APPENDIX A3
MSL Regional Assessments

December 2025

Appendix to the 2025 Transition Plan for System Security for the National Electricity Market

Minimum system load

Periods of minimum system load (MSL) occur when distributed generation, particularly passive rooftop PV, combines with low underlying demand to significantly reduce operational demand on the transmission system. At present, large-scale synchronous units are essential for delivering system security services, such as system strength (fault current), inertia, voltage control, and ramping. Synchronous generators need to operate at or above their minimum stable operating levels (MSOLs). When replacement essential system services have enabled the system to run at times without any synchronous generation, MSL thresholds will be a continuing requirement, reflecting overall supply and demand balance and interregional transfer limits.

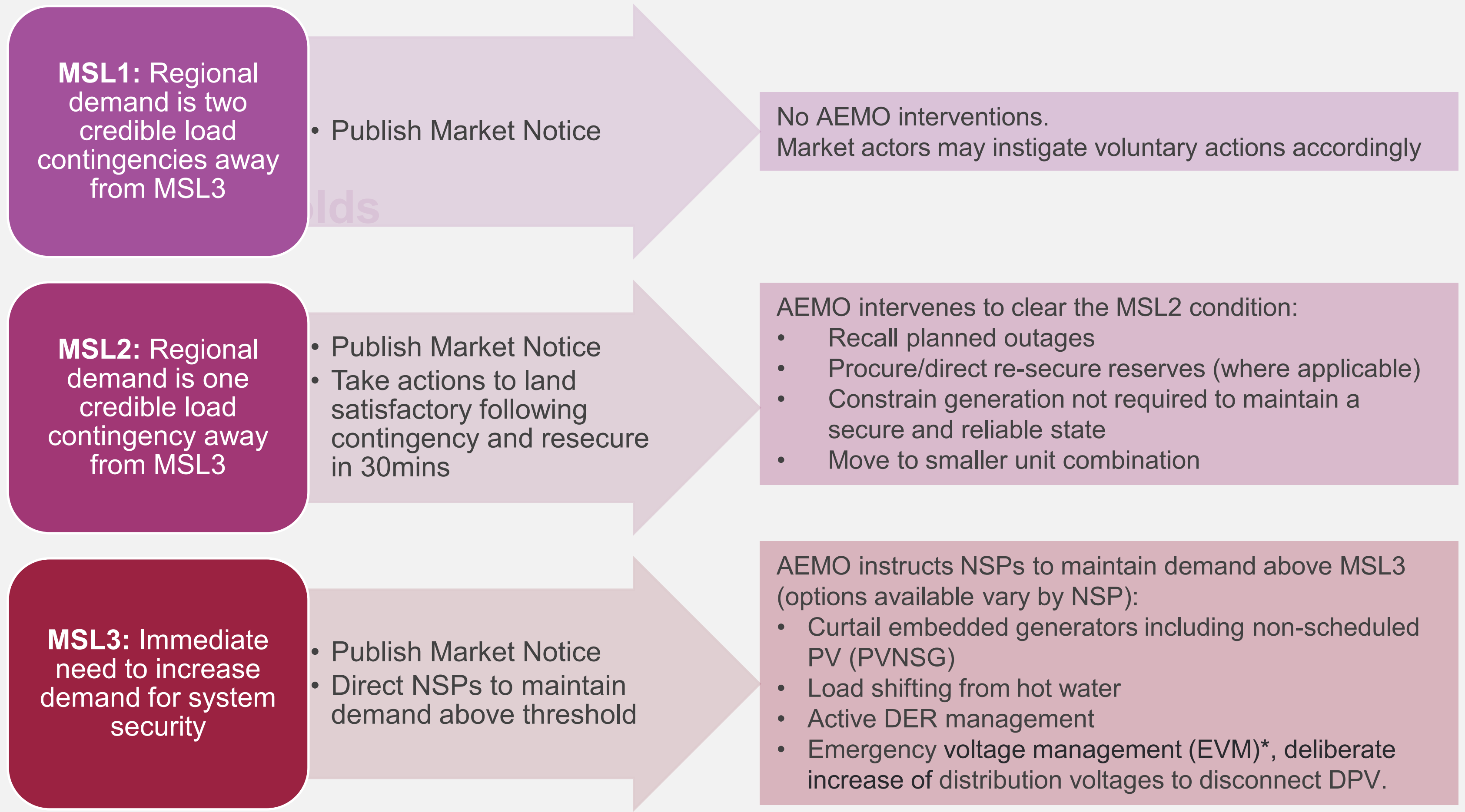
AEMO currently manages system security issues under MSL conditions on an individual region basis, based on the conditions in the specific region at the time, accounting for conditions in neighbouring regions.

Since 2017, AEMO has worked with NEM stakeholders to manage secure system operation during periods of high distributed PV generation and low demand. AEMO's current operational procedure for managing forecast MSL conditions, uncertainty in the load forecast and the technical envelope of the power system in operational timeframes is summarised in **Figure 1**.

To understand the future capability to manage MSL, this section of the TPSS presents an MSL readiness for each NEM region, assessed through two lenses:

1. **Near-term planning for onerous MSL conditions (pages 4 to 7)** – assesses whether there is sufficient capability to increase operational demand, in the next two years, if an onerous MSL3 event were to occur in extreme or unexpected conditions with limited opportunities for AEMO MSL2 actions to manage the condition.
2. **Incidence of MSL events under system normal (pages 8 to 12)** – considers the number of days each year where, during typical system normal interconnected conditions, at least one period is below an MSL threshold in the next five years. This provides an indication of:
   - How often MSL2 and MSL3 are forecast, and therefore how often AEMO would take actions to clear the condition (such as unit decommitment, recalling outages), which may eliminate the MSL condition.
   - How often MSL3 conditions persist post-action from AEMO. This indicates how often DNSPs may be required to undertake MSL3 actions to increase operational demand (such as hot water shifting, or rooftop PV disconnection) and maintain system security.

Figure 1 MSL thresholds and actions



*With relation to EVM, DNSPs need to assess risks and conduct modelling, testing and/or trials as necessary to confirm this option is suitable for their network (including consideration of relevant regulations and legislation) and maximise capabilities, while ensuring safety and low risk to customer equipment.

Evolving demand

The assessments presented in the upcoming pages reflect changing demand according to the 2025 ESOO demand forecast, using the *Step Change* scenario which represents the most likely and central scenario. The 2025 ESOO forecast includes factors such as load growth (for example, from data centres), electrification (such as EVs), and increased adoption of residential batteries. However, it does not factor in the behaviour or availability of large-scale BESS response during these times. Future analysis is required to integrate BESS scheduling patterns and their resulting effects on MSL incidences.

How to read the *Near-term planning for onerous MSL3 conditions* chart

The charts used on pages 4 to 7 provide an illustration of estimated capabilities from DNSPs to increase operational demand during MSL3, compared against an onerous MSL3 threshold.

MSL Thresholds: Indicative operational demand MSL thresholds are presented as horizontal lines, showing the demand that would need to be maintained based on the present operational toolkit and system conditions. Two scenarios are shown, to illustrate a range of potential future conditions:

- **Onerous MSL3 threshold:** Presents a plausible onerous scenario, defined separately for each region. The incidence of onerous conditions is hard to predict as they typically arise following an unplanned outage or unexpected system condition when there may be insufficient time to undertake AEMO MSL2 actions (such as recalling network outages or decommitting generators).

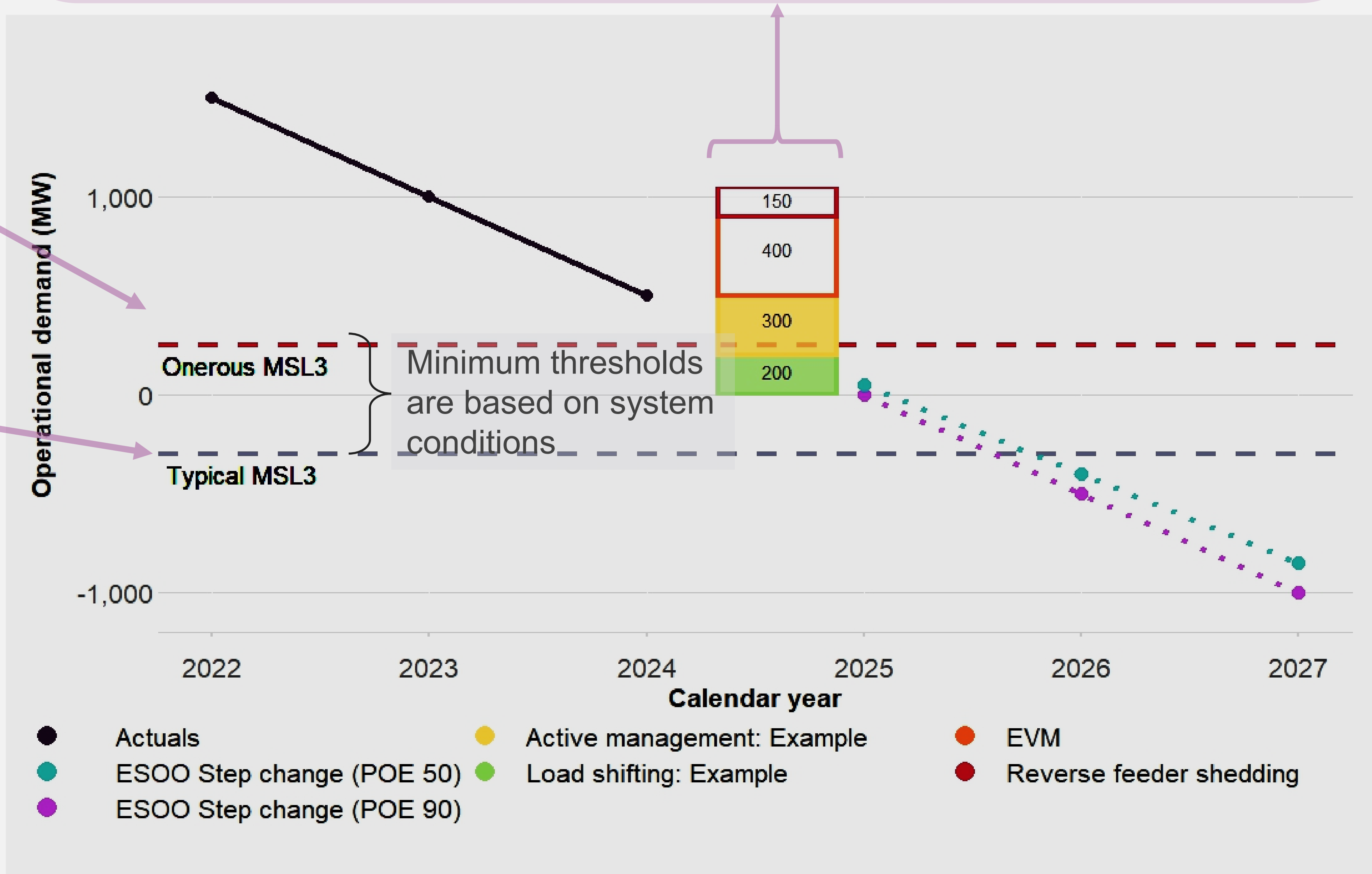
- **Typical MSL3 threshold:** based on typical large synchronous units operating at minimum levels under system normal conditions, typical export limits applying in low demand periods, and no significant outages (of lines, network elements, loads, storage, or generating units).

Note: this diagram is for explanation purposes only. Region-specific diagrams are shown in the following pages.

Stacked column of DNSP MSL3 actions: DNSP estimates of capabilities available to increase operational demand during MSL3, which can include:

- Curtailing embedded generators including PVNSG
- Load shifting (for example, from hot water)
- Active DER management (for example, via CSIP-AUS)
- Emergency voltage management (EVM), deliberate increase of distribution voltages to disconnect DPV*.

* With relation to EVM, DNSPs need to assess risks, consider pathways (including relevant regulations and legislation), conduct modelling, testing and/or trials as necessary to confirm whether this option is suitable for their network, while ensuring safety and low risk to customer equipment.



How to interpret the chart

The stacked column of DNSP actions indicates the ability to maintain system security under **onerous MSL3 conditions**.

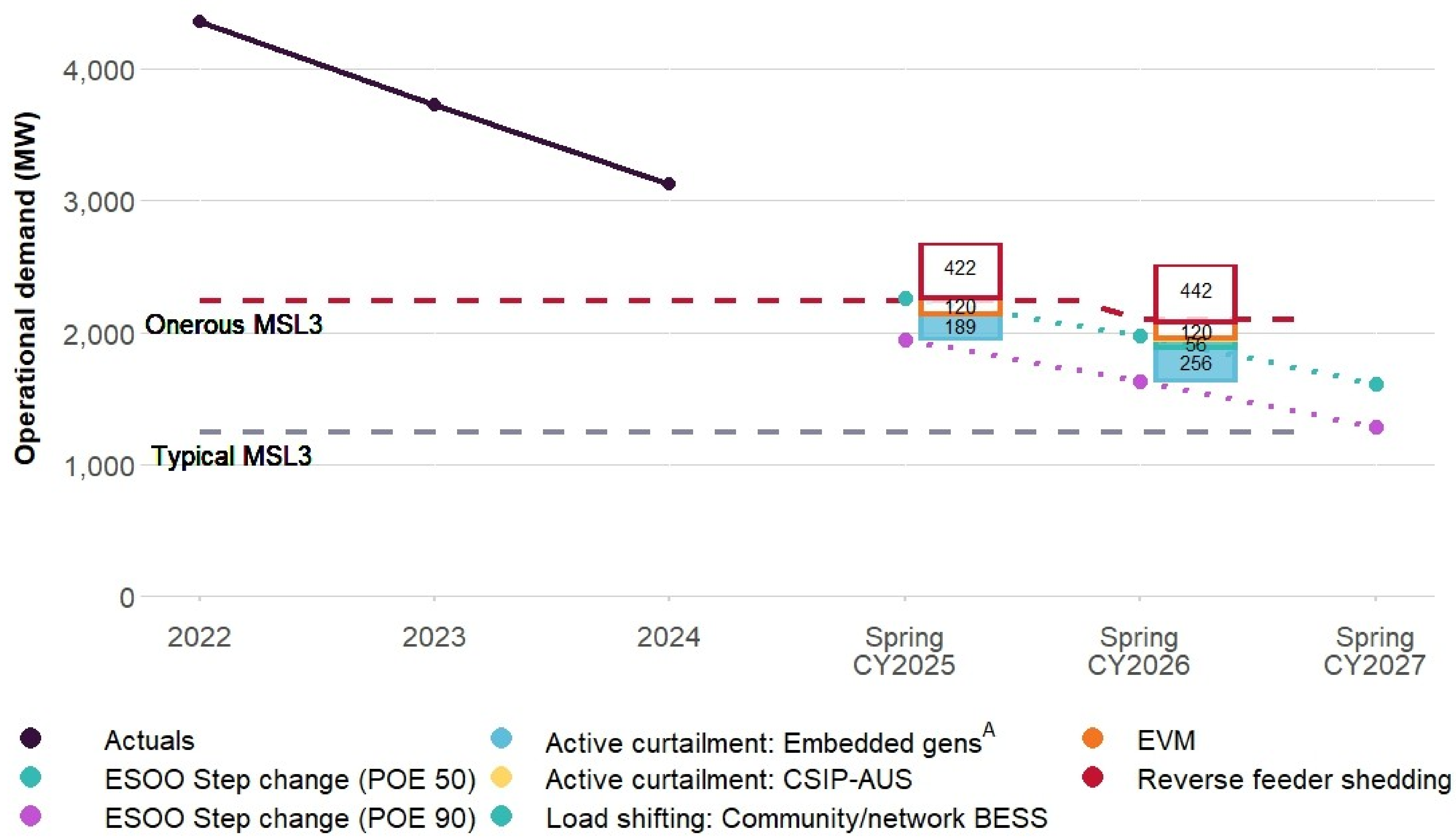
If the stack is below the dotted red line, there may be insufficient operational demand increase capabilities available in the present operational toolkit. This means the power system may be operating insecure if onerous conditions occur during times of low demand, presenting an increased risk of a system black.

Measures which have higher customer impacts are shown as outlines. An orange outline is shown for EVM, and a red outline is shown for shedding of whole reverse flowing feeders, which interrupts electricity supply to consumers on those feeders and is a last resort for management of system security, when other options are exhausted.

Capability to maintain system security in New South Wales and the Australian Capital Territory under onerous conditions

Near-term planning: Capabilities for DNSP actions to increase operational demand, under onerous conditions

The incidence of onerous conditions is challenging to predict, as they typically arise following an unplanned outage or unexpected system condition when there is insufficient time to decommit non-essential generators. **Onerous conditions are used for near-term planning, to ensure sufficient capability in extreme conditions** as a 'backstop' to maintain system security.



[A] Includes all curtailable generators. For internal consistency with the 2025 ESOO minimum demand forecast, generation has been adjusted to align with PVNSG capacity factor from the same scenario (*Step Change*, 90% POE).

Indicative MSL thresholds are based on the present operational toolkit. MSL thresholds depend on system conditions. An additional 2.6 GW/7.1 GWh of committed and commissioning utility-scale BESS is expected to be installed in New South Wales/Australian Capital Territory by spring 2026, and the study shows estimated reduction in the onerous MSL3 threshold based on present observations of market behaviour during very low demand days. Further improvements could be seen if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition. AEMO is continuing to assess and improve methods to incorporate BESS into MSL thresholds.

Two scenarios are shown, to illustrate a range of potential future conditions:

- **Typical MSL3** – 1,240 MW, based on typical large synchronous units operating at minimum levels under system normal conditions, typical export limits applying in low demand periods, and no significant outages (of lines, network elements, loads, storage, or generating units).
- **Onerous MSL3** – 2,240 MW, reducing to 2,099 MW with new utility-scale BESS. Based on a plausible onerous condition with 1) typical large synchronous units operating at minimum levels and 2) export from the region not possible (due to network outages or coincident low demand in neighbouring regions), and 3) Shoalhaven and Tumut 3 pumping loads unavailable.

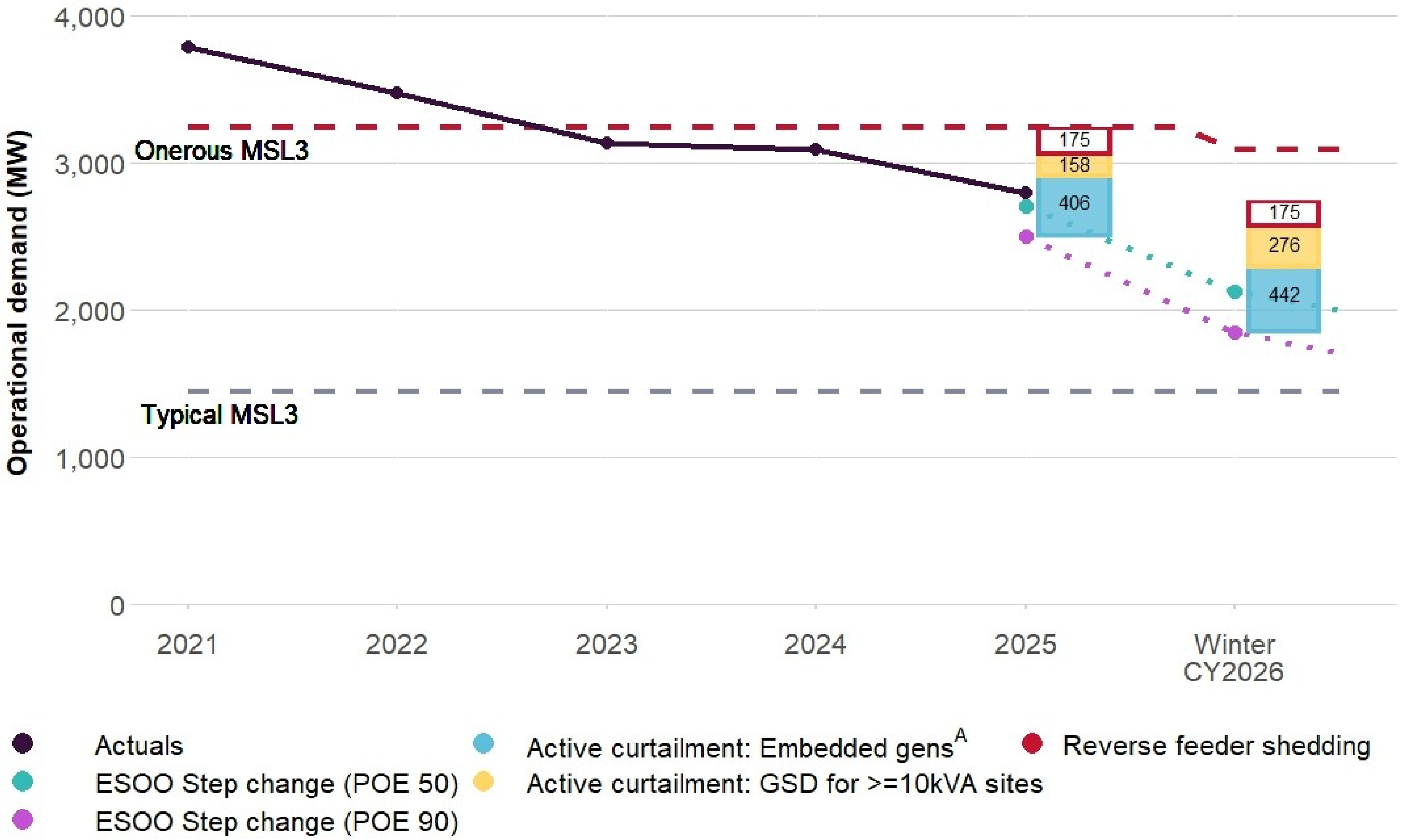
Based on this assessment, the quantity of operational demand increase available in New South Wales is projected to be close to sufficient for management of plausible onerous system conditions. Under some onerous MSL3 conditions, even with anticipated storage capability from utility scale BESS, it may be necessary for DNSPs to enact almost all mechanisms, including use of EVM.

AEMO recommends that the New South Wales and Australian Capital Territory DNSPs consider if there are any further cost-effective opportunities to expand mechanisms available to increase operational demand if necessary under onerous conditions. AEMO will continue to develop services, frameworks and actions with the aim to effectively incentivise utility-scale BESS to provide firm certainty of energy capacity throughout an MSL condition.

Capability to maintain system security in Queensland under onerous conditions

Near-term planning: Capabilities for DNSP actions to increase operational demand, under onerous conditions

The incidence of onerous conditions is challenging to predict, as they typically arise following an unplanned outage or unexpected system condition when there is insufficient time to decommit non-essential generators. **Onerous conditions are used for near-term planning, to ensure sufficient capability in extreme conditions** as a 'backstop' to maintain system security.



[A] Includes all curtailable generators. Queensland has a significant proportion of other non-scheduled generators (for example, bagasse), and historical values for those have been applied to the analysis.

Indicative MSL thresholds are based on the present operational toolkit. MSL thresholds depend on system conditions. An additional 2.3 GW/5.4 GWh of committed and commissioning utility-scale BESS is expected to be installed in Queensland by spring 2026, and the study shows an estimated reduction in the onerous MSL3 threshold based on present observations of market behaviour during very low demand days. Further improvements could be seen if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition. AEMO is continuing to assess and improve methods to incorporate BESS into MSL thresholds.

Two MSL thresholds are shown, to illustrate a range of potential future conditions:

- **Typical MSL3** – 1,450 MW, based on system normal conditions, typical large synchronous units operating at minimum levels, typical export limits applying in low demand periods, and no significant outages (of lines, network elements, loads, storage, or generating units).
- **Onerous MSL3** – 3,235 MW, reducing to 3,087 MW with new utility-scale BESS. Based on 1) Queensland operating as an island, 2) typical large synchronous units operating at minimum levels, 3) one Wivenhoe pump unavailable, and 4) one significant lower contingency FCAS provider unavailable. New entrants including pumped hydro load are expected in the second half of 2026 and may reduce the MSL threshold beyond winter 2026 once they are fully operational.

There is a present and growing shortfall in the ability to increase operational demand to the levels that might be required under a plausible onerous system condition in Queensland. To maintain system security in this onerous condition without shedding reverse flowing feeders, it is estimated that an additional ~170 MW of capability is required in 2025 (beyond the existing estimated capability), growing to an additional ~515 MW of capability required by Winter 2026.

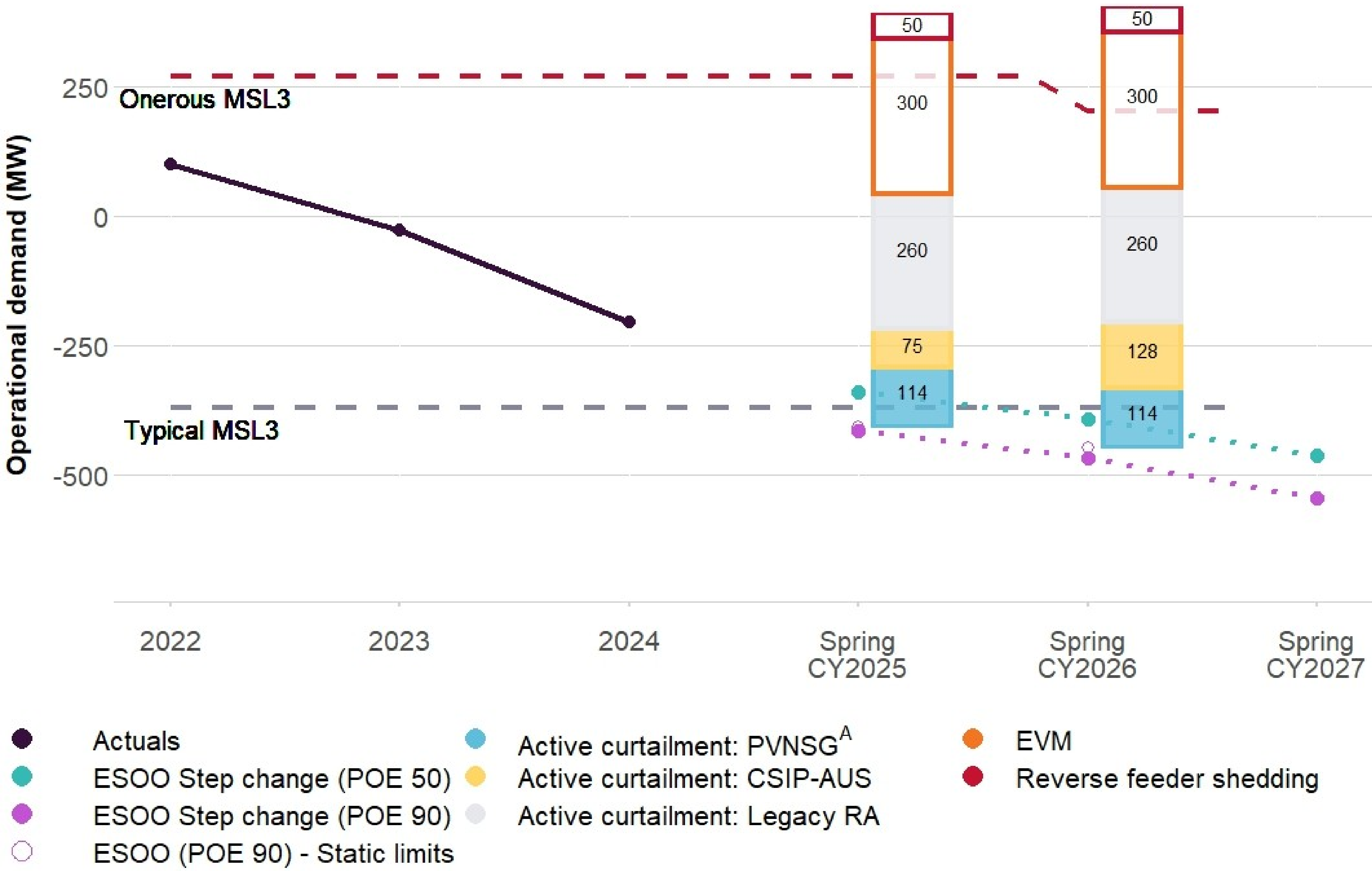
If this onerous condition arises, considerable shedding of reverse flowing feeders may be necessary to maintain power system security. This would have significant customer impact, and analysis indicates that even the total demand increase response available from shedding reverse flowing feeders may be insufficient to restore system security. This means that, under these rare but plausible conditions, the power system could be operating insecure for an extended period and places customers at escalated risk of black system events.

AEMO recommends that measures are progressed in Queensland to expand coverage of active management of DER to all new installations, as soon as possible. Measures to improve compliance with existing mechanisms should continue to be supported, alongside further measures to expand capabilities to increase operational demand. AEMO will continue to develop frameworks and actions with the aim to effectively incentivise utility-scale BESS to provide firm certainty of energy capacity throughout an MSL condition.

Capability to maintain system security in South Australia under <u>onerous conditions</u>

Near-term planning: Capabilities for DNSP actions to increase operational demand, under <u>onerous conditions</u>

The incidence of onerous conditions is challenging to predict, as they typically arise following an unplanned outage or unexpected system condition when there is insufficient time to decommit non-essential generators. **Onerous conditions are used for near-term planning, to ensure sufficient capability in extreme conditions** as a 'backstop' to maintain system security.



[A] Includes all curtailable generators. For internal consistency with the 2025 ESOO minimum demand forecast, generation has been adjusted to align with PVNSG capacity factor from the same scenario (*Step Change*, 90% OE).
RA = Relevant Agent, referring to the legacy framework for the emergency backstop mechanism in South Australia

Indicative MSL thresholds are based on the present operational toolkit. MSL thresholds depend on system conditions. An additional 0.4 GW/0.8 GWh of committed and commissioning utility-scale BESS is expected to be installed in South Australia by spring 2026 and the study shows estimated reduction in the onerous MSL3 threshold based on present observations of market behaviour during very low demand days. Further improvements could be seen if services, frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition. AEMO is continuing to assess and improve methods to incorporate BESS into MSL thresholds.

Two scenarios are shown, to illustrate a range of potential future conditions:

- **Typical MSL3** – -370 MW, based on typical large synchronous units operating at minimum levels, typical export limits applying in low demand periods, and no significant outages (of lines, network elements, loads, storage, or generating units).
- **Onerous MSL3** – 270 MW reducing to 203 MW with committed utility-scale BESS. Based on 1) South Australia operating as an island with no energy flows in or out of the region, 2) typical large synchronous units operating at minimum levels, and 3) one significant lower contingency FCAS provider unavailable. BESS installed in 2025 (Blyth, Mannum) are included in both 2025 and 2026 thresholds. Note that the demand threshold was previously set by distributed PV contingency risk, but following BESS additions is now set by MSL.

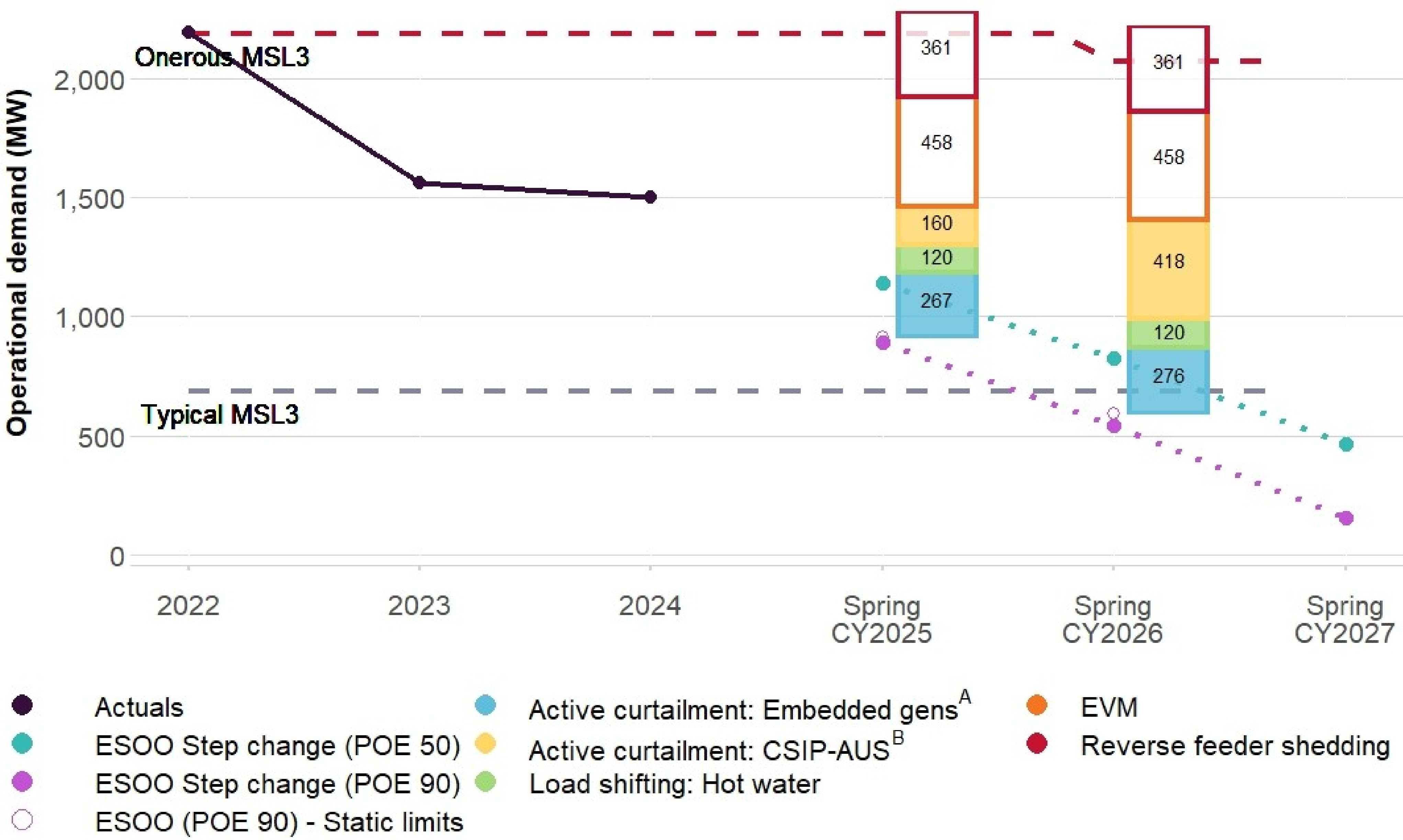
Based on this assessment, the quantity of operational demand increase capability in South Australia is projected to be sufficient to manage both typical conditions and plausible onerous system conditions, without the need to shed reverse flowing feeders (which should be avoided if possible, given this has considerable customer impact).

Under some onerous MSL3 conditions it may be necessary for SA Power Networks to enact almost all mechanisms, including curtailment of embedded generation, active DER management via CSIP-AUS and legacy Relevant Agent, and use of EVM. AEMO recommends that SA Power Networks continues to support measures to improve compliance and speed of response from existing mechanisms. AEMO will continue to develop services, frameworks and actions with the aim to effectively incentivise utility-scale BESS to provide firm certainty of energy capacity throughout an MSL condition.

Capability to maintain system security in Victoria under onerous conditions

Near-term planning: Capabilities for DNSP actions to increase operational demand, under onerous conditions

The incidence of onerous conditions is challenging to predict, as they typically arise following an unplanned outage or unexpected system condition when there is insufficient time to decommit non-essential generators. **Onerous conditions are used for near-term planning, to ensure sufficient capability in extreme conditions** as a 'backstop' to maintain system security.



[A] Includes all curtailable generators. For internal consistency with the 2025 ESOO minimum demand forecast, generation has been adjusted to align with PVNSG capacity factor from the same scenario (*Step Change*, 90% POE).
[B] Includes sites which respond to active management signals, as well as sites which correctly reduce to their fallback limit if they lose connection with the CSIP-AUS server.

Indicative MSL thresholds are based on the present operational toolkit. MSL thresholds and DNSP estimates of response capability depend on system conditions. An additional 0.5 GW/1 GWh of committed utility-scale BESS is expected to be installed in Victoria by spring 2026 and the study shows estimated reduction in the onerous MSL3 threshold based on present observations of market behaviour during very low demand days. Further improvements could be seen if services, frameworks and actions effectively incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition. AEMO is continuing to assess and improve methods to incorporate BESS into MSL thresholds.

Two scenarios are hence shown to illustrate a range of potential future conditions:

- **Typical MSL3** – 685 MW, based on typical large synchronous units operating at minimum levels, typical export limits applying in low demand periods, and no significant outages (of lines, network elements, loads, storage, or generating units).
- **Onerous MSL3** – 2,190 MW reducing to 2,073 MW with new utility-scale BESS. Based on a plausible onerous scenario with 1) typical large synchronous units operating at minimum levels, and 2) zero export and zero import into Victoria, due to network outages or coincident low demand in neighbouring regions South Australia, New South Wales, and Tasmania.

Present estimates indicate that managing an onerous MSL3 condition would require full application of almost all operational demand increase mechanisms available to DNSPs, including curtailment of embedded generation, load shifting hot water, active management of DER via CSIP-AUS, and use of EVM. Under some extreme onerous conditions, shedding of some reverse flowing feeders may also be required to maintain power system security.

AEMO recommends that Victorian DNSPs continue to support urgent measures to improve compliance with existing mechanisms, and consider if there are any further practicable opportunities to expand mechanisms available to increase operational demand, to avoid the need for shedding of reverse flowing feeders to manage the possibility of onerous MSL conditions. AEMO will continue to develop services, frameworks and actions with the aim to effectively incentivise utility-scale BESS to provide firm certainty of energy capacity throughout an MSL condition.

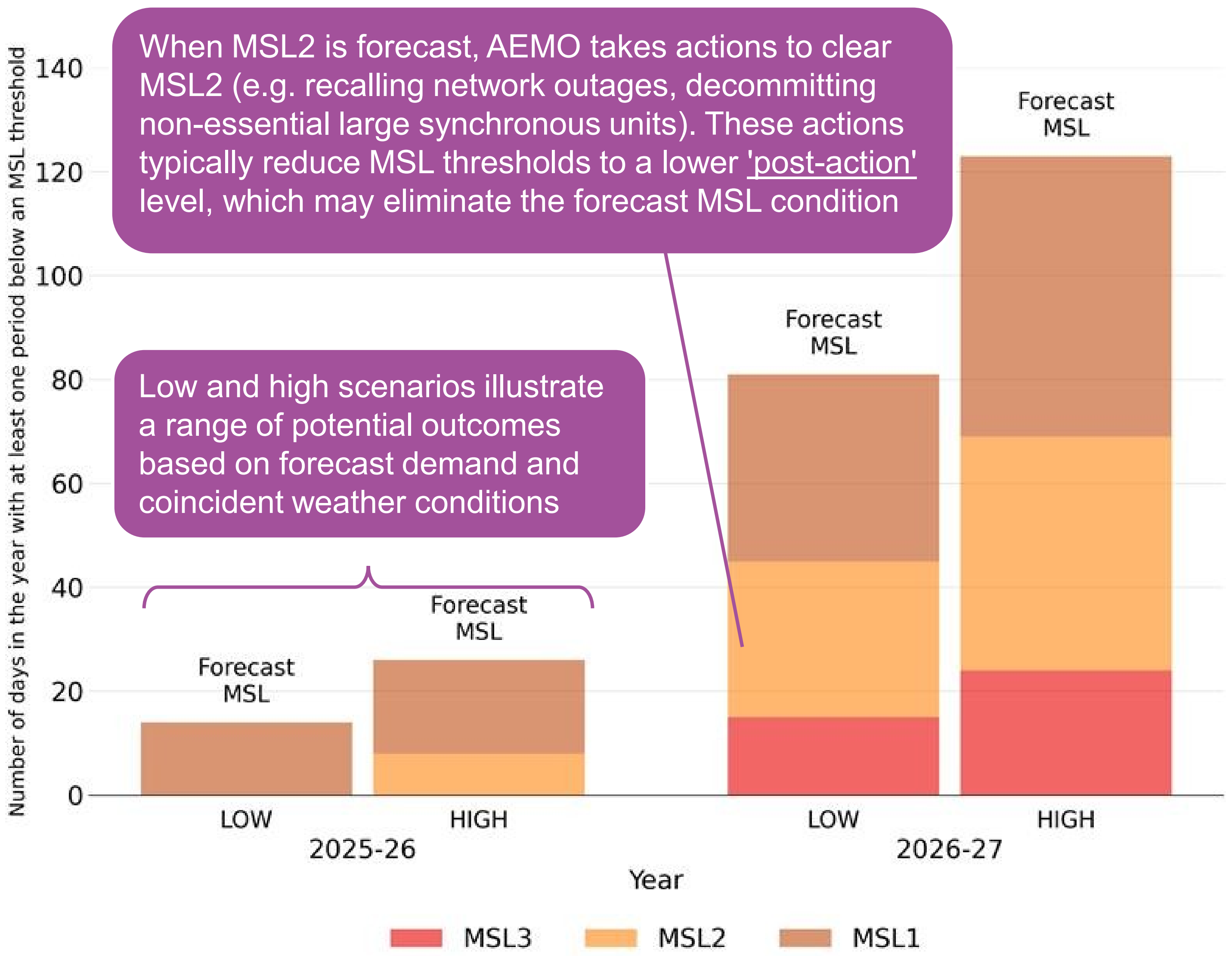
Incidence of MSL events in typical system normal conditions

The previous subsection focused on near-term planning, considering DNSP operational demand increase capabilities under onerous conditions as a 'backstop' to maintain system security, with typical MSL3 thresholds also shown as an indication of the large impacts that system conditions have on these thresholds. The incidence of onerous conditions is challenging to predict by nature of the fact that they are typically caused by unplanned system conditions.

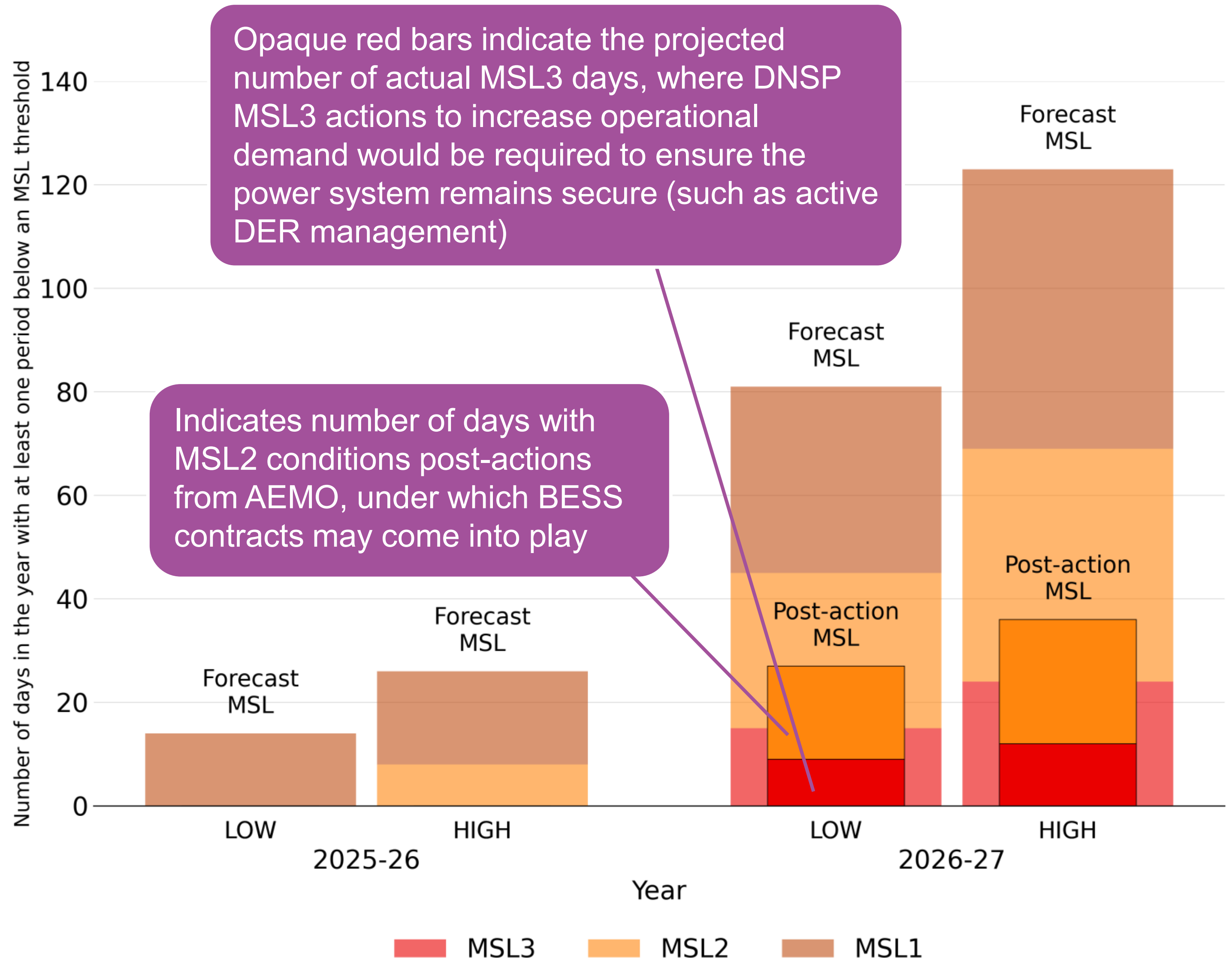
To provide an indication of how often MSL3 actions to increase operational demand are anticipated to be required under typical conditions, AEMO has modelled the number of days each year during **typical system normal interconnected conditions** where at least one period is projected to be below an MSL threshold. This estimate does not account for unplanned outages, which can mean an MSL condition arises suddenly under atypical conditions.

Forecast MSLs: This diagram provides an indication of how often AEMO may release forecast MSL market notices, based on typical MSL thresholds with typical synchronous units online.

Post-action MSLs: This gives an indication of the projected incidence of days containing actual MSL events.



Some MSL conditions persist post-actions from AEMO, shown in inner opaque bars



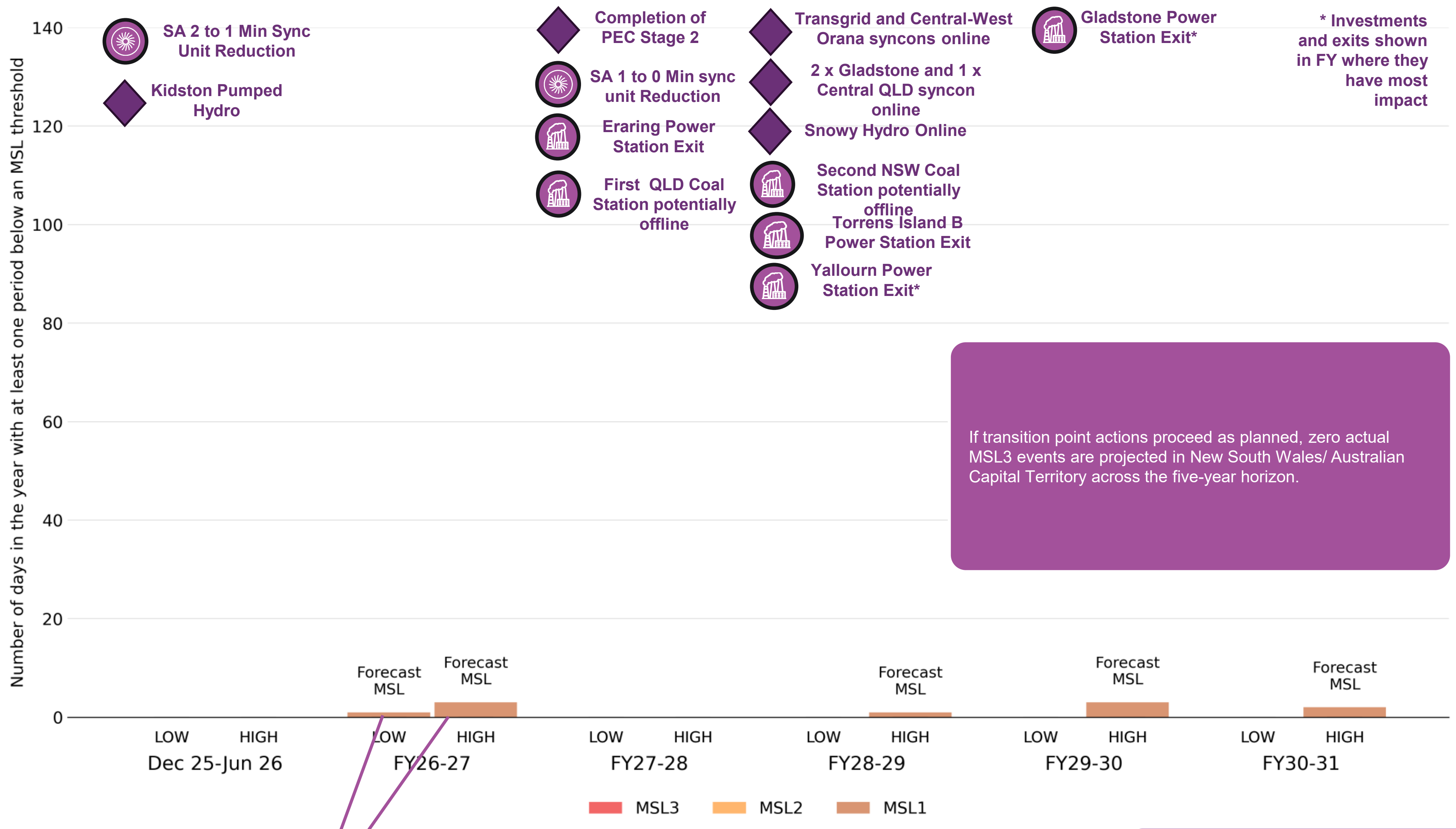
Note: these diagrams are for explanation purposes only. Region-specific diagrams are shown in the following pages.

Projected incidence of MSL events in New South Wales and the Australian Capital Territory under typical system normal conditions

Estimates are for system normal only, and do not account for unplanned outages and extreme conditions which may significantly escalate the incidence and severity of MSL conditions. Present estimates for typical conditions do not account for utility-scale BESS as their typical behaviour across the five-year horizon may vary widely with rapidly increasing numbers of BESS. AEMO is working to incorporate BESS in future analysis, which may result in improvements particularly if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition.

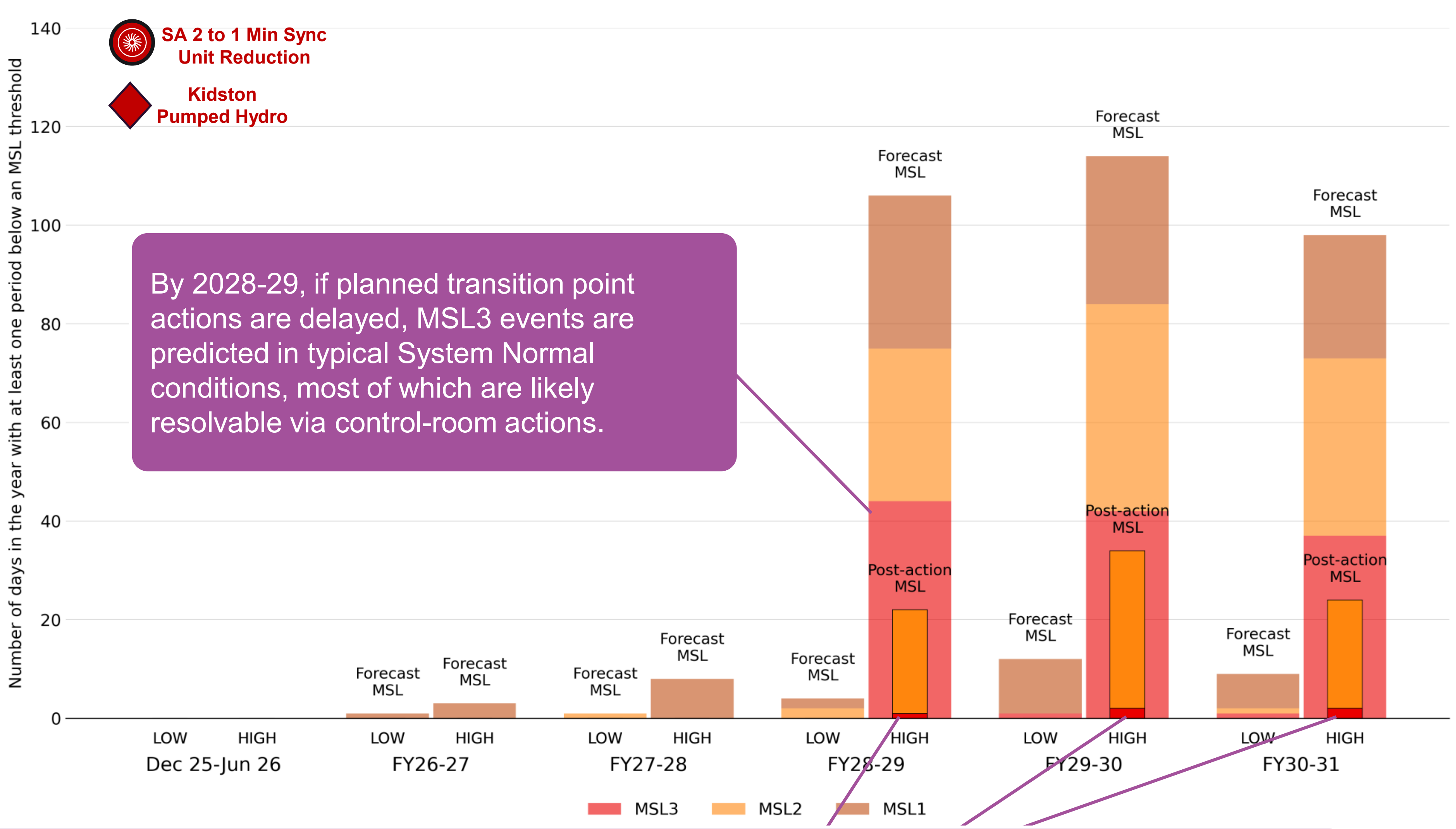
Low scenario: Greater of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the lowest total MSL incidence (forecast), and lowest MSL2+MSL3 incidence (post-action)
High scenario: Lesser of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the highest total MSL incidence (forecast), and highest MSL2+MSL3 incidence (post-action)

NEM-wide transition point actions proceed, lowering MSL thresholds



Possibility of forecast MSL1, projected to be resolvable by control room actions.

NEM-wide delays in transition point actions



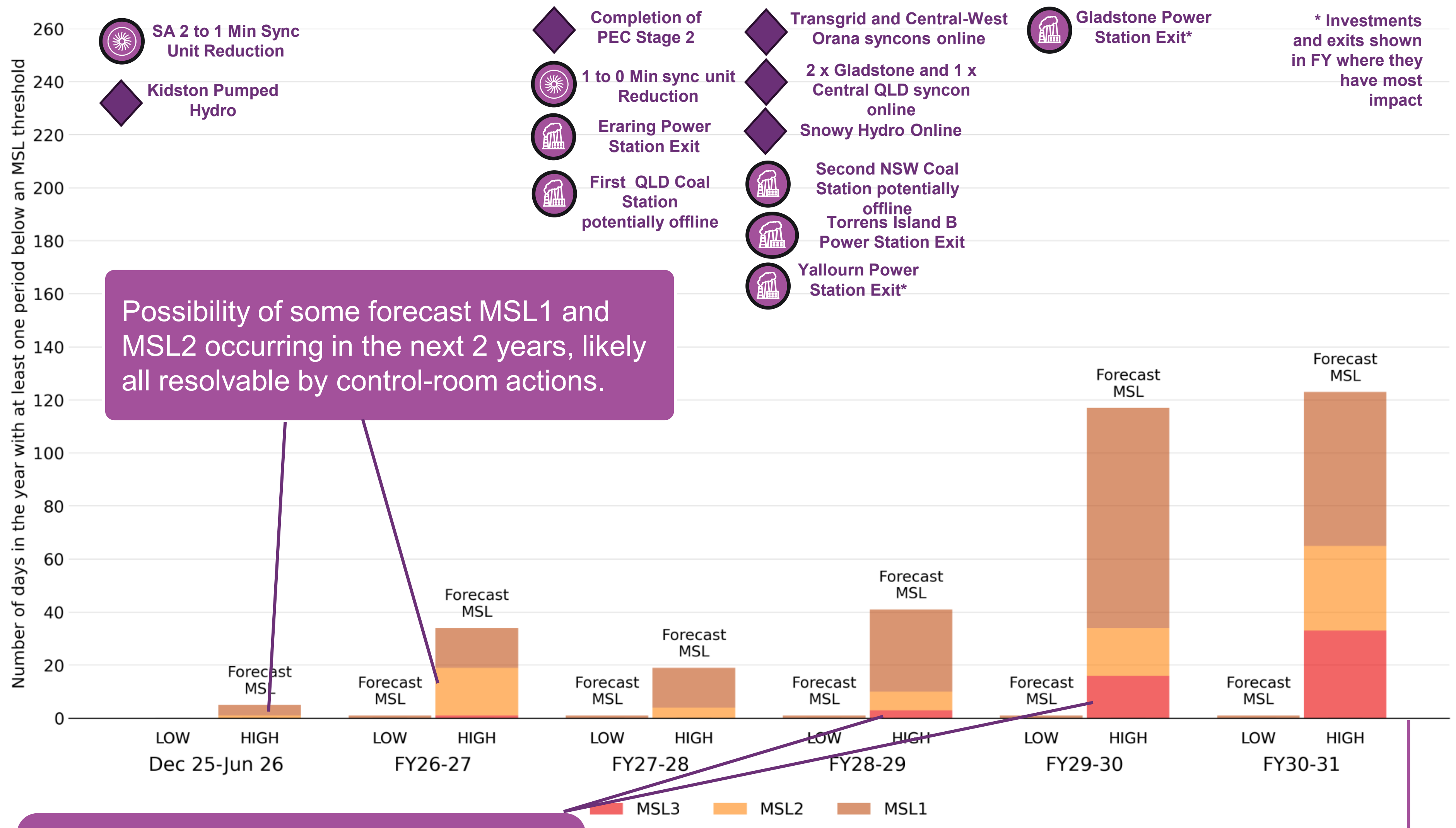
If investment in alternative sources of system services are delayed, requiring thermal units to remain online during MSL periods, the MSL thresholds will be higher due to thermal unit minimum stable operating levels (MSOLs). Then, in typical system normal conditions, an estimated one day of post-action MSL3 events may emerge from 2028-29, increasing to two days from 2029-30. Managing these conditions would require use of NSP MSL3 actions to increase operational demand (such as active management via CSIP-AUS and EVM). Further parallel actions could reduce incidence of MSL events, such as reducing unit MSOLs, or actions to encourage greater responsiveness of customer assets to system conditions.

Projected incidence of MSL events in Queensland under typical system normal conditions

Estimates are for system normal only, and do not account for unplanned outages and extreme conditions which may significantly escalate the incidence and severity of MSL conditions. Present estimates for typical conditions do not account for utility-scale BESS as their typical behaviour across the five-year horizon may vary widely with rapidly increasing numbers of BESS. AEMO is working to incorporate BESS in future analysis, which may result in improvements particularly if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition.

Low scenario: Greater of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the lowest total MSL incidence (forecast), and lowest MSL2+MSL3 incidence (post-action)
High scenario: Lesser of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the highest total MSL incidence (forecast), and highest MSL2+MSL3 incidence (post-action)

NEM-wide transition point actions proceed, lowering MSL thresholds

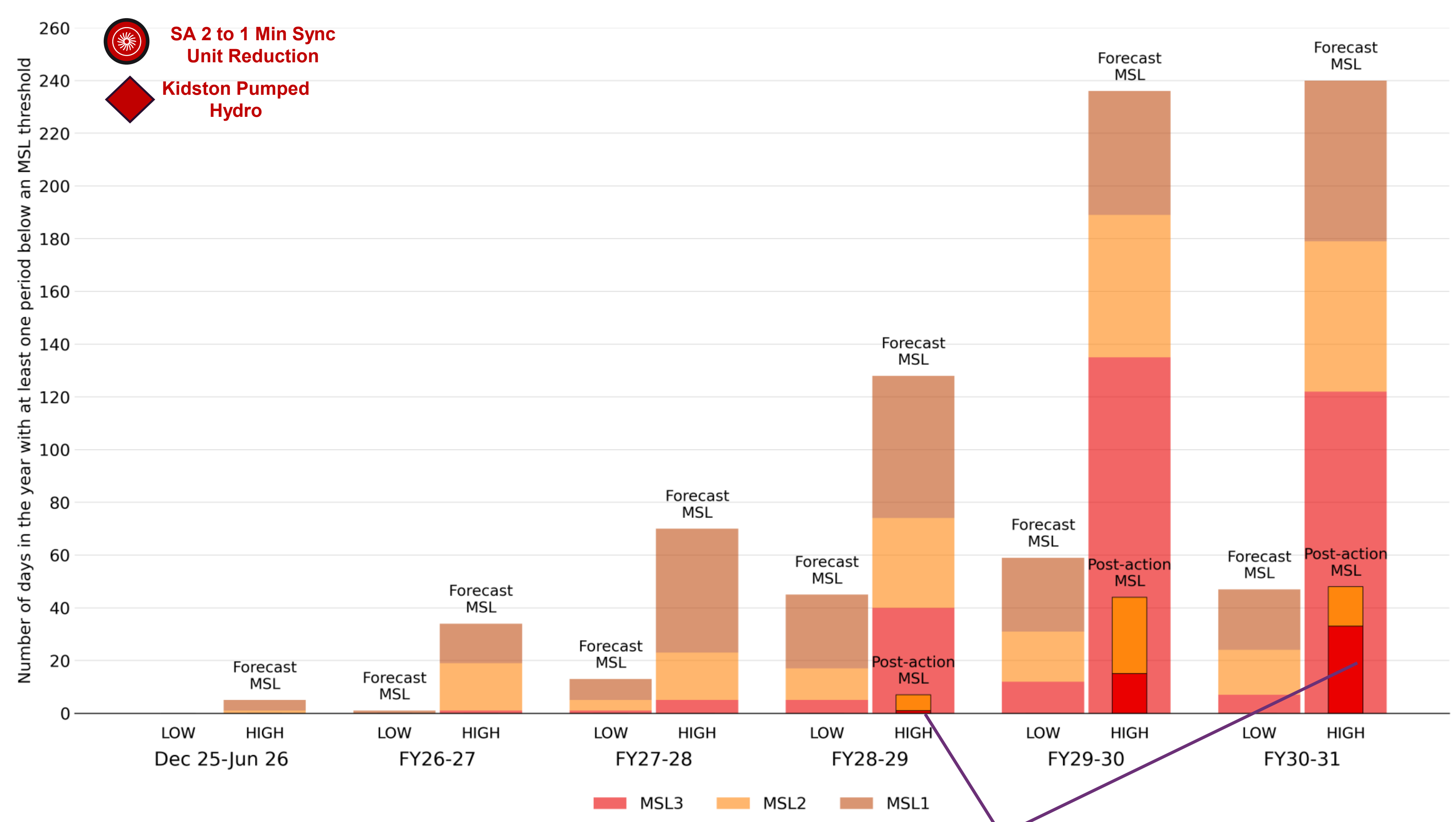


Possibility of some forecast MSL1 and MSL2 occurring in the next 2 years, likely all resolvable by control-room actions.

From 2028-29, forecast MSL3 events in System Normal conditions may occur in up to three days, increasing to 16 days by 2029-30. All forecast MSL3 conditions are projected to be resolvable by control room actions.

If transition point actions proceed as planned, zero actual MSL3 events are projected in Queensland across the five-year horizon.

NEM-wide delays in transition point actions



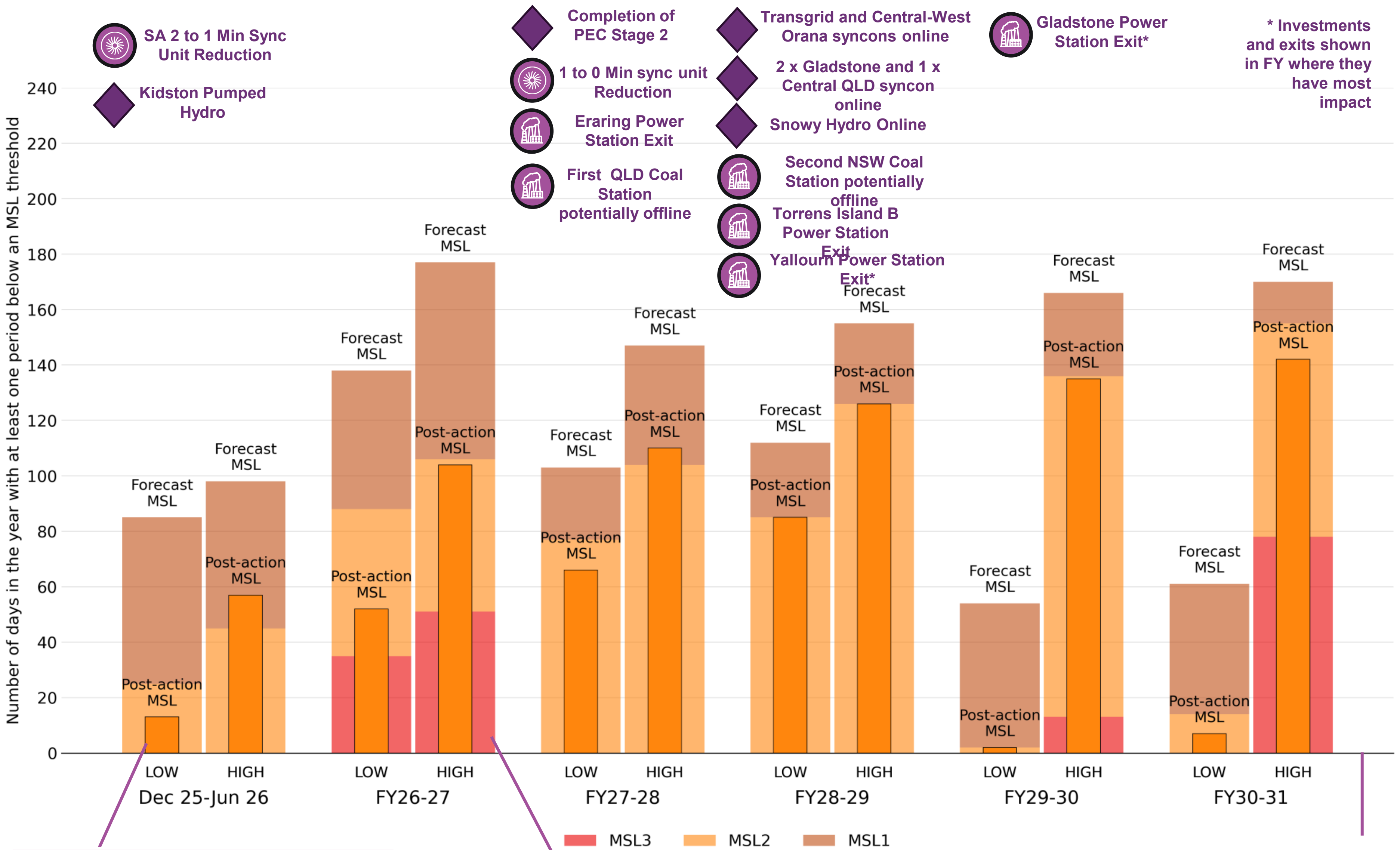
If investment in alternative sources of system services are delayed, requiring thermal units to remain online during MSL periods, the MSL thresholds will be higher due to thermal unit minimum stable operating levels (MSOLs). Then, in typical system normal conditions, post action MSL3 events may start to emerge (in one day) from 2028-29, increasing through the outlook horizon to up to 33 days a year in 2030-31. Managing these conditions would require use of NSP MSL3 actions to increase operational demand. Further parallel actions could reduce incidence of MSL events, such as reducing unit MSOLs, or actions to encourage greater responsiveness of customer assets to system conditions.

Projected incidence of MSL events in South Australia under <u>typical system normal conditions</u>

Estimates are for system normal only, and do not account for unplanned outages and extreme conditions which may significantly escalate the incidence and severity of MSL conditions. Present estimates for typical conditions do not account for utility-scale BESS as their typical behaviour across the five-year horizon may vary widely with rapidly increasing numbers of BESS. AEMO is working to incorporate BESS in future analysis, which may result in improvements particularly if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition.

Low scenario: Greater of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the lowest total MSL incidence (forecast), and lowest MSL2+MSL3 incidence (post-action)
High scenario: Lesser of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the highest total MSL incidence (forecast), and highest MSL2+MSL3 incidence (post-action)

NEM-wide transition point actions proceed, lowering MSL thresholds

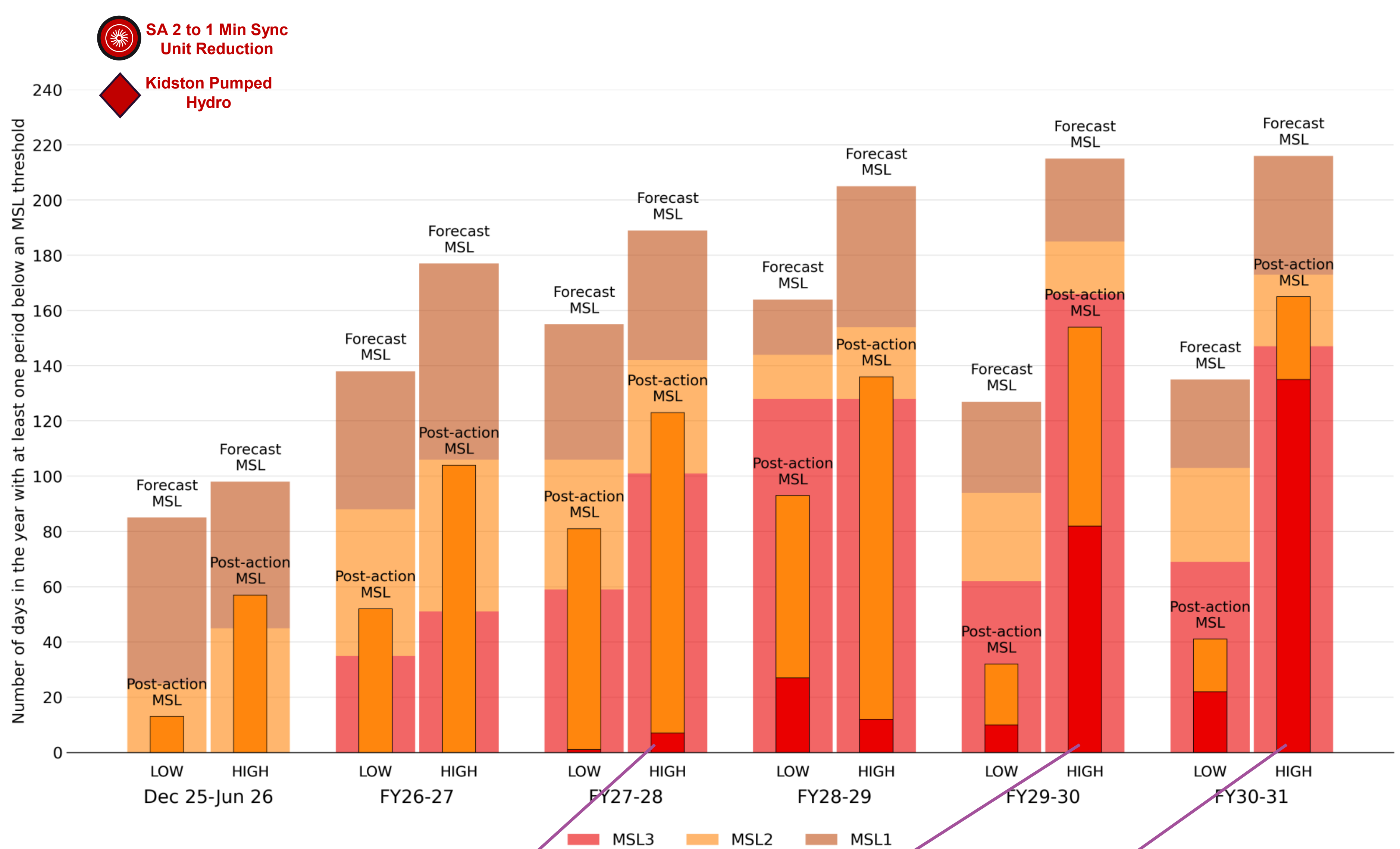


Already projecting forecast and post-action MSL2 in high and low scenarios.

Forecast MSL3 emerge in 2026-27 in up to 51 days, and all are projected to be resolvable via control room actions.

If transition point actions proceed as planned, zero actual MSL3 events are projected in South Australia across the five-year horizon.

NEM-wide delays in transition point actions



If there are delays in NEM-wide investments, ability to export from South Australia would be reduced. Then, in system normal conditions, post action MSL3 events may emerge in up to seven days from 2027-28, increasing to up to 82 days by 2029-30, and 135 days by 2030-31. Managing these conditions would require use of NSP MSL3 actions to increase operational demand (such as active management via CSIP-AUS and EVM). Further parallel actions across the NEM could reduce incidence of MSL events in South Australia, such as investing in alternative sources of system services, reducing unit minimum stable operating levels, or actions to encourage greater responsiveness of customer assets to system conditions.

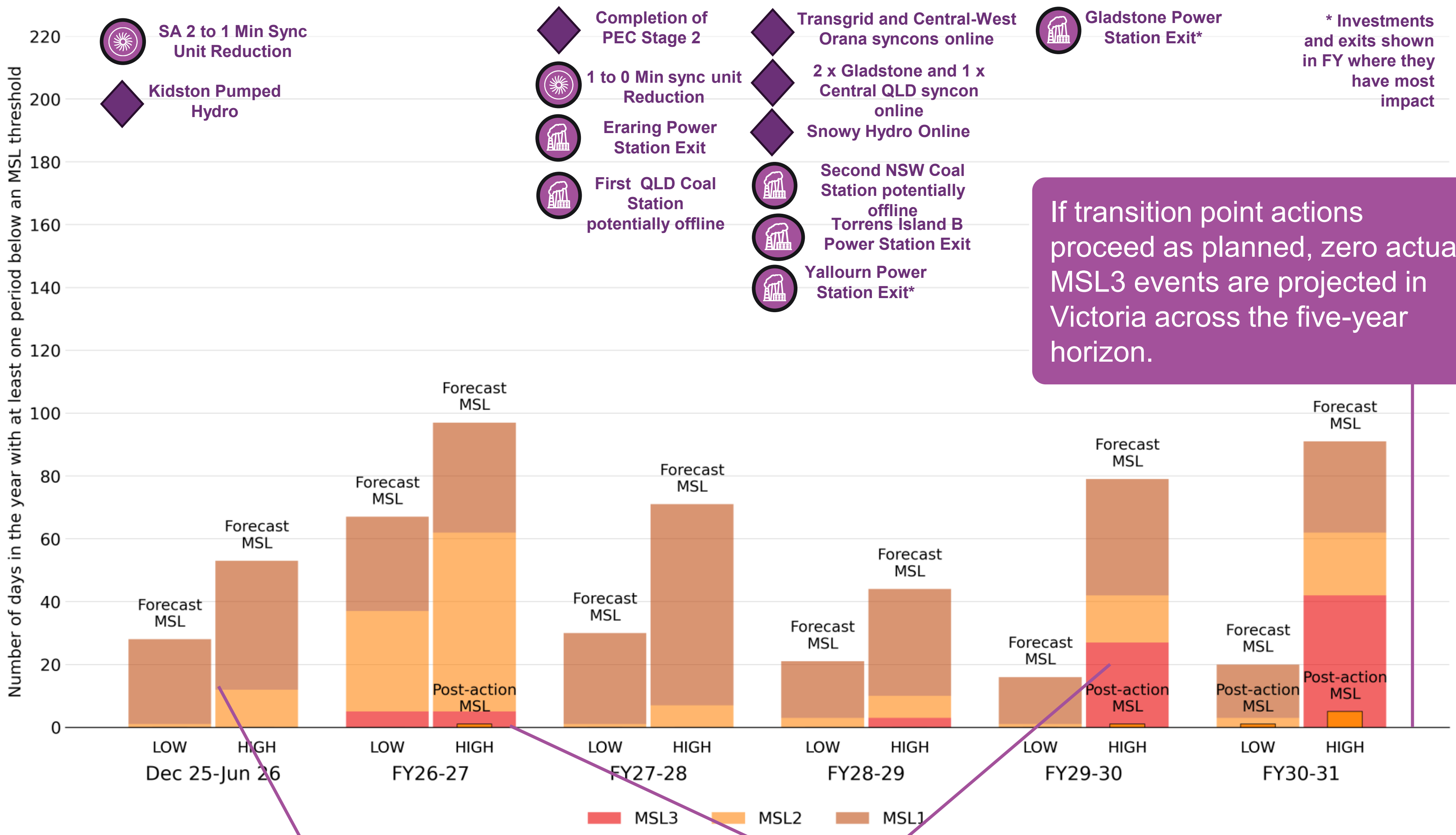
Projected incidence of MSL events in Victoria under typical system normal conditions

Estimates are for system normal only, and do not account for unplanned outages and extreme conditions which may significantly escalate the incidence and severity of MSL conditions. Present estimates for typical conditions do not account for utility-scale BESS as their typical behaviour across the five-year horizon may vary widely with rapidly increasing numbers of BESS. AEMO is working to incorporate BESS in future analysis, which may result in improvements particularly if frameworks and actions are implemented to incentivise BESS to provide firm certainty of energy capacity throughout an MSL condition.

Low scenario: Greater of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the lowest total MSL incidence (forecast), and lowest MSL2+MSL3 incidence (post-action)

High scenario: Lesser of 2025 ESOO *Step Change* and *Slow Change* scenario demand forecast, and reference year which produces the highest total MSL incidence (forecast), and highest MSL2+MSL3 incidence (post-action)

NEM-wide transition point actions proceed, lowering MSL thresholds

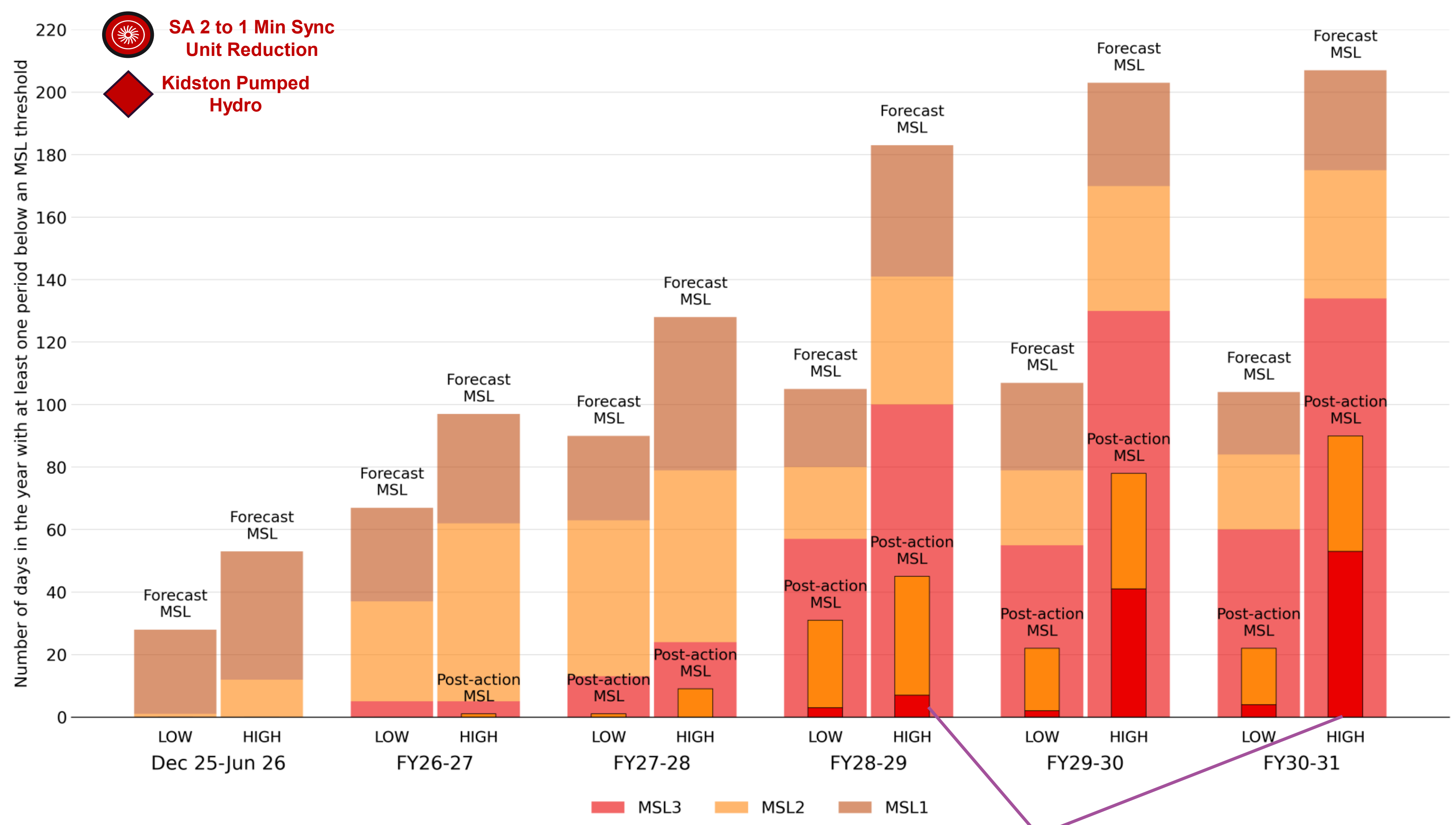


If transition point actions proceed as planned, zero actual MSL3 events are projected in Victoria across the five-year horizon.

Already possibility of forecast MSL1 and MSL2, even in low scenario. Forecast MSL2 may occur in up to 12 days a year from 2025-26, all of which are projected to be resolvable by control room actions.

Forecast MSL3 emerge in 2026-27 in up to five days, increasing to 27-42 days from 2029-30. If transition point actions proceed as planned, all forecast MSL3 over the forecast horizon are projected to be resolvable via control room actions.

NEM-wide delays in transition point actions



If investment in alternative sources of system services are delayed, requiring thermal units to remain online during MSL periods, the MSL thresholds will be higher due to thermal unit minimum stable operating levels (MSOLs). Then, in system normal conditions, up to seven days in 2028-29 could have post-action MSL3. This is projected to increase to up to 53 days a year by 2030-31. Managing these conditions would require use of NSP MSL3 actions to increase operational demand (such as active management via CSIP-AUS and EVM). Further parallel actions could reduce incidence of MSL events, such as reducing unit MSOLs, or actions to encourage greater responsiveness of customer assets to system conditions.