



Consumer
Trustee

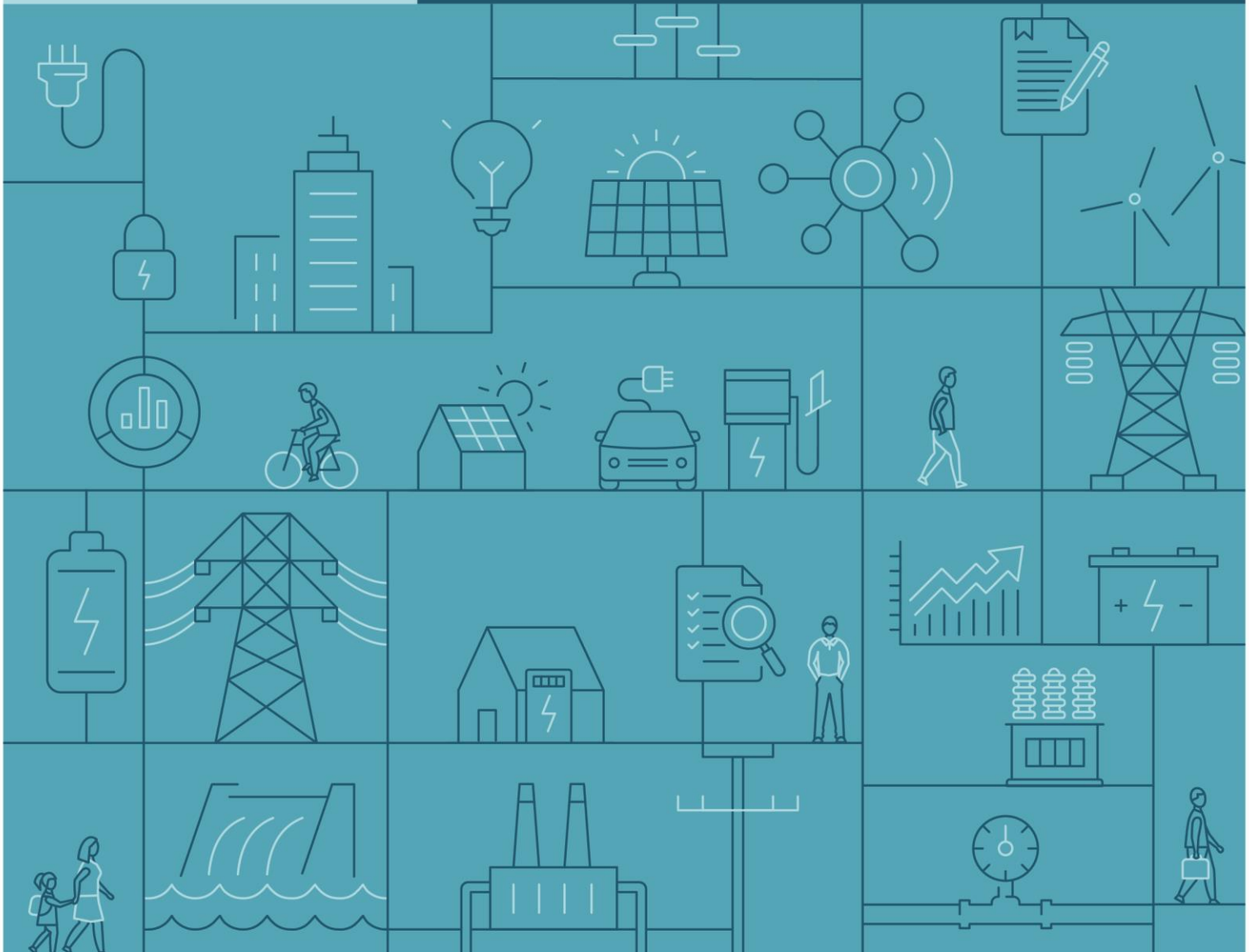


The value of long-duration storage

February 2024

Review of storage infrastructure
requirements for the NSW
market

Advice for the NSW Government



Important notice

PURPOSE

At the request of the NSW Government's Office of Energy and Climate Change (OECC), AEMO Services Limited (AEMO Services) has conducted a review into the storage requirements of the NSW market, with consideration of possible amendments to the definition of long-duration storage infrastructure in the *Electricity Infrastructure Investment Act 2020* (EII Act). With this report, AEMO Services offers insights informed by quantitative analysis and AEMO Services' experience in the role of NSW Consumer Trustee.

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VERSION CONTROL

Version	Release date	Changes
1	23/1/2024	-
1.1	19/2/2024	Additional data for unserved energy event duration, tender outcomes and net capacity
1.2	1/3/2024	Additional graphical representation of capacity secured and remaining to achieve the objective

Executive summary

At the request of the NSW Government's Office of Energy and Climate Change, AEMO Services conducted a review into the storage requirements of the NSW market, with consideration of possible amendments to the definition of long-duration storage infrastructure in the *Electricity Infrastructure Investment Act 2020*.

It is AEMO Services' view, based on our analysis and experience as NSW Consumer Trustee, that the NSW Government should consider two objectives for a potential change to the EII Act, to:

1. Provide the Consumer Trustee with more flexibility to incentivise storage to address near term reliability needs cost effectively, by reducing the minimum duration for long-duration storage to 4 hours, and
2. Continue to incentivise storage with a duration of 8 hours or more to provide for longer term needs to mitigate tail risks to reliability in NSW.

AEMO Services considers that reducing the definition of long-duration storage under the EII Act to 4 hours minimum dispatchable capacity, alongside the 16 GWh target, is in the long-term financial interest of NSW electricity customers. A more flexible definition has the potential to increase participation in tenders and so expand AEMO Services' visibility to a wider range of storage projects, de-risking the delivery of substantial energy storage capacity at lower cost to consumers.

However, the increased flexibility should be balanced by a requirement for the Consumer Trustee to value longer-duration storage where practicable, so as not to write-off considerable investment in developing these projects and stifle innovation that is likely to be required in the medium to longer term. Longer-duration projects have the potential to mitigate tail-risks to reliability, however are not likely to be incentivised under current market frameworks in the absence of this signal.

If the change in the minimum duration were to be pursued, AEMO Services recommends provisions in legislation or delegated legislation to:

- Require the Consumer Trustee, in recommending LTESAs for long-duration storage, to preference projects of 8 hours or more; and/or
- Limit the Consumer Trustee's ability to recommend projects with a duration of less than 8 hours to circumstances where this is prudent to address near-term reliability risks.

1. Background to the review

1.1 A Roadmap for storage infrastructure

The Electricity Infrastructure Roadmap (Roadmap) was developed as the State's plan to coordinate investment in electricity infrastructure as ageing coal-fired power plants are retired. Large-scale storage and firming infrastructure were considered essential to balance the supply of variable renewable energy. This considered infrastructure and technology types including:

- Long-duration storage, through pumped hydro over periods of hours to days, hydrogen over seasons, and possibly from longer-duration batteries in the future.
- Short-duration storage, through batteries over periods up to a few hours.
- Gas-fired generation, for back-up more independent of weather.

The Roadmap's enabling legislation, the EII Act, set separate infrastructure investment objectives for the construction of three types of infrastructure: generation, long-duration storage and firming infrastructure. Long-duration storage, with reliability events and pumped hydro in mind, was defined in the legislation as units with capacity to dispatch for at least 8 hours. The minimum objective for this long-duration storage infrastructure was set in the EII Act at 2 GW of capacity constructed before 2030, accompanied by an overall objective to meet the reliability standard.

1.2 An Electricity Supply and Reliability Check Up

In 2023, almost three years after the Roadmap was released and established in law, the NSW Government commissioned a Check Up to identify any additional steps that NSW needs to take to deliver the Roadmap to ensure a reliable supply of clean, affordable energy. The Check Up found that NSW is very unlikely to achieve the 2 GW target for long-duration storage if the infrastructure is restricted to pumped hydro.¹ It noted the potential for other technologies to meet this requirement, however the Check Up went on to recommend that alternative pathways to achieving the Roadmap storage targets are considered.

The NSW Government accepted this recommendation, and the OECC asked AEMO Services to consider:

- the distribution of duration for storage projects that would be built to meet the minimum objective in the absence of an 8 hour constraint, and
- the cost to consumers of the storage built in this scenario compared to that under the 8 hour requirement currently in force.

This report sets out AEMO Services findings with respect to the above based on quantitative analysis as well as AEMO Services insights from conducting tenders as the NSW Consumer Trustee.

1.3 Bill introduced to NSW Parliament

In the context of a potential revision to the definition of long-duration storage, the OECC flagged to AEMO Services that the NSW Government proposed to change the minimum objective to 2 GW *and* 16 GWh to preserve the original policy intent with respect to the total minimum quantity of capacity and energy storage. The *Energy Legislation Amendment Bill 2023* (the Bill) was introduced to NSW Parliament on 21 November 2023 to amend the EII Act and give effect to these proposed changes, in addition to other matters.²

¹ Documentation related to the Electricity Supply and Reliability Check Up is available at: energy.nsw.gov.au/nsw-plans-and-progress/regulation-and-policy/electricity-supply-and-reliability-check

² Documentation related to the Energy Legislation Amendment Bill 2023 is available at: parliament.nsw.gov.au/bills/Pages/bill-details.aspx?pk=18534

The Bill passed both Houses on 28 November 2023, and the minimum objective for long-duration storage is now at least 16 GWh of storage and 2 GW of capacity. AEMO Services understands that the definition, in terms of duration, will be revisited with the benefit of this review.

2. Methodology for the review

2.1 Overall Approach

AEMO Services has conducted quantitative analysis using the Central scenario from AEMO's 2023 Electricity Statement of Opportunities (ESOO) to provide an assessment of storage requirements for forecast reliability needs to 2030. This follows AEMO's ESOO methodology, which calculates the additional firm capacity (in MW) required to reduce the annual expected unserved energy (USE) to the relevant standard.³ The 2023 ESOO Reliability Forecast includes existing, committed and anticipated projects in the July 2023 generation information page. Anticipated projects are now included in the ESOO (as of 2023) but are subject to a delay to reflect commissioning uncertainty.⁴ Other proposed projects are not considered in AEMO's reliability modelling.

This scenario was used to explore the storage durations needed to close the forecast 'firm, unconstrained'⁵ reliability gap in 2030. AEMO Services determined the amount of storage required to meet the Interim Reliability Measure (IRM) in terms of durations of 2, 4, 8, 24 and 48 hours and various combinations of these.

Build costs for these storage configurations were then calculated using cost projections for 2030 from CSIRO's GenCost 2022-23 reporting which informed AEMO's 2023 Inputs, Assumptions and Scenarios Report (IASR). Estimates for maximum liabilities for NSW electricity customers associated with long-term energy service agreements (LTESAs) for long-duration storage were also calculated using information obtained by AEMO Services through tender processes. This information is presented at an aggregate level to protect the integrity and confidentiality of these tenders, some of which are currently live and conducted under strict probity arrangements

Build costs and LTESA liabilities were assessed on absolute and normalised (per GWh) basis, and portfolio configurations were ranked.

In preparing this analysis, AEMO Services has also considered the ongoing the relationship between firming and long-duration storage infrastructure in meeting reliability needs, and risks associated with the energy transition as it relates to the necessary capacity and configuration or different infrastructure.

2.2 Limitation to reliability assessment methodology limitations

2.2.1 Deratings for short duration storage based on AEMO estimates

Prior to publishing the 2023 ESOO, AEMO consulted with stakeholders on an adjusted methodology for the treatment of short duration storages in the reliability forecasts. AEMO established that derating factors should be applied to short duration storage to better reflect a more realistic reliability contribution, given their otherwise likely over-optimised availability to operate with likely intraday forecast inaccuracies and modelled perfect foresight at the precise time of peak demand or supply scarcity. Accordingly, AEMO applied the following storage capacity deratings in its 2023 ESOO:

- For devices with 1.5 to (less than) 3.5 hours of storage, storage capacity was reduced by 25%.
- For devices with 3.5 to (less than) 7.5 hours of storage, storage capacity was reduced by 10%.

³ More information on the ESOO and Reliability Forecast Methodology is available at: aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-reliability/nem-electricity-statement-of-opportunities-esoo

⁴ Anticipated projects which have provided an expected commissioning date are assumed to become fully available one year after the Full Commercial Use Date (FCUD) provided by the developer.

⁵ Firm, unconstrained capacity must be operable across the breadth of system challenges that may lead to reliability risks. This requirement to be dispatchable and continuously available means capacity requirements may be greater than ideally assumed when considering energy limits and/or power system constraints.

AEMO's reliability assessment methodology penalises 2 hour storage systems to address these likely intraday forecast inaccuracies and modelled perfect foresight. This penalty is an important modelling parameter to ensure that reliability forecasts are accurate. Without this penalty, or with a lesser penalty, less short-duration storage infrastructure than shown below may be required to meet reliability needs, assuming these storages were actually able to dispatch with perfect foresight to meet power system reliability requirements.

2.2.2 Conservative assumptions

The ESOO methodology also makes conservative assumptions regarding planned infrastructure construction, such that only projects that are existing, committed or anticipated by AEMO are considered in AEMO's reliability modelling, and committed and anticipated projects may have an assumed delay in delivery.

AEMO Services also notes that the Australian Government's announced Capacity Investment Scheme (CIS) may accelerate changes in the National Electricity Market (NEM), such that NEM capacity in 2030 may approach what was previously forecast for later in the decade, with implications for firm capacity and reliability needs.

2.2.3 Optimistic assumptions

Contrary to the conservative nature of these assumptions, other aspects of AEMO's reliability assessment could be considered to be optimistic or idealised. Identified capacities required to close the reliability gap are assumed to be placed in ideal locations. The ESOO methodology also does not include a range of circumstances that can affect system operation, with resulting implications for unserved energy, including transmission line outages due to faults or emergencies such as fires, planned generator and transmission outages, earlier retirements of coal generators than publicly announced, or extended renewable energy lulls beyond what has been observed in the applied historical datasets (including the impact of climate change).

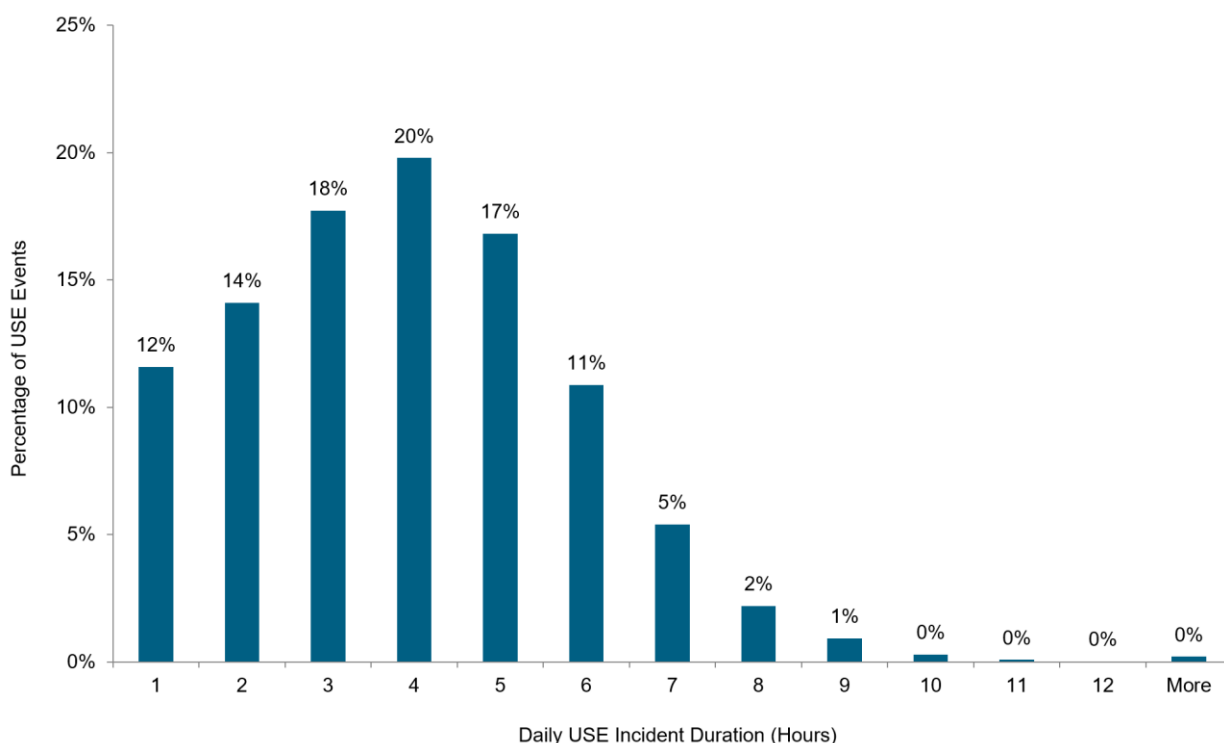
It is possible that reliability needs are greater than forecast when these limitations are considered. As a result of this, the value of longer-duration storage in mitigating tail-risk may be underestimated in this reliability analysis. These factors add weight to efforts to address potential market failure related to longer-duration storage, whereas industry insights suggest the market values short-duration storage in a way that could balance penalties in reliability analysis.

3. Results

3.1 Duration of modelled unserved energy events

Figure 1 below shows the modelled distribution of unserved energy events in 2030 under the Central scenario from AEMO's 2023 ES00, where only existing, committed and anticipated projects proceed. Under this scenario, almost all (96%) the modelled events are less than 8 hours, and the majority (63%) are less than or equal to 4 hours.

Figure 1: Duration of forecast unserved energy events in 2030 under the Central scenario from AEMO's 2023 ES00, where only existing, committed and anticipated projects proceed



3.2 Meeting the overall objective (reliability)

Table 1 below shows the total build cost to close to address unserved energy events in 2030 under AEMO's ES00 central scenario so as to meet the Interim Reliability Measure.

This suggests the following:

- Portfolios comprised of entirely short durations (2 hour battery systems) and entirely deep durations (24 and 48 hours pumped hydro) represent higher build costs
- Long-duration storage portfolios comprised of 4 and 8 hour storages represent lower total build costs, using this methodology, as they provide a balance of rated capacity with energy storage.
- Storage portfolios limited to longer-duration builds additional depth than is forecast to be necessary to meet reliability needs, which negates their significant advantage in cost per unit of energy (\$/GWh) by paying for depth (more GWh per GW) that may not be economically utilised.

Table 1: Forecast storage infrastructure requirement to meet the Interim Reliability Measure (IRM) in 2030, capacity and build cost estimates

Portfolio	Configuration					Capacity		Build cost	
	(percentage, capacity (MW) basis)					to meet IRM		Absolute to meet IRM	Normalised
	Battery system			Pumped hydro		Capacity	Energy		
	2 hour	4 hour	8 hour	24 hour	48 hour	GW	GWh	\$ b	\$ m/GWh
Portfolio 1	100%	-	-	-	-	5.77	11.54	7.05	611
Portfolio 2	50%	50%	-	-	-	3.39	10.18	5.35	525
Portfolio 3	-	100%	-	-	-	2.43	9.71	4.68	482
Portfolio 4	-	95%	5%	-	-	2.33	9.77	4.66	476
Portfolio 5	-	80%	20%	-	-	2.11	10.14	4.68	461
Portfolio 6	-	70%	30%	-	-	2.02	10.50	4.76	453
Portfolio 7	-	60%	20%	20%	-	1.93	16.97	5.18	305
Portfolio 8	-	-	100%	-	-	1.77	14.16	5.93	418
Portfolio 9	-	-	-	100%	-	1.75	41.96	7.52	179
Portfolio 10	-	-	-	-	100%	1.75	83.91	11.73	140

3.3 Meeting the minimum objective

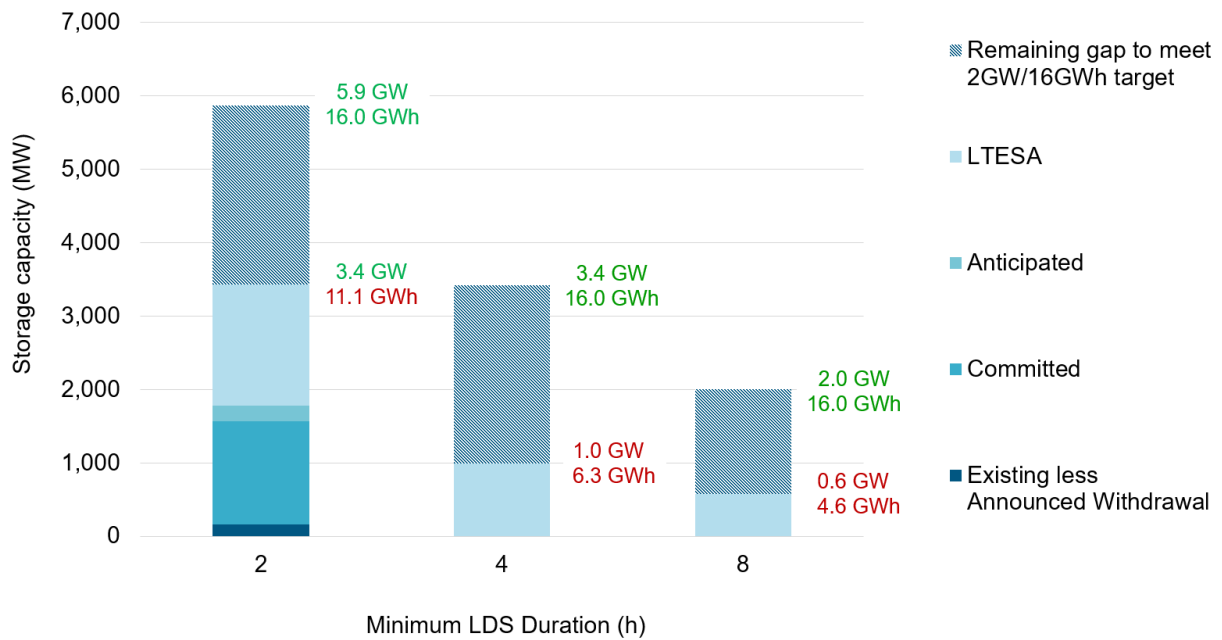
Where the minimum duration for long duration storage is reduced, without a change in the date of committed project status, at which projects become eligible, then there will be a number of projects which will already count towards the 2 GW / 16 GWh objective. Table 2 below shows the current capacity that is either already existing, committed, anticipated (based on AEMO’s January 2024 Generation Information page) or has received an LTESA from AEMO Services Tender Rounds 1, 2 and 3.

Table 2: Storage infrastructure capacity required to meet the 2 GW and 16 GWh objective

Minimum duration	Current capacity		Remaining capacity		Total required	
	GW	GWh	GW	GWh	GW	GWh
2 hours	3.4	11.1	2.4	4.9	5.9	16.0
4 hours	1.0	6.3	2.4	9.7	3.4	16.0
8 hours	0.6	4.6	1.4	11.4	2.0	16.0

While the current capacity secured under a 2 hour minimum duration threshold (3.4 GW) substantially exceeds 2 GW, there is still a gap of 4.9 GWh to meeting the total storage required (16 GWh). This is shown visually for capacity (GW) and energy (GWh) in Figure 2 below. As discussed above, it is also possible that reliability needs are greater than forecast when reliability related tail-risks are considered. For these reasons, AEMO Services does not recommend a 2 hour minimum objective.

Figure 2: Storage infrastructure capacity (MW) for 2, 4 and 8 hour minimum dispatchable capacity, secured and remaining required to meet the 2 GW and 16 GWh objective



3.4 Meeting both the minimum and overall objectives

Based on a comparison between the remaining capacity in Section 3.2 and the capacity required to meet the IRM in Section 3.3, it is unlikely that building an additional 4.9 GWh of 2 hour duration storage or 9.7 GWh will be sufficient to meet the IRM. Table 3 below shows the total build cost for each storage duration to meet the minimum objectives and then to meet the IRM (taken from Table 1 above). The greater of these costs then represents the total build cost to achieve both the minimum and overall infrastructure investment objectives by 2030, showing that a portfolio comprised entirely of 4 hour storage is lowest cost⁶.

Table 3: Build cost estimates to meet the 2 GW and 16 GWh objective

Portfolio	Configuration			Additional build cost to meet 2030 minimum objectives (A)	Additional build cost to meet IRM in 2030 (B)	Additional cost to meet IIOs by 2030 (greater of A and B)
	2 hour	4 hour	8 hour	\$ b	\$ b	\$ b
Portfolio A	100%	-	-	2.99	7.05	7.05
Portfolio B	-	100%	-	4.70	4.68	4.70
Portfolio C	-	-	100%	4.77	5.93	5.93

⁶ Note that the gap against the IRM is calculated using the 2023 ESOO Central scenario for 2030, which assumed only projects existing, committed and anticipated at the time of modelling are included. This did not include some projects that now have LTESAs, and therefore this gap and associated cost may be conservative

3.5 LTESA Tender Insights

In Tender Round 3 (LDS), the average equivalent Annuity Cap (which describes the maximum potential liability to NSW electricity customers) for successful long-duration storage projects (lithium-ion battery and compressed air 8h duration), was estimated to be around \$150,000/MW/year (real 2023, over 14 years, escalating at lesser of CPI or 3% p.a.). In Tender Round 2 (Firming Infrastructure), the Annuity Cap was \$40,000/MW/year (nominal, capacity-weighted average. Not escalating, over 10 years, discounted) across the successful battery (2 and 4 hour) and demand response projects.

Tender information accordingly suggests that LTESA liabilities for shorter duration storage (less than 8 hours) may be lower for NSW electricity customers on a per MWh basis. AEMO Services considers that this is a result of:

- reduced wholesale market arbitrage revenues for longer duration storage on a per MWh basis
- the ability of shorter duration storage to derive a higher percentage of required revenues from non-energy markets (e.g. Frequency Control Ancillary Services, FCAS), noting that these revenues are subject to future uncertainty depending on the evolution of these markets.

It should be noted however, that these cost estimates are based on a small sample of projects, so these values are considered illustrative for the purpose of this review. LTESA tender insights data is also limited to 2, 4 and 8 hour energy storage systems, so can only be compared to a sub-set of the portfolios in the reliability assessment above in Table 1.

Regardless, AEMO Services does see this as illustrative of general observations that shorter duration storage projects require less support to achieve commercial viability and reach financial close. This has been observed in key commercial terms bid by proponents, including thresholds and contracted percentages.

Considering storage projects are proceeding in this manner suggests that the market is functioning adequately at present for short-duration systems. Battery energy storage can rely on a number of revenue streams to achieve commercial viability. Systems with less than 4 hours of storage have a high power capacity (in relative terms) which helps them to profit from volatile market events. Additional duration has decreasing marginal returns, and AEMO Services has heard from proponents that receiving an LTESA would mean the difference between proceeding as a shorter-duration project and extending to 8 hours of storage.

Projects with durations of 8 hours or more continue to struggle to reach financial close without some form of underwriting or other support from government policy. Engagement with industry suggests, however, that investors are responding to signals from AEMO Services and proponents are actively developing storage projects with an 8 hour duration.

Innovation amongst this sector is resulting in cost reductions in long-duration storage technologies. AEMO Services observed that Financial Value Bids received for long-duration storage in Tender Round 3 showed a reduction in Bid Prices compared with Tender Round 1.⁷ The successful projects were assessed as providing financial value by bidding competitively low Annuity Caps and Net Revenue Threshold, shorter contract terms than the maximum allowed, excluding Annuity Periods, and by bidding a schedule of Annuity Caps in nominal dollars.

⁷ Further information on outcomes of tenders for long-duration storage infrastructure is available in Market Briefing Notes published the AEMO Services website: aemoservices.com.au/support-and-resources

4. Recommendations and policy considerations

AEMO Services' analysis suggests there is a need for investment in reliability in NSW, before and after 2030, and that storage infrastructure projects will play an important role in meeting that need. As observed by the Electricity Supply and Reliability Check Up commissioned by the NSW Government, there are risks associated with delivering that infrastructure in the necessary timeframe. Some indications suggest industry development is balancing risks associated with pumped hydro projects with innovative technological solutions. However, expanding the definition of long-duration storage may reduce costs for NSW electricity customers and de-risk the delivery of energy storage capacity for reliability needs, through projects of 4 hours or more that represent higher value to consumers.

It is AEMO Services' view, based on our analysis and experience as NSW Consumer Trustee, that the NSW Government should consider two objectives for a potential change to the EII Act, to:

1. Provide the Consumer Trustee with more flexibility in how it tenders for long-duration storage infrastructure to meet the reliability standard, by reducing the minimum duration for long-duration storage to 4 hours.
2. Continue to signal to investors the long-term need for storage with a duration of 8 hours or more to mitigate tail-risks to achieving reliability outcomes.

The need for decision-making flexibility with regard to duration is considered particularly important in the short term, where forecast gaps against the reliability standard are likely to be more cost effectively met by shorter-duration storage projects which investors have shown more readiness to deliver within the required timeframes. This should be balanced by a requirement for the Consumer Trustee to value longer-duration storage where practicable, so as not to write-off considerable investment in developing these projects and stifle innovation that is likely to be required in the medium to longer term.

The need identified by the Roadmap to coordinate large-scale storage and firming infrastructure to balance the supply of variable renewable energy has not changed. A holistic consideration of reliability and energy security risks associated with the energy transition suggests that this remains an important issue to address. Modelling for the 2023 IIO Report also indicates that delays to key network infrastructure projects bring forward the need for long-duration storage and firming, which will become challenging for projects with inherently long lead times to achieve.

Longer-duration projects have the potential to mitigate tail-risks to reliability, however are not likely to be incentivised under current market frameworks in the absence of this signal.

4.1 Definition of long-duration storage and the minimum objective

Based on this analysis, AEMO Services considers that reducing the definition of long-duration storage under the EII Act to 4 hours minimum dispatchable capacity, alongside a GWh target, is in the long-term financial interest of NSW electricity customers. A more flexible definition has the potential to increase participation in tenders and so expand AEMO Services' visibility to a wider range of storage projects, de-risking the delivery of substantial energy storage capacity at lower cost to consumers.

While this flexibility would be helpful, addition of short-duration storage in the near-term to address a more immediate reliability need has the potential to undermine the viability of long-duration storage, which may be more beneficial to the system over time. Implications of a shorter duration definition include that additional committed projects would then count toward the existing minimum objective. Broader policy considerations may thus favour retaining the 8 hour definition, which could stimulate industry development and better address tail-risk.

The addition of provisions for flexibility, with limitations, regarding the duration of storage projects could balance arguments in favour of short and long-duration storage in meeting the future reliability needs of NSW. If this option were to be pursued, AEMO Services recommends provisions in legislation or delegated legislation to:

- Require the Consumer Trustee, in recommending LTESAs for long-duration storage, to preference projects of 8 hours or more; and/or
- Limit the Consumer Trustee's ability to recommend projects with a duration of less than 8 hours to circumstances where this is prudent to address near-term reliability risks.

4.2 Investor engagement

Regardless of the mechanism pursued by the NSW Government, investors require certainty to make investment decisions. Providing investment certainty is a central principle of the Roadmap policy, and AEMO Services considers that it would be unhelpful to add only an open-ended provision in legislation at this time, which may lead to ongoing speculation. Care should also be taken about the timing of future legislation and regulation with respect to any live tenders. AEMO Services intends to continue to proactively communicate to investors what we value in conducting tenders as the NSW Consumer Trustee.

Despite the need for this infrastructure, commercial insights from investors suggest that market reform is required to efficiently deliver long-duration storage without government intervention.