Transgrid
People. Power. Possibilities.

Meeting system strength requirements in NSW

Outcomes of the Project Assessment Draft Report (PADR)

24 June 2024

Acknowledgement of Country

In the spirit of reconciliation, Transgrid acknowledges the Traditional Custodians of the lands where we work, the lands we travel through and the places we live.

We pay our respects to the people and the Elders past, present and emerging. And we celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the land and water.

Welcome

Marie Jordan – Executive General Manager, Network

Agenda

Please note: today's workshop will be recorded (available for 60 days)

No.	Time	Agenda item	Presenter
1.	3:00pm (5 mins)	Welcome	• Marie Jordan (Executive General Manager, Transgrid)
2.	3:05pm (40 mins)	Outcomes of the system strength Project Assessment Draft Report (PADR)	• Jesse Steinfeld (Energy Transition Manager, Transgrid) • Ann Whitfield (Partner, HoustonKemp)
3.	3:45pm (10 mins)	Next steps	• Jesse Steinfeld
4.	3:55pm (35 mins)	Q&A	• Jesse Steinfeld • Ann Whitfield • Ian McDonnell (Senior Manager, Baringa) • Li-Wen Yip (Energy Transition Specialist, Transgrid)

Q&A via Menti (www.menti.com): 4220 1136

Context

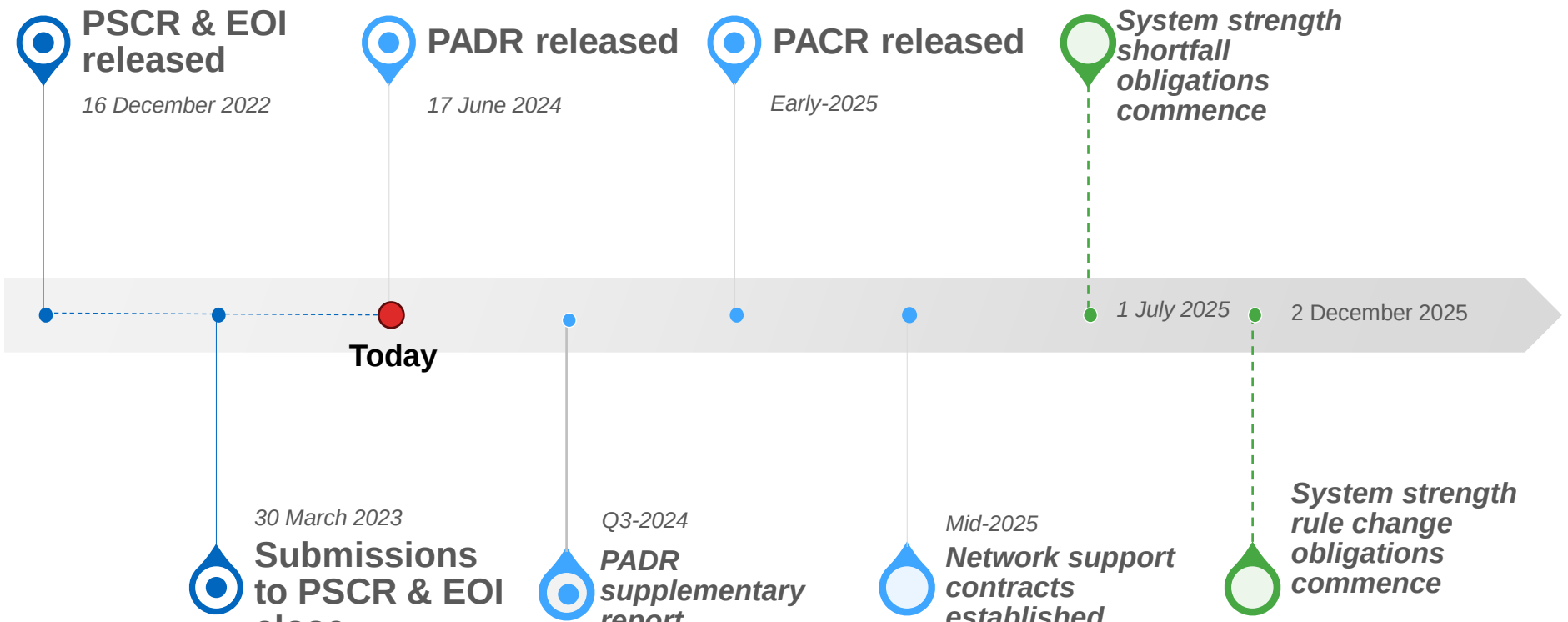
What is system strength?

The retirement of NSW's coal generators and the growth in inverter-based resources in the coming decade is driving an urgent need to add new sources of system strength to the power system.

- System strength can broadly be described as the ability of the power system to maintain and control the voltage waveform at any given location in the power system, both during steady state operation and following a disturbance (AEMO)
- A network without adequate system strength will result in stability issues. In a system with low system strength:
  - > generators may be unable to remain connected during disturbances on the power system;
  - > control of the system voltage becomes more difficult; and
  - > protection systems that ensure safe operation of the network may not operate correctly.
- Transgrid's obligations are to:
  - > maintain the minimum three phase fault level specified by AEMO at the system strength nodes; and
  - > achieve stable voltage waveforms for the level and type of IBRs and market network service facilities projected by AEMO in steady state conditions and following any credible contingency or protected event.

*We need a strong system **heartbeat** to enable the flow electricity around NSW – it needs to be robust enough to sustain incidents like lightning strikes and equipment failure*

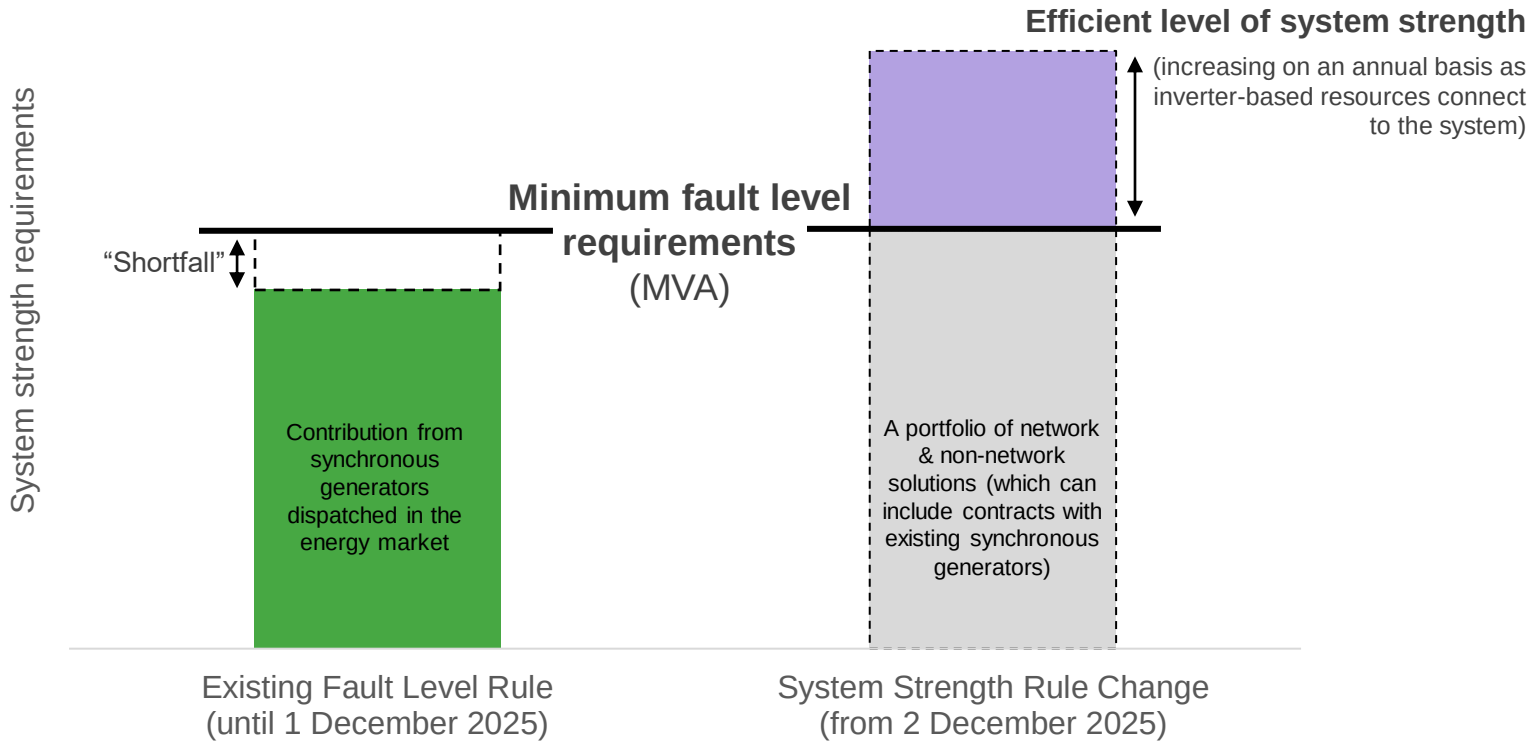
System strength RIT-T timeline



Evolving regulatory obligations

From December 2025 System Strength Service Providers must proactively deliver system strength services to maintain the secure operation of the power system (minimum level) and to support the stable operation of new inverter-based resources (efficient level)

Conceptual representation of evolving system strength obligations



Network need

The growing need for system strength

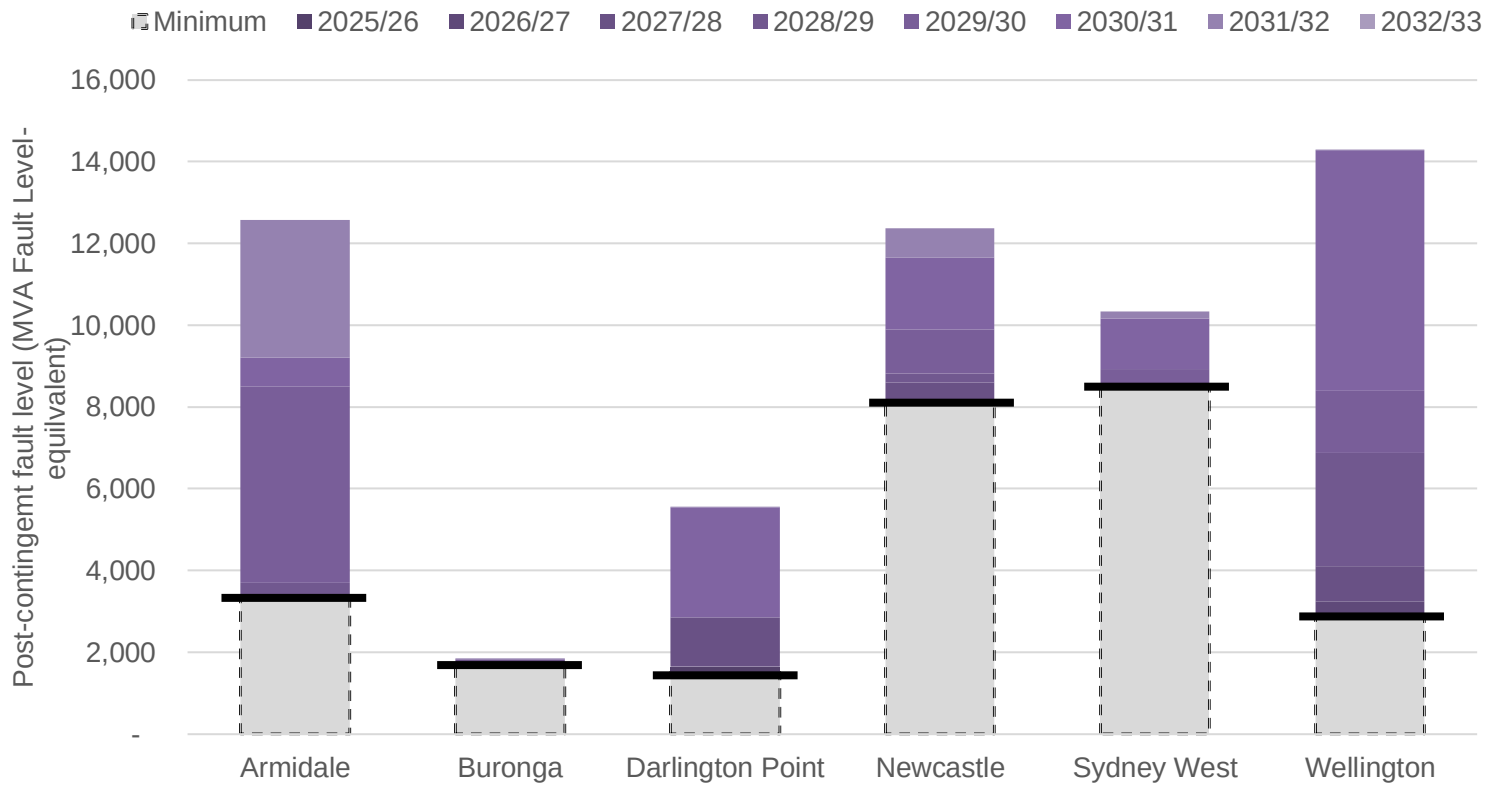
Transgrid's obligations are driven by AEMO's minimum fault level requirements at each system strength node, plus AEMO's annual inverter-based resource forecasts which are driven by the Integrated System Plan, Step Change scenario

1 July – 1 December 2025:

AEMO-declared fault level shortfalls of 1,420 MVA and 1,165 MVA at Newcastle and Sydney West.

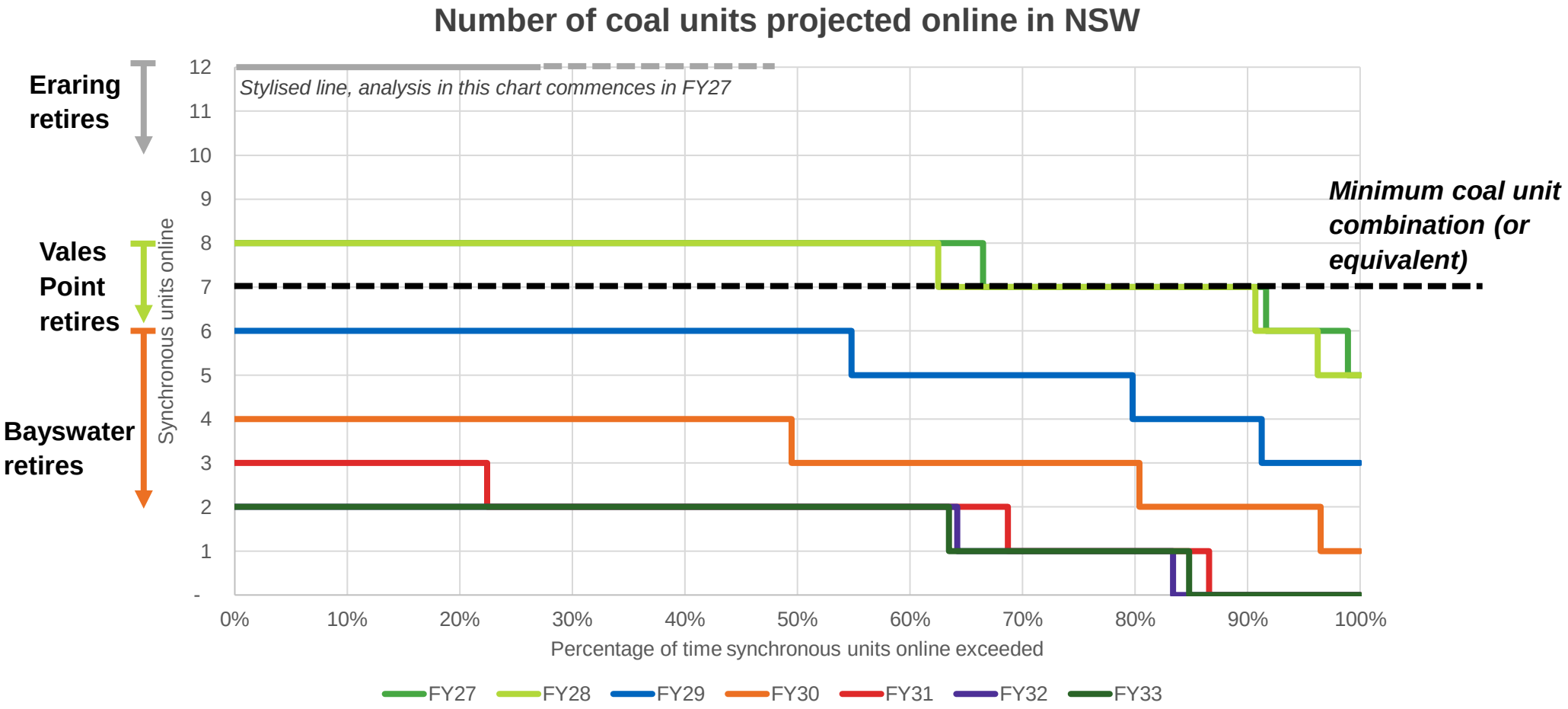
System strength requirements in NSW, from 2 December 2025 to 2032/33

(minimum levels + support for the connection of new inverter-based resources)



Coal retirements will drive a growing gap in system strength

Gaps in system strength grow as coal units take outages, economically de-commit themselves or retire.



Note this analysis was undertaken prior to Eraring's extension, using draft 2024 ISP retirements

Note this analysis excludes planned maintenance, which further increases the coincident 'unavailability' of units

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Over 100 individual options assessed

Over 100 individual system strength solutions were assessed

Our system strength EOI process resulted in non-network option submissions from 25 parties, covering over 60 individual potential technology solutions. Transgrid has also identified 40 unique network solutions that could help meet the need

Network solutions	Network synchronous condensers	‘Targeted’ grid-forming BESS	Network grid-forming STATCOMs + supercapacitor		
Existing synchronous machines (non-network)	Existing synchronous plant without synchronous condenser mode	Existing synchronous plant with the ability to run in synchronous condenser mode	Existing synchronous plant requiring upgrades to run in synchronous condenser mode		
New synchronous machines (non-network)	Pumped hydro	Gas	Biomass	Non-network synchronous condensers	Compressed air storage (with a clutch to run in synchronous condenser mode)
Batteries (non-network)	Committed and anticipated grid forming-BESS	Committed and anticipated grid-following BESS, converted to grid-forming	EOI-proposed grid-forming BESS	‘Targeted’ (not currently proposed) grid-forming BESS	ISP ‘modelled’ grid-following BESS, converted to grid-forming

Assessment approach

Solving for the optimal portfolio of solutions

In order to assess over 100 system strength solutions, where a combination of many solutions is required to meet the need, Transgrid employed a 'portfolio optimisation' approach (in partnership with Baringa Partners)

An automated 'portfolio formation' approach was required because:

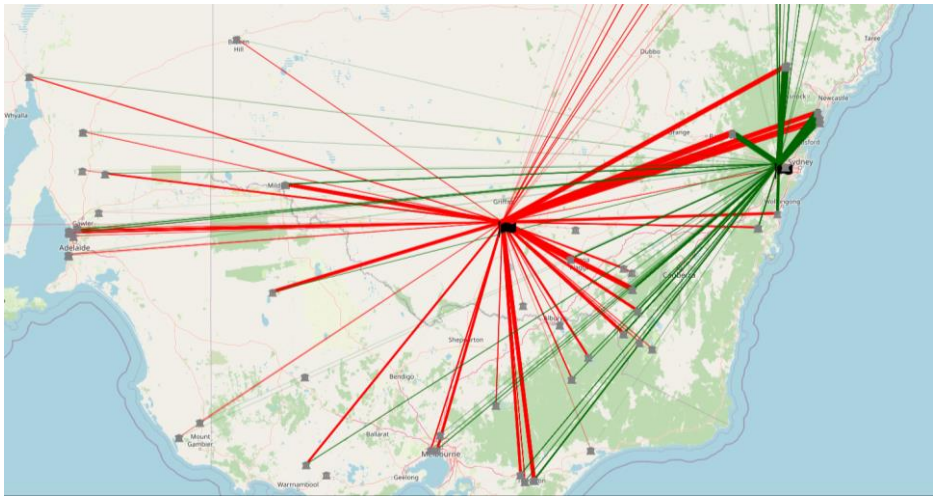
- Over 100 individual non-network and network options
- Co-optimisation required across 6 system strength nodes in NSW, plus many points of connections of future renewables
- No single solution can meet the need – in fact, dozens of solutions across NSW will be required at any one time
- System strength contributions are dynamic and non-linear. The contribution of each individual solution depends on which other units are operating at the same time and state of the network
- System strength is measured in $MVA_{fault\ level}$ and "stable voltage waveform"

Approach for portfolio formation:

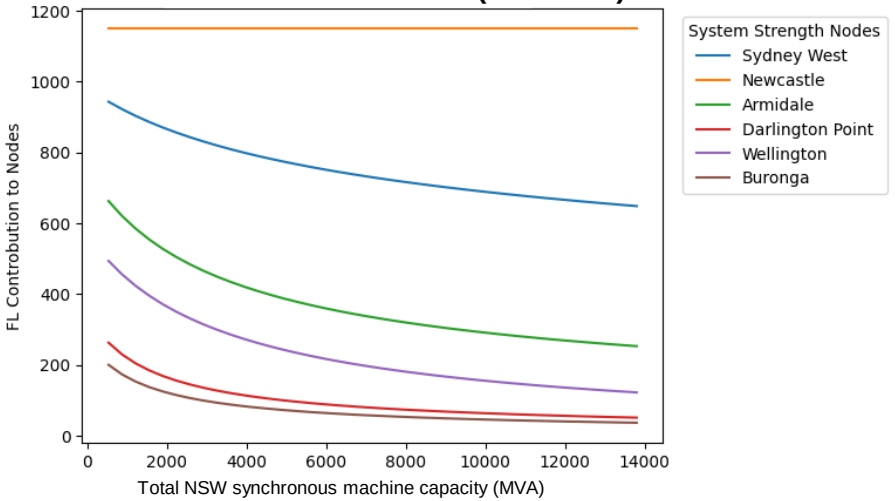
- System strength constraints have been incorporated into PLEXOS
- Using its 'Long-Term' functionality to 'self-solve' for the optimal portfolio of solutions – akin to what the ISP does to optimise transmission, generation and storage build
- Test different variations to the optimal portfolio
- Iteration between PLEXOS and PSSE to tune system strength constraints and validate requirement

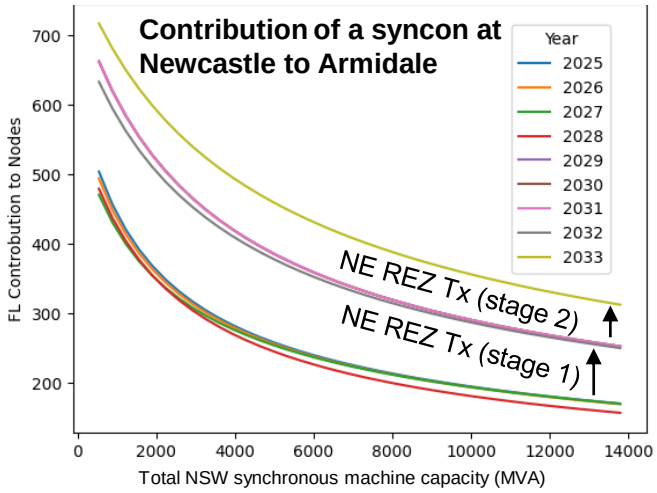
Incorporating system strength coefficients into PLEXOS

Contribution of all NEM generators to Darlington Point and Sydney West

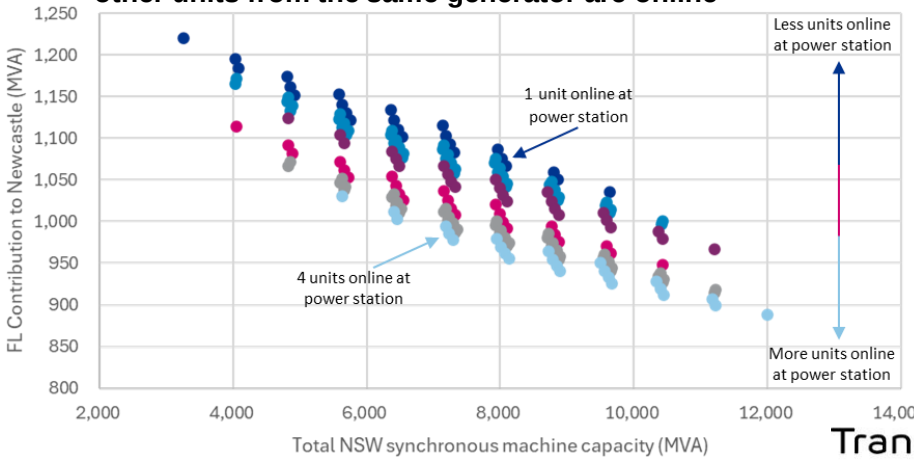


Contributions from a syncon at Newcastle to the NSW fault level nodes (in FY2030)





Contribution of a single coal unit to Newcastle, when other units from the same generator are online



Maturity of grid-forming batteries for system strength

AEMO has determined that minimum faut level requirements

- *"must be delivered by devices that can provide protection-quality levels of fault current – such as new synchronous condensers, service contracts with existing hydro or thermal units, or through the retrofit of those existing units themselves"*

(May 2024 update to the 2023 ESOO)

Transgrid also engaged Aurecon to undertake an assessment of the maturity of grid-forming batteries. Aurecon:

Until FY2033

- Concluded that there is insufficient evidence (either at-scale deployments or in modelling) to currently rely on grid forming batteries to support the **"minimum" fault current requirements**.
  - The ability for grid forming batteries to provide a satisfactory fault current response to enable the safe operation of protection equipment in the transmission network has not been confirmed.
  - The performance and stability of grid forming batteries at their rated current limits, when fault current injection is critical, is not yet established, nor has the stability of grid forming batteries been confirmed for strong areas of the grid.

Up to a maximum of 50% of the efficient level solution size

- Concluded grid forming batteries have a key role to play for **"stable voltage waveform" support** for new connecting renewables
  - Transgrid recognises grid forming batteries can provide more "stable voltage waveform" support than as indicated by their fault current contribution (via preliminary PSCAD studies).
  - Our market modelling 'boosts' the contribution of batteries by 3 x fault current contribution

Note, another relevant study by Sandia National Laboratories explores this topic.

PADR portfolio options & sensitivities

All 100+ non-network (e.g. coal, hydro, gas, batteries) and network (syncons, grid forming batteries, grid-forming STATCOMs) solutions assessed. Portfolio options below are a blend of these system strength solutions

Core portfolio option constraints

Portfolio option 1	Portfolio option 2	Portfolio option 3	Portfolio option 4
Syncons commissioned in 2028/29	Syncons commissioned in 2027/28 (i.e. accelerated)	Portfolio option 1 + confidential proposal assumed technically feasible	Portfolio option 1 with restriction on number of gas units contracted with
Credible Option	Credibility TBC	Credibility TBC	Credible Option

Portfolio option 1 as the basis for these sensitivities

Sensitivities to test robustness of portfolio

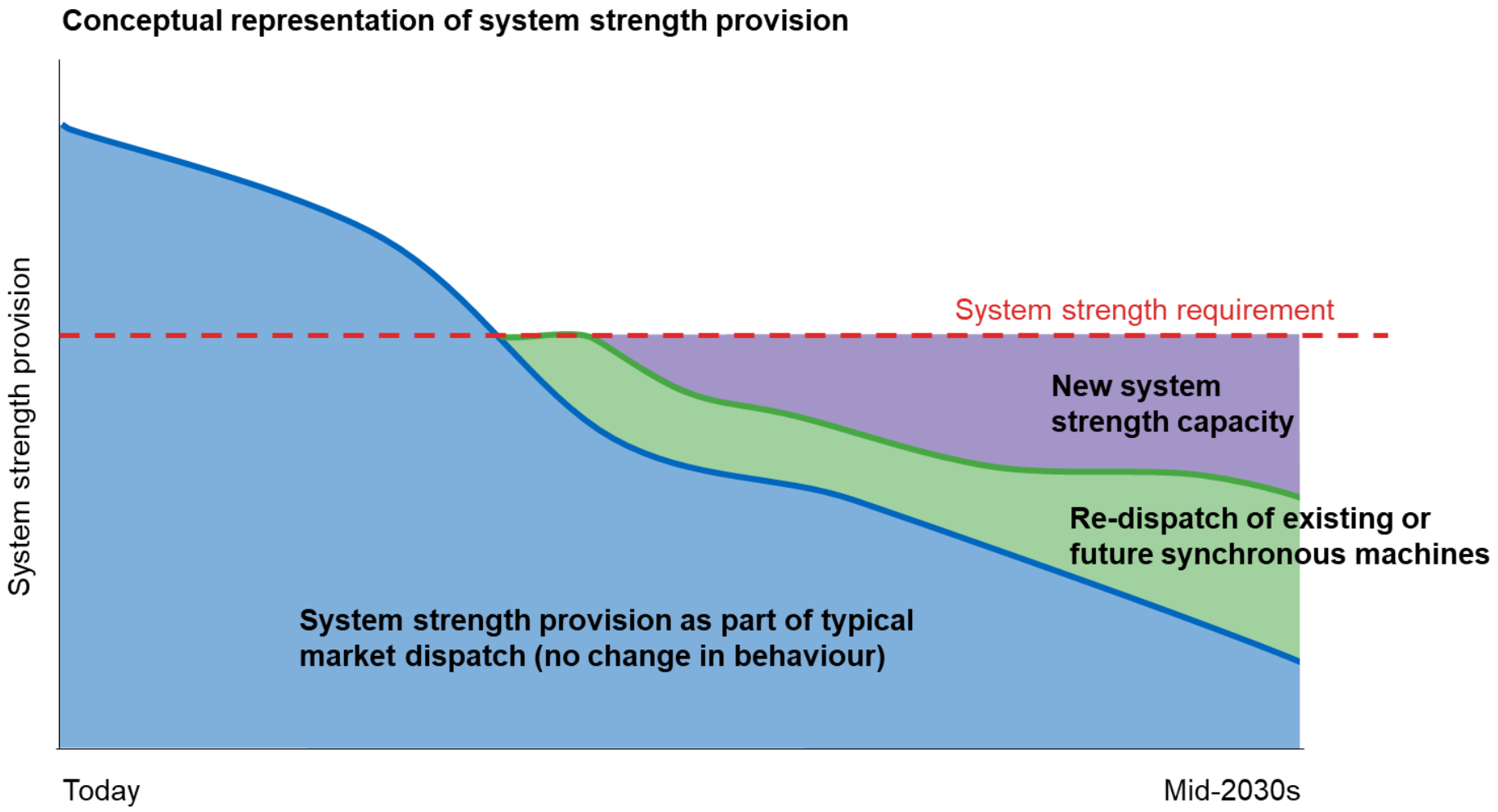
- With the official 'Value of Emissions Reduction'
- With a 1-year delay to contracting with batteries & one hydro unit modification
- Grid-forming batteries provide more 'stable voltage waveform' support than currently expected

Sensitivities to test a reduction in need (+ mitigate "Material Change in Circumstances")

- If all batteries in AEMO's IBR forecasts are deployed in grid-forming mode
- If CWO REZ stage 2 & New England REZ is self-remediated
- Battery and REZ sensitivity combined

Results

Three categories of solutions to meet the need



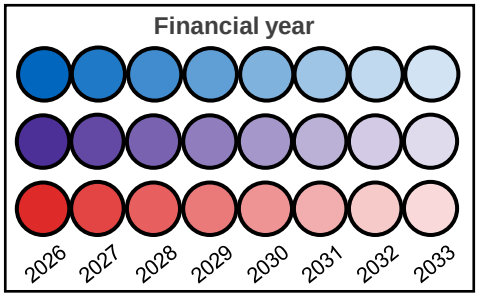
Portfolio of system strength solutions

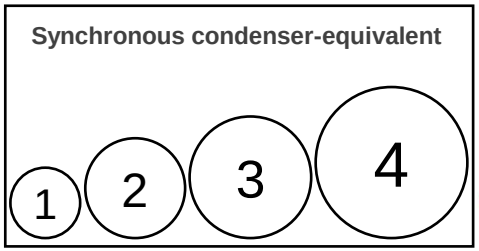
14 synchronous condensers *

>550MW of synchronous machine modifications

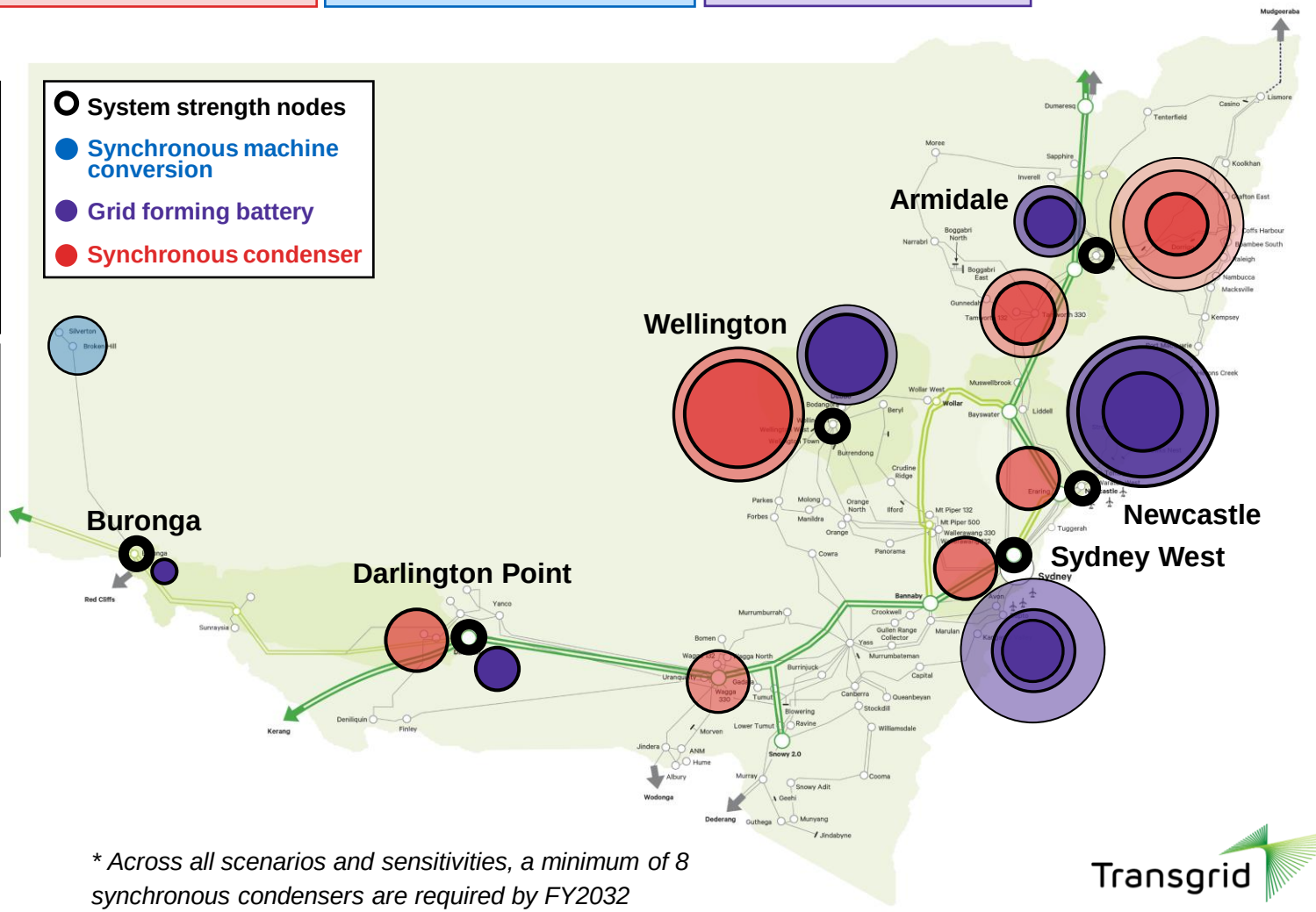
4.8GW of grid-forming batteries

By 2032/33 (under Portfolio option 1)





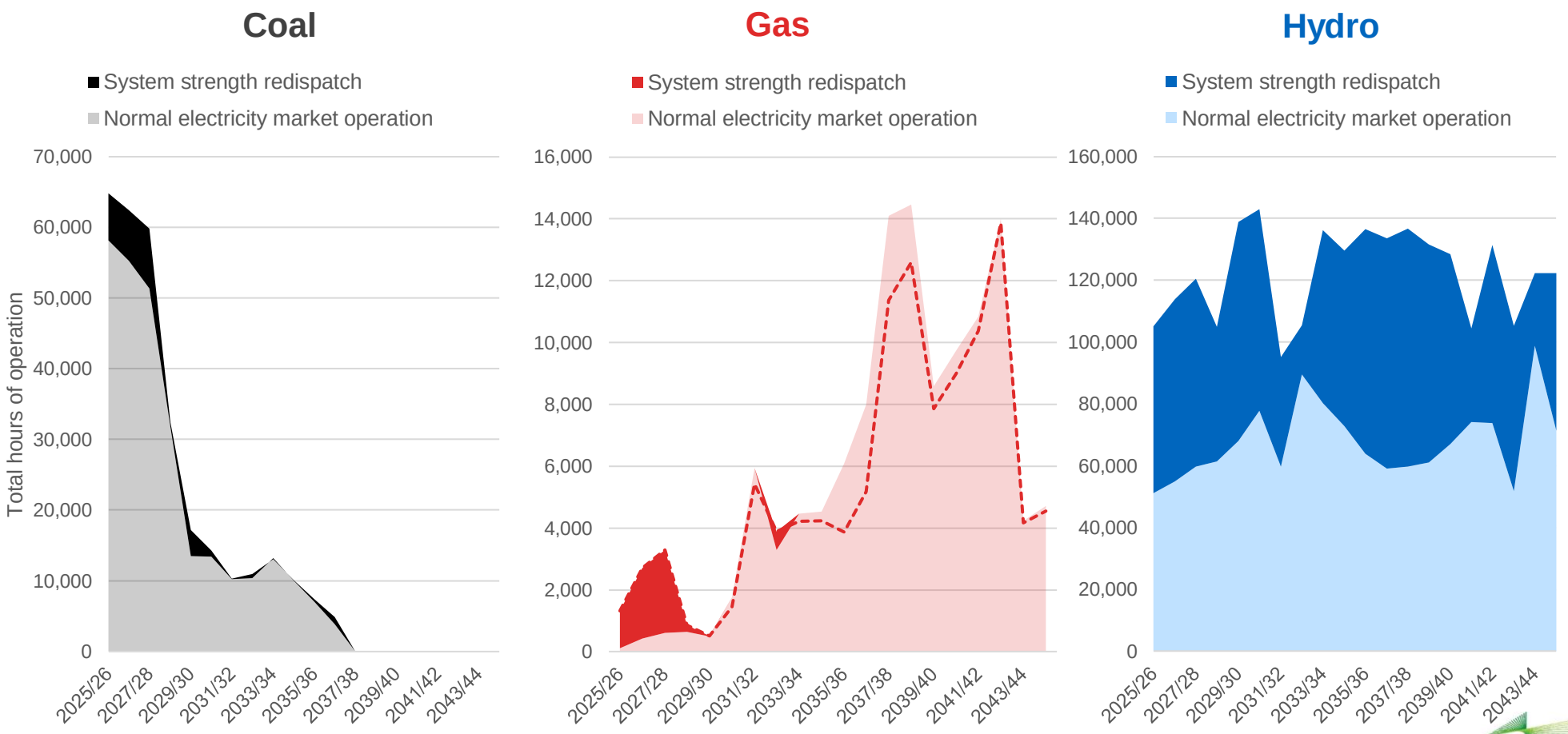
Note: This figure does not show the redispatch of existing machines, and some new solutions are not displayed for confidentiality.



** Across all scenarios and sensitivities, a minimum of 8 synchronous condensers are required by FY2032*

Re-dispatch of existing generators for system strength

Projected hours of operation for synchronous machines in NSW, portfolio option 1
(in normal market operations + co-optimised with system strength constraints)



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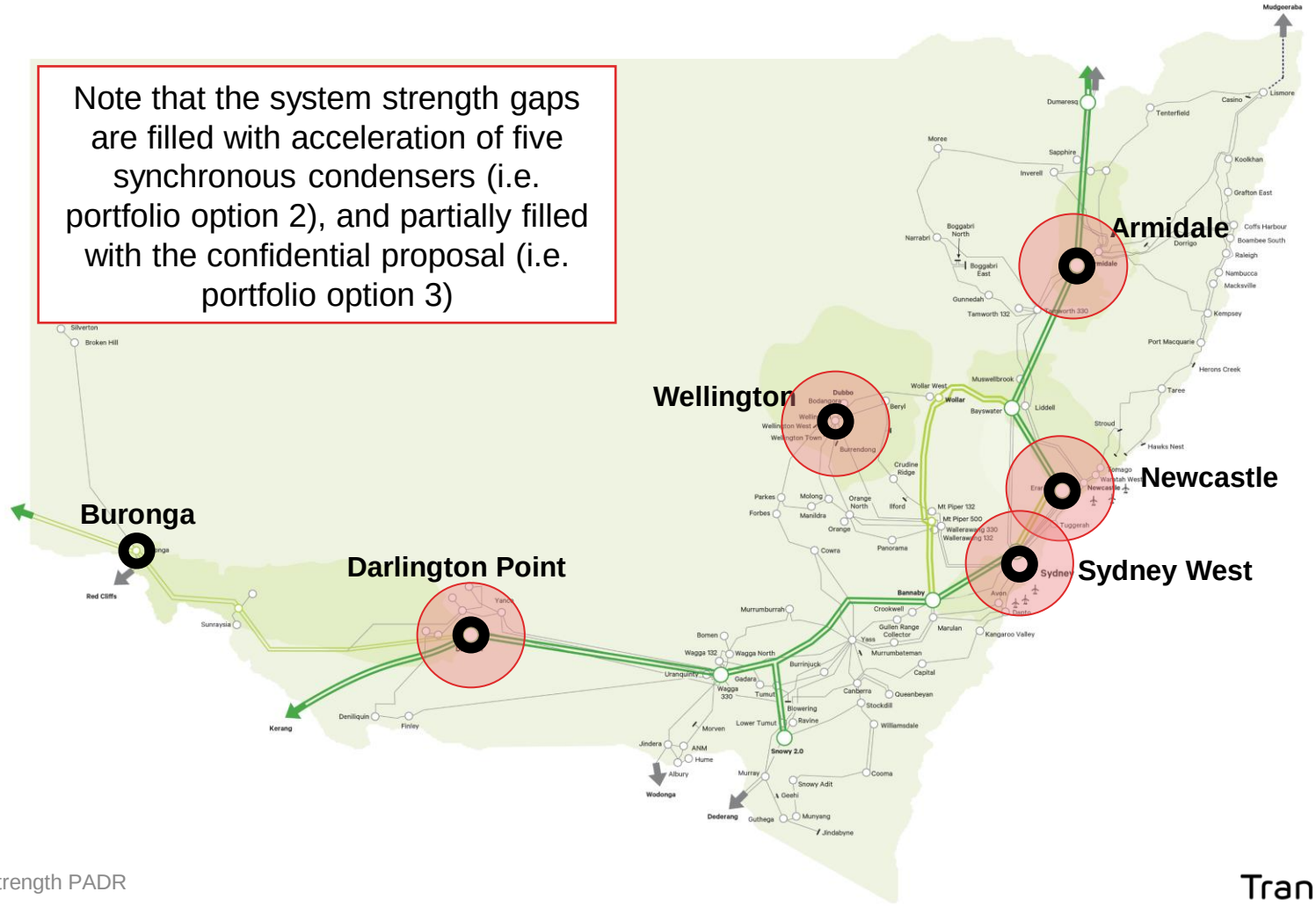
System strength risks prior to new synchronous condensers

Portfolio option 1 - gaps in system strength in 2027/28

Note that the system strength gaps are filled with acceleration of five synchronous condensers (i.e. portfolio option 2), and partially filled with the confidential proposal (i.e. portfolio option 3)



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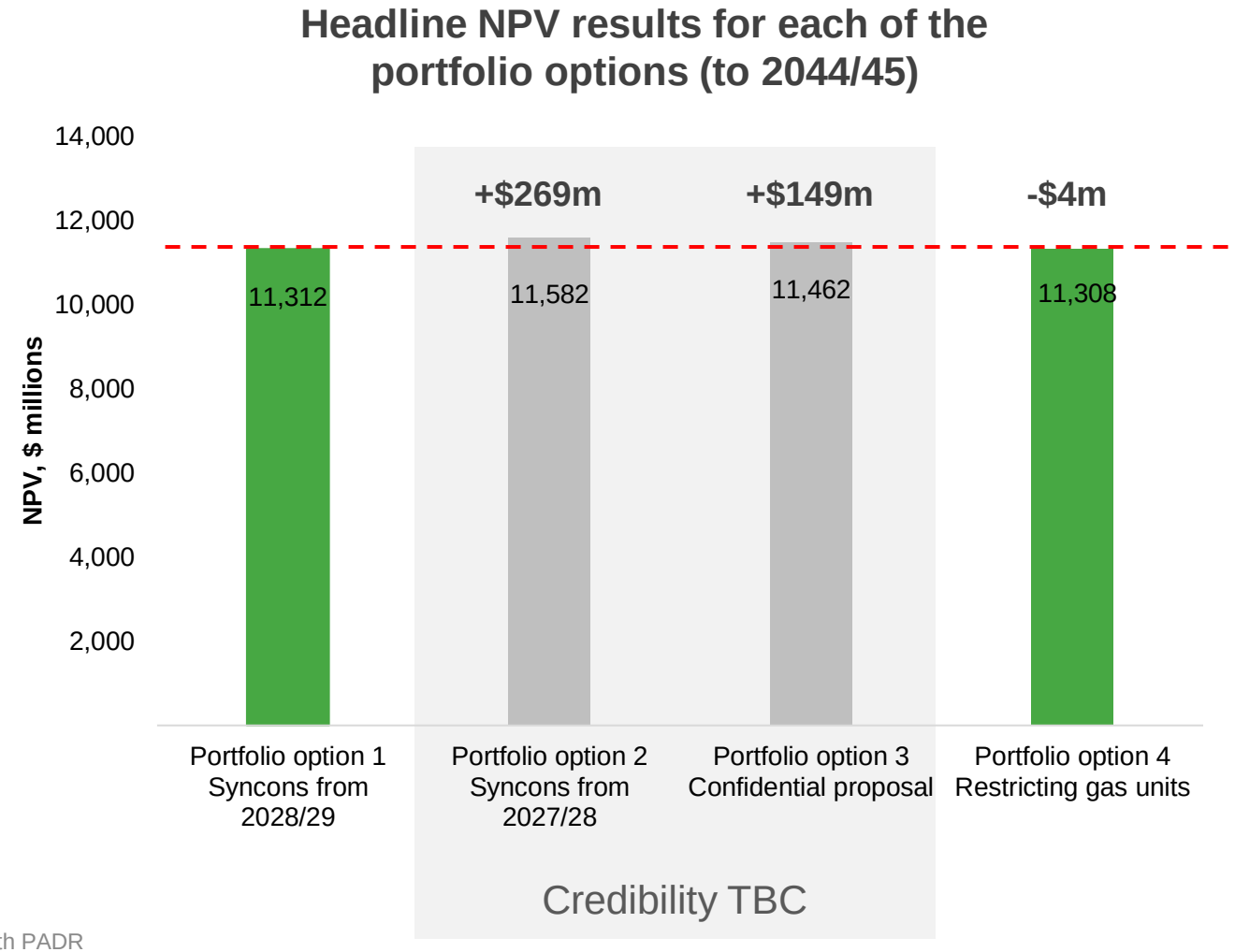
Comparison of the portfolios of solutions

Option	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	By 2044/45
Synchronous condensers – cumulative number of units (each providing 1,150MVA$_{fault\ current}$)									
1	–	–	–	8	10	13	14	14	26
2	–	–	5	8	10	13	14	14	26
3	–	–	–	5	7	10	10	10	24
4	–	–	–	10	10	13	13	13	26
Upgrades to synchronous machine to allow synchronous condenser mode (existing and new units) – cumulative capacity (MW)									
1	–	50	550	550	550	550	550	550	550
2	–	50	550	550	550	550	550	550	550
3	–	50	550	550	550	550	550	550	550
4	–	50	550	550	550	550	550	550	550
Coal generator enablement for system strength – share of system strength re-dispatch hours (%)									
1	11%	10%	12%	2%	5%	1%	–	4%	–
2	11%	10%	4%	2%	6%	1%	1%	4%	–
3	11%	10%	10%	1%	5%	2%	1%	4%	–
4	11%	11%	9%	2%	5%	2%	–	5%	–
Gas generator enablement for system strength – share of system strength re-dispatch hours (%)									
1	2%	3%	4%	–	–	–	–	3%	–
2	2%	3%	1%	–	–	–	–	3%	–
3	2%	3%	4%	–	–	–	–	3%	1%
4	2%	3%	3%	–	–	–	–	3%	–
Hydro generator enablement for system strength – share of system strength re-dispatch hours (%)									
1	87%	86%	84%	98%	95%	99%	100%	93%	100%
2	87%	86%	95%	98%	94%	99%	99%	93%	100%
3	87%	87%	87%	99%	95%	98%	99%	93%	99%
4	87%	86%	88%	98%	95%	99%	100%	92%	100%
Grid-forming BESS – cumulative capacity (MW)									
1	750	2,600	2,600	3,500	4,800	4,800	4,800	4,800	4,800
2	750	2,600	2,850	3,600	4,750	4,800	4,800	4,800	4,800
3	750	3,050	3,050	4,100	4,800	4,800	4,800	4,800	4,800
4	750	2,550	2,550	3,200	4,800	4,800	4,800	4,800	4,800

Net market benefits assessment

Headline Net Present Value results

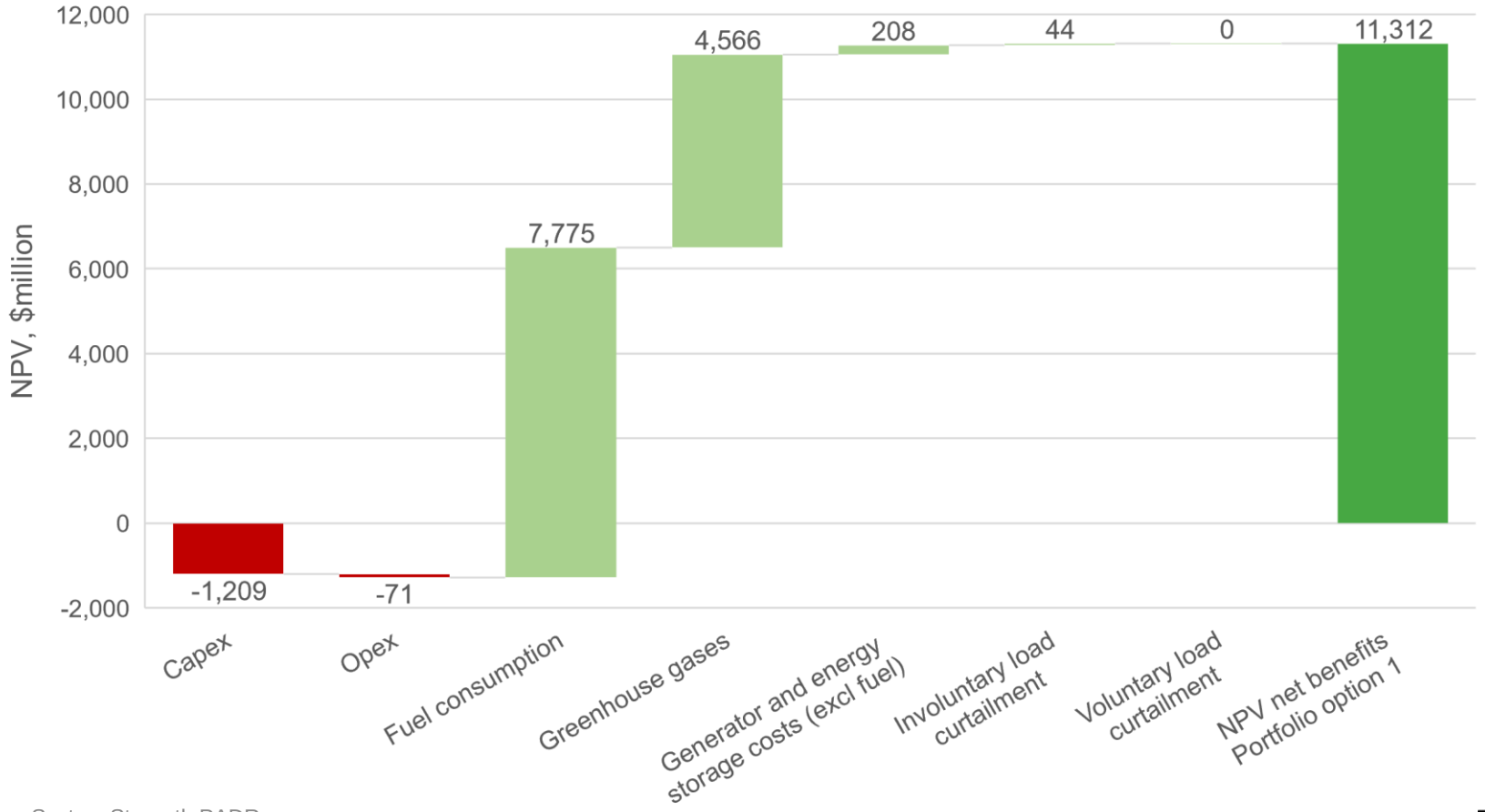
The PADR finds that all 'portfolio options' produce substantial net benefits over the assessment period (~$11-12b)



Breakdown of Net Market benefits for portfolio option 1

Net market benefits are primarily driven by avoided fuel consumption and avoided greenhouse gases (at the VER)

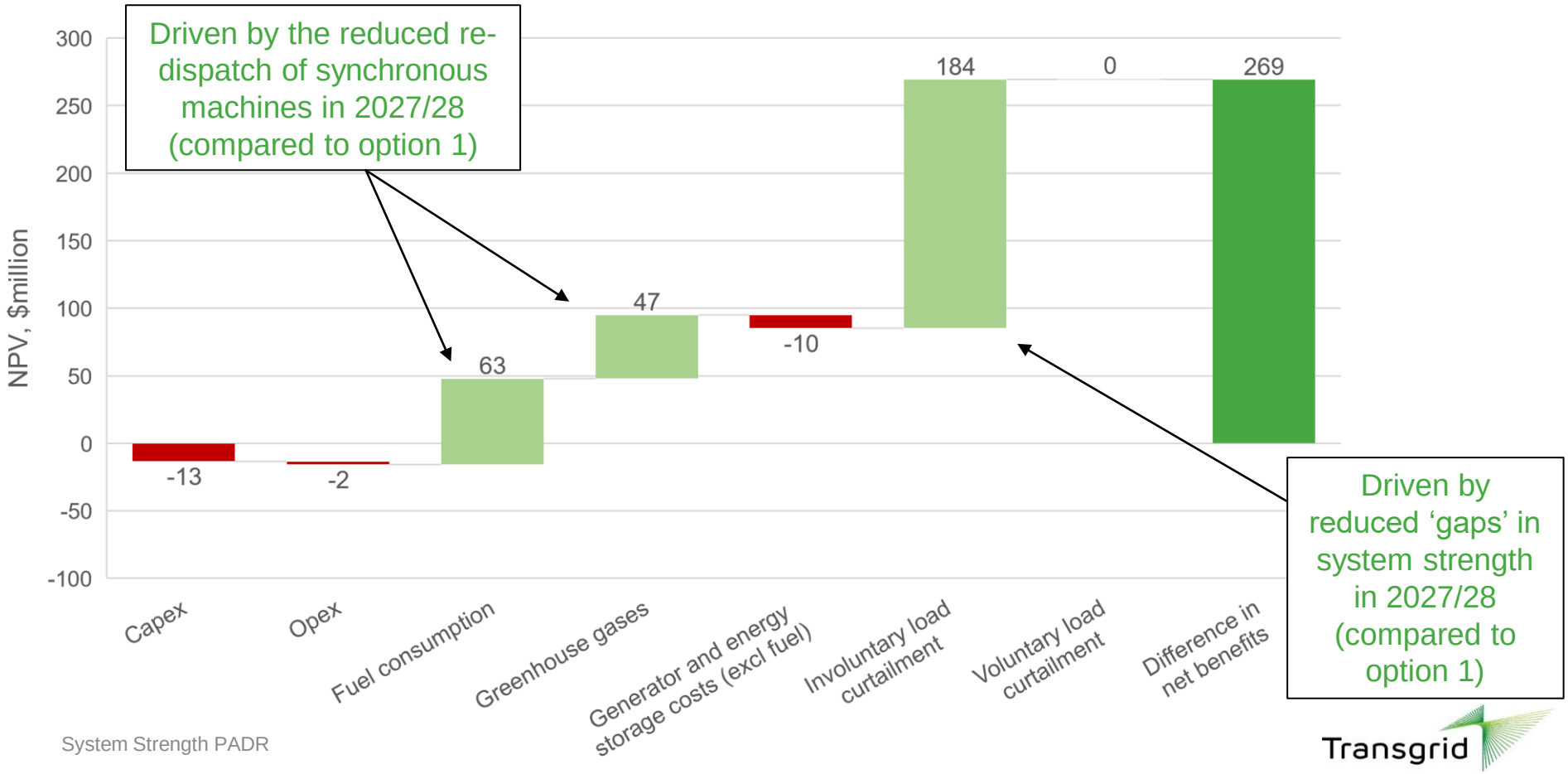
Portfolio option 1 – composition of the estimated net benefits, against a do-nothing base case



Comparison of portfolio option 2

Option 2 increases expected net benefits primarily due to additional avoided unserved energy

<u>Portfolio option 2</u> – changes in the composition of the estimated net benefits, compared to option portfolio 1



Testing the effects of changes that could emerge in the future

Portfolio formation 'sensitivities' have informed our proposed re-opening triggers (new MCC Rules)

New BESS choosing to self-remediate their system strength impact

Self-remediation of the New England REZ and/or Central West Orana (CWO) REZ stage 2

Grid-forming BESS being able to provide more 'stable voltage waveform' support than expected

Delays in contracting with GFM BESS and a hydro generator that has proposed to upgrade their plant

Our sensitivity testing shows that the following are not triggers:

- Variations to the published VER
- Cost increase to synchronous condensers
- Cost increases for BESS upgrades
- Credible changes to the discount rate

Should any of these occur, they would change the number, or timing, of syncons as part of the preferred portfolio option (everything else is largely unaffected)

→ These will be firmed up between the PADR and PACR (and so may not be relevant as potential triggers for the PACR)

Implications of changes that could emerge in the future

Changes in the optimal portfolio of solutions from sensitivities on portfolio option 1

Financial year	2025/26	2026/27	2027/28	2028/29	2029/30	2030/31	2031/32	2032/33	By 2044/45
Synchronous condensers – cumulative number of units (each providing 1,150MVA$_{fault\ current}$)									
Portfolio option 1	–	–	–	8	10	13	14	14	26
BESS self-remediating	–	–	–	7	8	11	11	11	24
REZ self-remediating	–	–	–	7	8	9	9	9	11
Both self-remediating	–	–	–	6	7	8	8	8	10
Increased grid-forming BESS support	–	–	–	6	7	9	9	9	22
One-year delay grid-forming BESS and hydro upgrade	–	–	–	9	10	14	14	14	27
Upgrades to synchronous machine to allow synchronous condenser mode (existing and new units) – cumulative capacity (MW)									
Portfolio option 1	–	50	550	550	550	550	550	550	550
All sensitivities	–	50	550	550	550	550	550	550	550
Grid-forming BESS – cumulative capacity (MW)									
Portfolio option 1	750	2,600	2,600	3,500	4,800	4,800	4,800	4,800	4,800
BESS self-remediating	750	3,000	3,000	3,650	4,800	4,800	4,800	4,800	4,800
REZ self-remediating	750	2,550	2,550	2,550	3,500	3,500	3,500	3,500	4,800
Both self-remediating	750	2,300	2,300	2,300	2,950	2,950	2,950	3,500	4,100
Increased grid-forming BESS support	750	1,900	2,300	3,200	4,800	4,800	4,800	4,800	4,800
One-year delay grid-forming BESS and hydro upgrade	750	2,300	2,550	3,200	4,100	4,100	4,100	4,100	4,100

Next steps

Next steps for Transgrid

- Investigate the advancement the procurement and commissioning of no-regret synchronous condensers. This would require commencement of procurement of synchronous condensers prior to the conclusion of the RIT-T and AER's approval of a contingent project application (CPA);
- Work with the proponent to confirm the technical feasibility of the confidential proposal to provide synchronous condenser services in the vicinity of Newcastle and Sydney West;
- Identify credible approaches to minimise expected network support payments without materially impacting the optimal portfolio of solutions (e.g., contracting with less gas, coal or hydro units);
- Identify additional non-network solutions (providing protection-quality levels of fault current) that can contribute to meeting system strength gaps at Armidale, Sydney West, Newcastle, Wellington and Darlington Point in 2027/28;
- Assess the technical feasibility of each proposed grid-forming battery project via a request for PSCAD models (which is considered necessary before each project can be considered part of the optimal portfolio of solutions at the final PACR stage).

Next steps for non-network option proponents

System strength proponent briefing – tomorrow, 25th June, sign up here

- We welcome submissions on Transgrid's system strength PADR, due 2 August 2025
- Submit a new or updated Expression of Interest (EOI) for non-network solutions (excluding commercial pricing), due 2 August 2025
- Provide PSCAD and other required models to support Transgrid's assessment of the technical credibility of your solution (in particular for grid-forming batteries), due 2 August 2025
- Await Transgrid's request for you to update the commercial component of your EOI, which will proceed AEMO's publication of minimum scheduling requirements on 30 June 2024

Additional information

Document	Description
Information for system strength non-network option proponents	An explanation of the RIT-T, procurement and contracting process, areas of interest for new EOIs and high-level technical guidance for system strength services
EOI response questionnaire	An Excel workbook that gives proponents the opportunity to update or submit new EOIs
Technical performance and power system modelling requirements for synchronous machines	Detailed technical performance and power system modelling requirements for synchronous machines (for consultation)
Technical performance and power system modelling requirements for grid-forming BESS	Detailed technical performance and power system modelling requirements for grid-forming inverters (for consultation)
Effectiveness Factors	An Excel workbook that indicates the effectiveness of different locations for system strength provision

Q&A

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