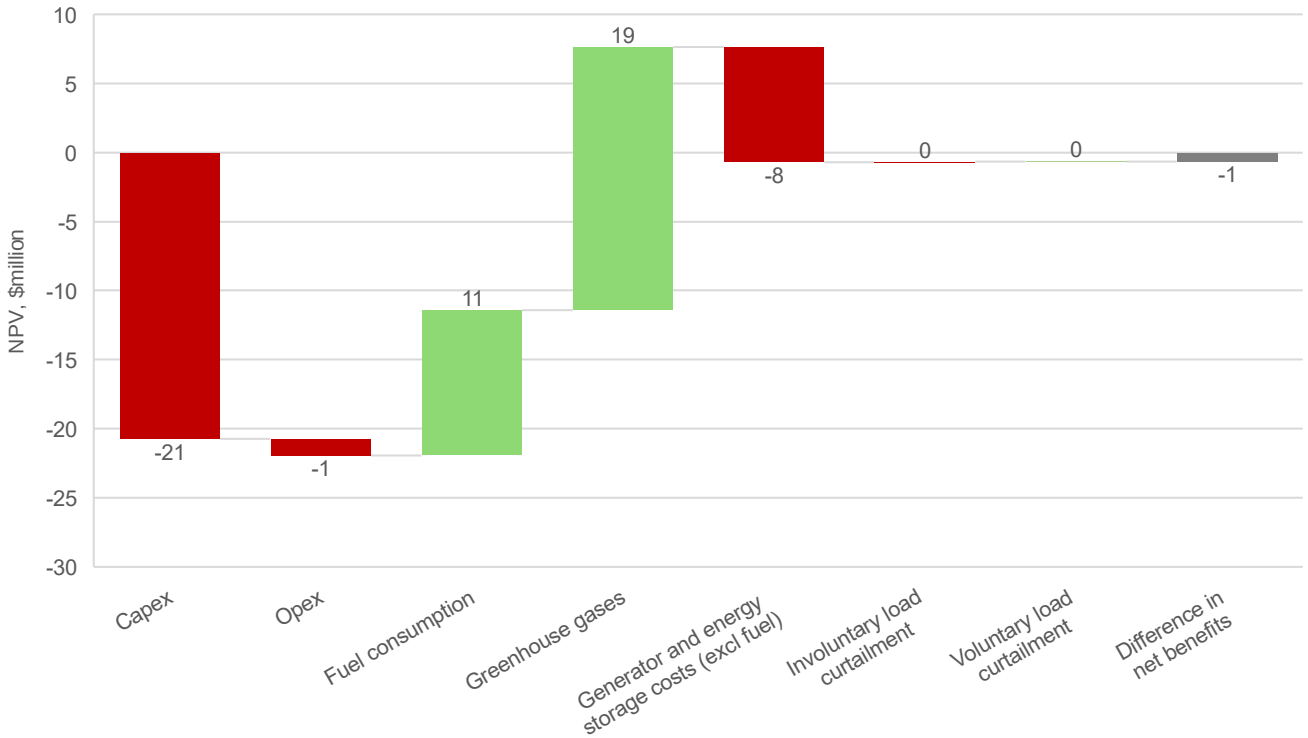
Under this expedited synchronous condenser sensitivity, the expected net market benefits decrease by only $1 million in present value terms (equivalent to 0.01%) over a 20-year period, compared to the estimated net market benefits of portfolio option 1 (being $11,312 million).

The marginal decrease in quantified net market benefits in this sensitivity is driven primarily by the increase in present value of capital costs (i.e. no change in real terms), due to the earlier commissioning and operation of synchronous condensers. There is also higher generator start-up and shut-down costs due to less overall reliance on coal and gas generators (which results in more frequent start-ups and shut-downs).

These costs are predominately offset by the additional market benefits derived from decreased fuel consumption and the associated reduction in greenhouse gases due to less additional coal and gas dispatch required for system strength provision.

The breakdown in the change in the estimated net market benefits by benefit class is shown in Figure 4.

Figure 4. Key changes in the composition of the estimated net market benefits for Sensitivity 3, compared to portfolio option 1 in the PADR



Additional unquantified benefits of a more robust portfolio of system strength solutions

While this theoretical sensitivity shows that bringing forward the commissioning of four synchronous condensers reduce quantified net market benefits by $1 million over the 20-year modelling period (equivalent to a 0.01% reduction), there are other unquantified benefits which are likely to provide greater additional benefits to consumers. These benefits include:

- increasing competition between synchronous generators resulting in potentially lower contracting costs with non-network synchronous generators, as a result of a reduced need for synchronous machine redispatch to fill gaps in system strength;
- enhancing resilience of the electricity system against earlier than expected retirement of coal generators and multiple coincident planned or unplanned outages of generators; and
- mitigating risks associated with**:**
    - delayed entry of new grid-forming battery capacity;
    - delayed or unsuccessful modifications to synchronous machines to operate in synchronous condenser mode;
    - delayed or unsuccessful contracting with non-network synchronous generators; and
    - delayed procurement of synchronous condensers due to increasing global demand and supply chain constraints.

We intend to explore further in the PACR the benefits of bringing forward the commissioning of synchronous condensers, as well as other non-network options where appropriate, to provide resilience and insurance against the uncertainty in future conditions and supply chains, and in turn delivering greater benefits to consumers.

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