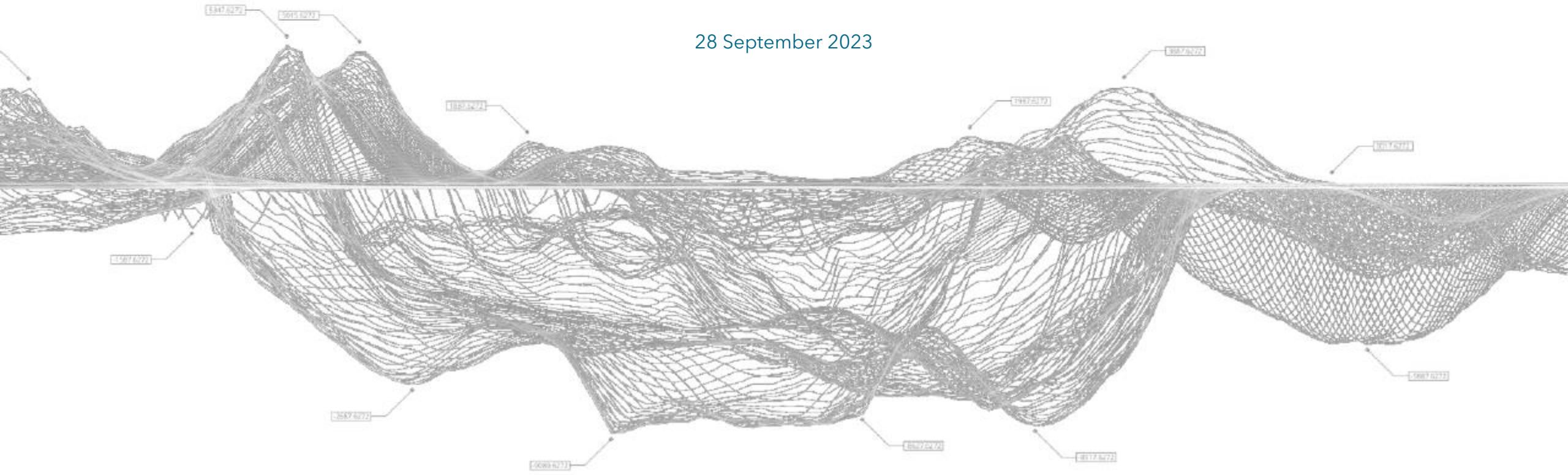
ENDGAME ECONOMICS

Modelling make-whole costs for system strength enablement

Final report for Energy Networks Australia

28 September 2023



Contents

We are seeking to estimate make-whole costs of system strength enablement

Under the system strength framework, a subset of Transmission Network Service Providers (TNSPs) called System Strength Service Providers (SSSPs) are required to procure the minimum and efficient level of system strength (the system strength standard). SSSPs are required to meet this either through investment in network assets (e.g. synchronous condensers) or by contracting with providers of system strength services (e.g. synchronous generators).

If SSSPs contract for system strength services with non-network assets, this can expose SSSPs to volatile contract payments due to volatility in wholesale spot prices. Where SSSP's forecast of contractual payments differ from actual payments this creates a cash flow risk for SSSPs.

In this context, Energy Networks Australia has engaged Endgame Economics to undertake quantitative analysis to estimate the level and variability in cash flows under system strength contracts over time.

The scope of this engagement is limited to estimating variable "make-whole" costs only based on the difference between spot price revenues and the short-run marginal cost of enabled resources. The analysis does not encompass start costs or availability payments. We also do not consider market power or commercial realities which may be important factors in contractual negotiations.

In addition, we are taking the total system strength enablement requirement as given in each financial year based on the difference between the efficient level of system strength and the amount provided by generation in AEMO and Endgame dispatch modelling. In practice, synchronous generators may bid unavailable, particularly during low price periods, which would increase the system strength enablement requirement.

Taking these factors into account, we consider that our estimate of make-whole costs is a conservative estimate of the level and variability of actual costs of system strength enablement.

This report sets out our approach and key findings.

What is the level and variability of make-whole costs of system strength enablement over time?

Modelled wholesale prices suggest that the level and variability of make-whole costs of system strength enablement is increasing over time due to increasing system strength enablement requirement and more frequent low spot prices.

Variability in make-whole costs varies by quantity and price

- We have modelled make-whole costs as the difference between spot price revenue and short-run marginal cost of enabled resources for system strength enablement.
- This is a conservative approach that may understate the level and variability of true costs to a network of contracting with system strength providers.
- In practice, the system strength enablement requirement may change due to: bidding behaviour of synchronous units; availability payments for system strength providers; commercial considerations and potentially market power of system strength providers.
- There are two sources of variation in our modelled make-whole costs:
    1. The quantity of the system strength requirement
    2. The level and volatility in spot prices

1. The quantity of system strength enablement is increasing over time

- The requirement to meet the system strength requirement is increasing over time due to lower generation from synchronous units and an increase in variable renewable energy (VRE) generation.
- The overall system strength enablement requirement to reach the efficient level for QLD, NSW and SA is assumed to be fixed in each financial year. It is calculated as the difference between the efficient level and the level provided by synchronous unit generation in AEMO and Endgame modelling.
- In reality, bidding behaviour from synchronous units may increase the required level of system strength enablement.

2. There is a greater frequency of low and negative prices across the NEM over time

- We modelled 100 simulations of the NEM over the period FY 2026 – 30 across different reference years, demand levels and outage traces.
- Increasing entry of VRE leads to lower spot prices over time. There is a greater frequency and depth of negative spot prices over time.
- Variability is seasonal with a greater proportion of negative prices occurring over shoulder and summer months, driving greater make-whole costs of system strength enablement in these months.

We have modelled make-whole payments as the difference between spot price revenue and the short-run marginal costs of enabled resources

Modelling approach

- Our objective is to estimate the level and variability in make-whole payments for enabled system strength resources.
- Make-whole payments are calculated for the the period FY 2026 – FY 2030. Costs are calculated as the difference between spot price revenue and the short-run marginal cost of enabled resources:

*Make-whole costs[1] = Enabled generation (MWh) * (RRP - SRMC)*

- Enabled generation is determined as the difference between the efficient system strength quantity in each region and the generator dispatch quantity under AEMO (from the 2022 System Strength Report) and Endgame modelling.
- Where spot prices are greater than SRMC the make-whole payment is calculated as zero.
- Wholesale prices are taken from Endgame Economics' wholesale price modelling based on 100 simulations of the system (with different demand, reference year and forced outage traces).
- System strength shortfall is assumed to align with the lowest prices in 4-hour blocks in the region for that financial year. For e.g. if a unit is required for 5% of the year it is assumed to be the lowest 5% of 4-hour price blocks in that region for that year.
- The overall system strength enablement requirement to reach the efficient level for QLD, NSW and SA is assumed to be fixed in each financial year as the difference between the efficient level and the level provided by dispatch in AEMO and Endgame modelling. (i.e. we do not account for strategic behaviour from synchronous generators).
- The results are then aggregated by month and by year for each simulation providing a distribution of modelled costs over time.
- Negative wholesale prices have been calibrated to historical price outcomes to capture dynamics in very low spot price bands (e.g. $-1,000 to $-100/MWh).

[1] *Note that we present make-whole costs as a positive number in our main results to aid interpretation.*

Our modelling assumptions may underestimate true costs

- Estimating make-whole costs necessarily requires a number of simplifying assumptions.
- We set out some key modelling assumptions here noting that they are conservative which likely means that our modelled make-whole cost results are an underestimate of the level and variability of actual system strength contracting costs:

1. We have modelled make-whole costs as the difference between spot price revenues and generator direct costs. This can be thought of as a "make whole payment" – it is what enabled generators would require to break even from being enabled to provide system strength.

2. The total quantity of system strength enablement in each financial year is fixed based on the difference between the efficient level of system strength and the level provided by synchronous resources in AEMO and Endgame modelling. We do not account for behaviour by synchronous resources that results in an increased the system strength requirement (for e.g. by bidding to reduce availability during low price periods).

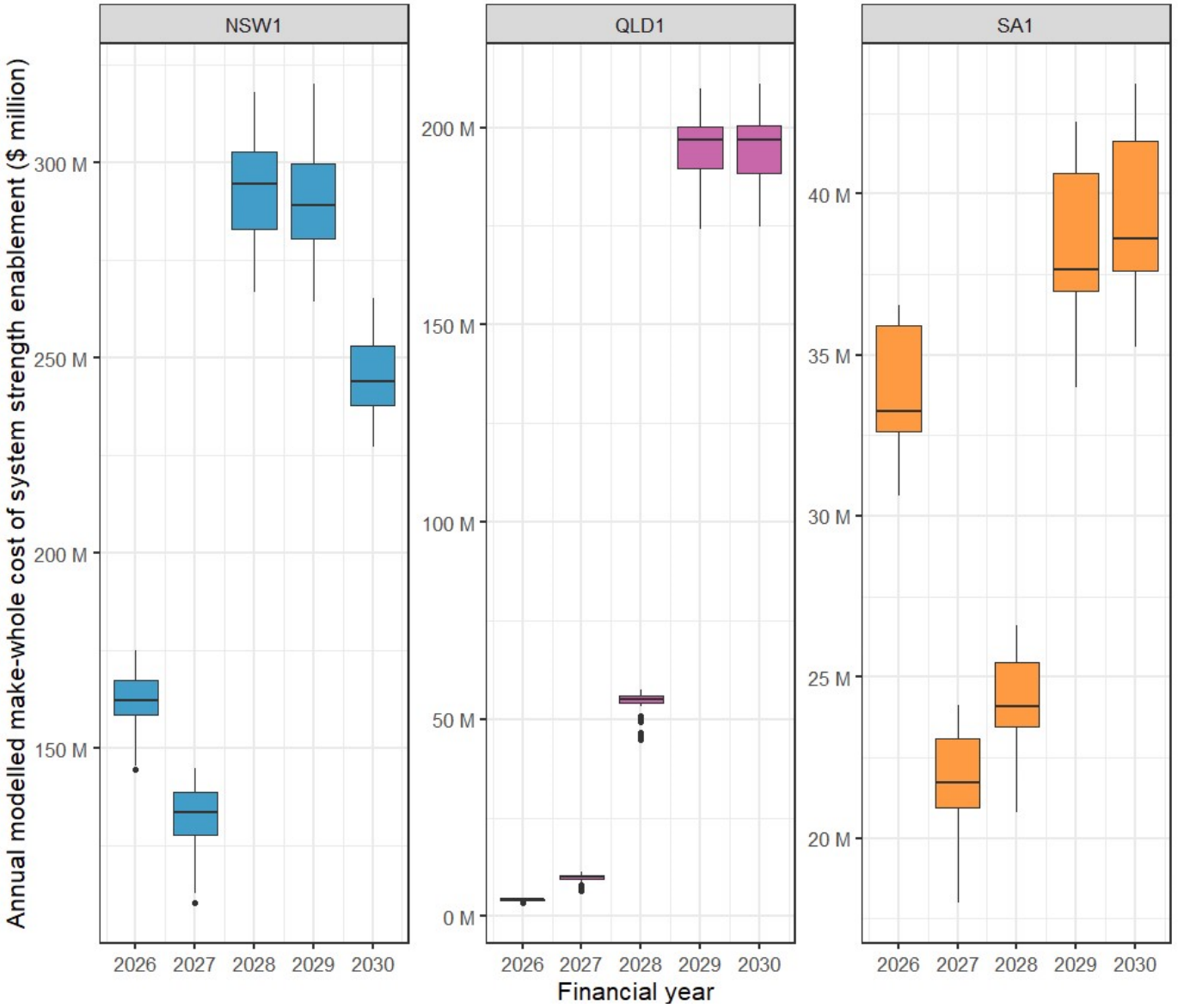
3. Generator direct costs are based on short-run marginal cost. We have not modelled start-up costs as this would introduce significant complexity and uncertainty. Therefore make-whole costs are likely to be a significant underestimate of actual contracting costs for the SSSP. We have also not included any availability payments but this is likely to impact the *level* rather than the variability in contracting costs.

4. We have not attempted to determine actual system strength contract costs which would depend on negotiation between generators and SSSPs. This is important to note as commercial negotiations would likely increase contracting costs. The risk increases later in the modelling period as a significant proportion of available synchronous units are required late in the modelling period.

5. In NSW, based on industry information, we have assumed that a majority of hydro units provide system strength at zero cost by operating as synchronous condensers. This is unlikely in practice as there is a (small) marginal cost of operating in synchronous condenser mode and the operator of these units will require payment to provide this service. From FY 2028 a large number of hydro units are assumed in NSW which raises the potential for the exercise of market power by these operator(s).

The annual results show variability in costs over time

Annual modelled make-whole cost of system strength enablement ($ millions, real 2023)

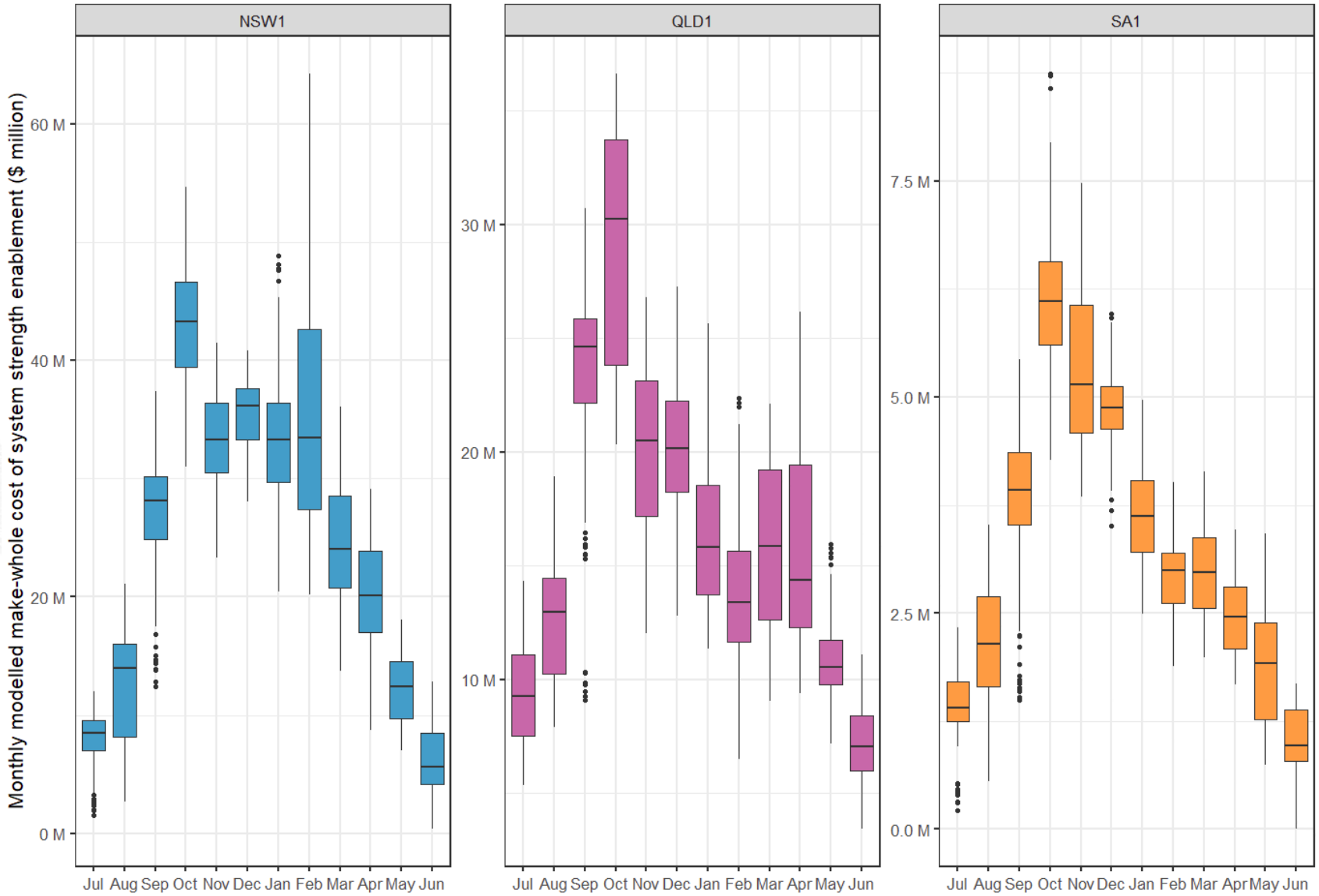


- This chart presents the range of modelled make-whole costs across different simulations by financial year.
- The results show a high degree of variability within and across financial years.
- The difference between years is driven by a combination of increases in the required level of system strength enablement over time and different spot prices.
- The variability *within* years reflects different spot price outcomes under different simulations.
- As we will show in the next slide, the variability at an annual level masks a much greater monthly variability.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

Monthly results show an even greater degree of variability in make-whole costs

Annual modelled make-whole cost of system strength enablement in FY 2029 ($ millions, real 2023)



- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2029.
- The results show a high degree of variability within and across months.
- The variability is driven by different spot price outcomes under different simulations. This changes both the quantity of enablement and the make-whole cost of that enablement within a simulation.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

The annual results show variability in costs over time

QLD modelled make-whole costs ($ millions, real 2023)

Region	FY	Min annual cost	Average annual cost	Max annual cost	St dev annual cost	Range annual cost (max - min)	Range annual cost (% of avg)
QLD1	2026	3.6 m	4.2 m	4.5 m	0.2 m	0.9 m	22.7%
QLD1	2027	6.4 m	9.6 m	11.2 m	1.1 m	4.8 m	49.7%
QLD1	2028	44.9 m	54.0 m	57.5 m	3.4 m	12.6 m	23.4%
QLD1	2029	174.1 m	194.9 m	209.8 m	8.7 m	35.6 m	18.3%
QLD1	2030	174.8 m	194.9 m	210.9 m	8.5 m	36.2 m	18.6%

- The modelled make-whole cost of system strength provision in QLD is generally increasing over time.
- This is due to an increasing requirement for system strength, particularly from FY 2028, and more frequent low and negative prices.
- The range in costs between simulations changes from year to year, creating uncertainty in cash flows.

The annual results show variability in costs over time

NSW modelled make-whole costs ($ millions, real 2023)

Region	FY	Min annual cost	Average annual cost	Max annual cost	St dev annual cost	Range annual cost (max - min)	Range annual cost (% of avg)
NSW1	2026	144.7 m	162.3 m	175.2 m	7.2 m	30.5 m	18.8%
NSW1	2027	110.6 m	132.0 m	145.1 m	8.5 m	34.5 m	26.1%
NSW1	2028	266.8 m	292.9 m	318.0 m	12.3 m	51.2 m	17.5%
NSW1	2029	264.3 m	289.6 m	320.1 m	12.6 m	55.8 m	19.3%
NSW1	2030	227.3 m	245.7 m	265.3 m	9.4 m	38.0 m	15.5%

- The modelled make-whole cost of system strength provision in NSW is generally increasing over time.
- This is due to an increasing requirement for system strength enablement.
- In 2029, the range between the highest and lowest simulation grows to $55.8 million (21% of the average cost).

The annual results show variability in costs over time

SA modelled make-whole costs ($ millions, real 2023)

Region	FY	Min annual cost	Average annual cost	Max annual cost	St dev annual cost	Range annual cost (max - min)	Range annual cost (% of avg)
SA1	2026	30.6 m	33.9 m	36.5 m	1.8 m	5.9 m	17.5%
SA1	2027	18.0 m	21.7 m	24.1 m	1.6 m	6.1 m	28.2%
SA1	2028	20.8 m	24.2 m	26.6 m	1.5 m	5.8 m	23.9%
SA1	2029	34.0 m	38.4 m	42.2 m	2.3 m	8.2 m	21.5%
SA1	2030	35.3 m	39.4 m	43.4 m	2.3 m	8.1 m	20.6%

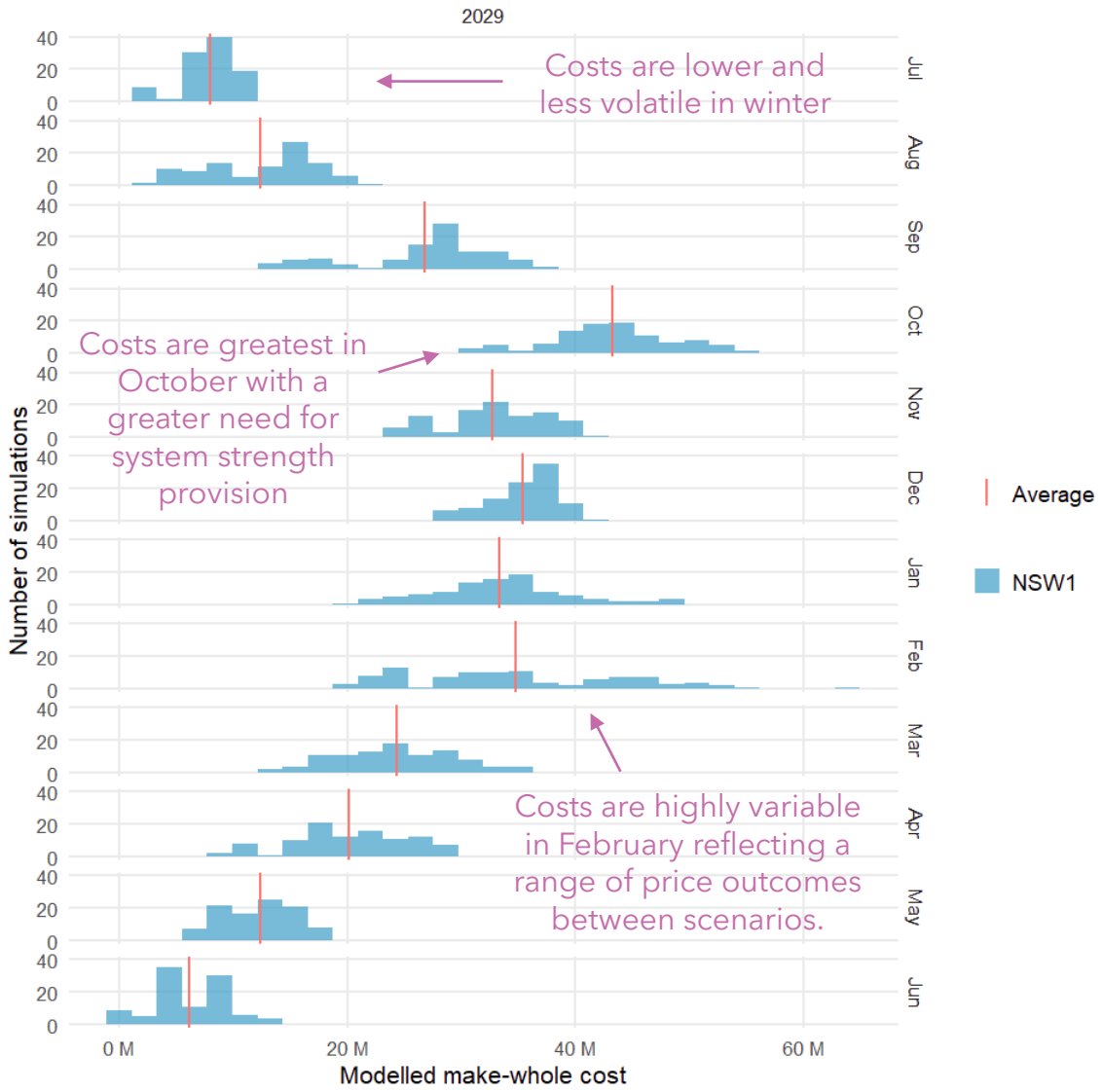
- The modelled make-whole cost of system strength provision in SA is increasing over time.
- This is due to the increasing system strength enablement between FY 2028 and FY 2029 and the increased frequency of low and negative prices.

Monthly results show a greater degree of variability in make-whole costs

- The annual results mask a greater degree of variability within individual months.
- In the following slides we show the distribution of monthly make-whole costs for 100 price simulations across all financial years (FY 2026 – FY 2030).
- These charts show that the level and variability of charges is increasing over time.
- There is also a significant seasonal element. Costs are lowest in winter and highest in spring (usually October).
- This seasonality may pose cash flow risks for networks that contract with non-network system strength providers as the recovery of revenue through transmission prices tends to be evenly spread over the financial year.

Introduction to main results – modelled make-whole costs of system strength provision

NSW modelled make-whole costs in FY 2029 ($ millions, real 2023)



We introduce our main results with an example of NSW for a single modelled year, FY 2029.

This chart shows the distribution of modelled make-whole costs of system strength provision from 100 simulations of prices in NSW in FY 2029.

Modelled make-whole costs are lower and less variable in winter. Modelled make-whole costs are higher and more variable in summer and spring when VRE output is higher, increasing the need for system strength provision.

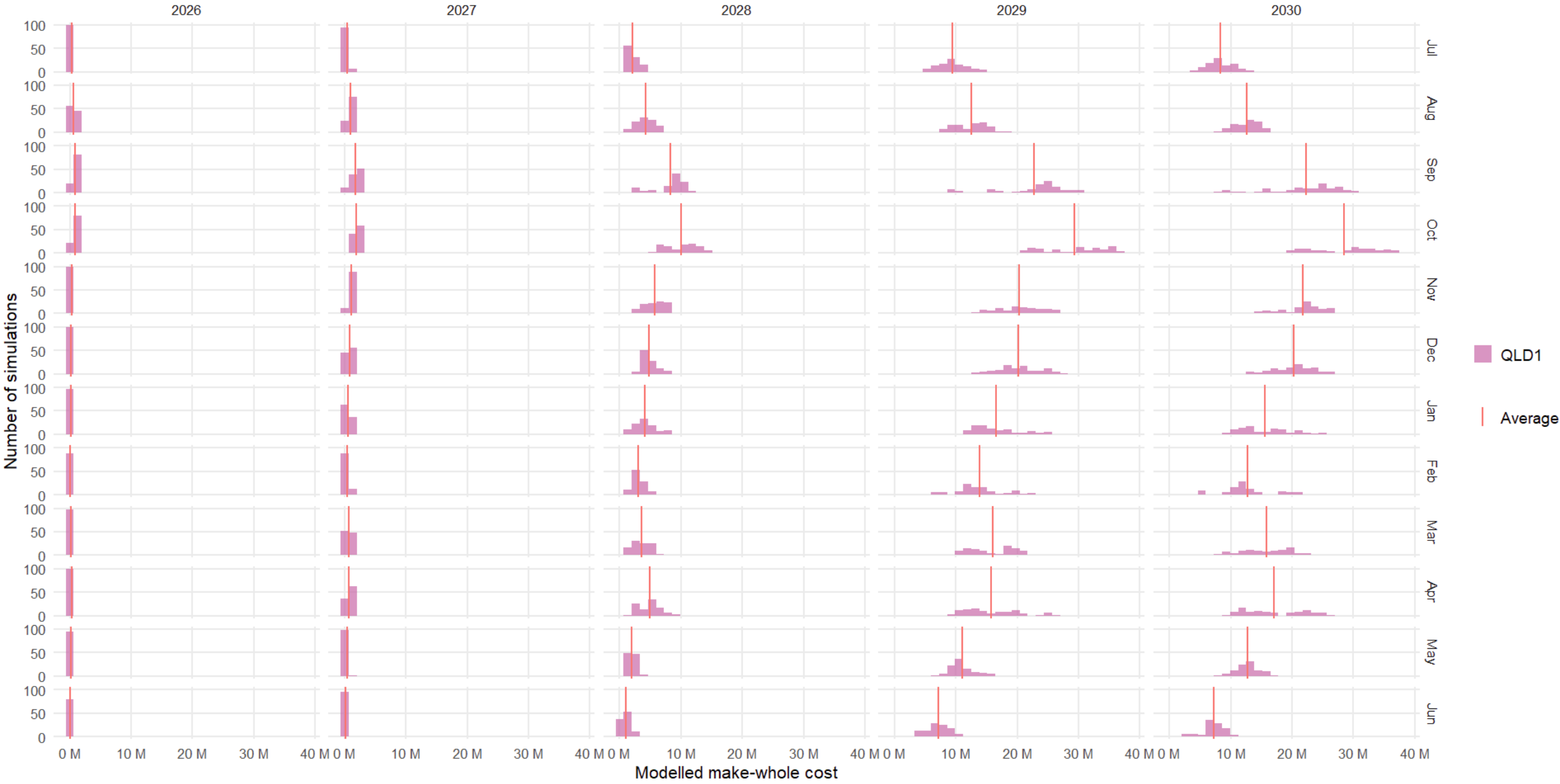
There are two sources of variability in modelled make-whole costs:

1. Spot price revenue
2. Resource run costs (proxied by SRMC)

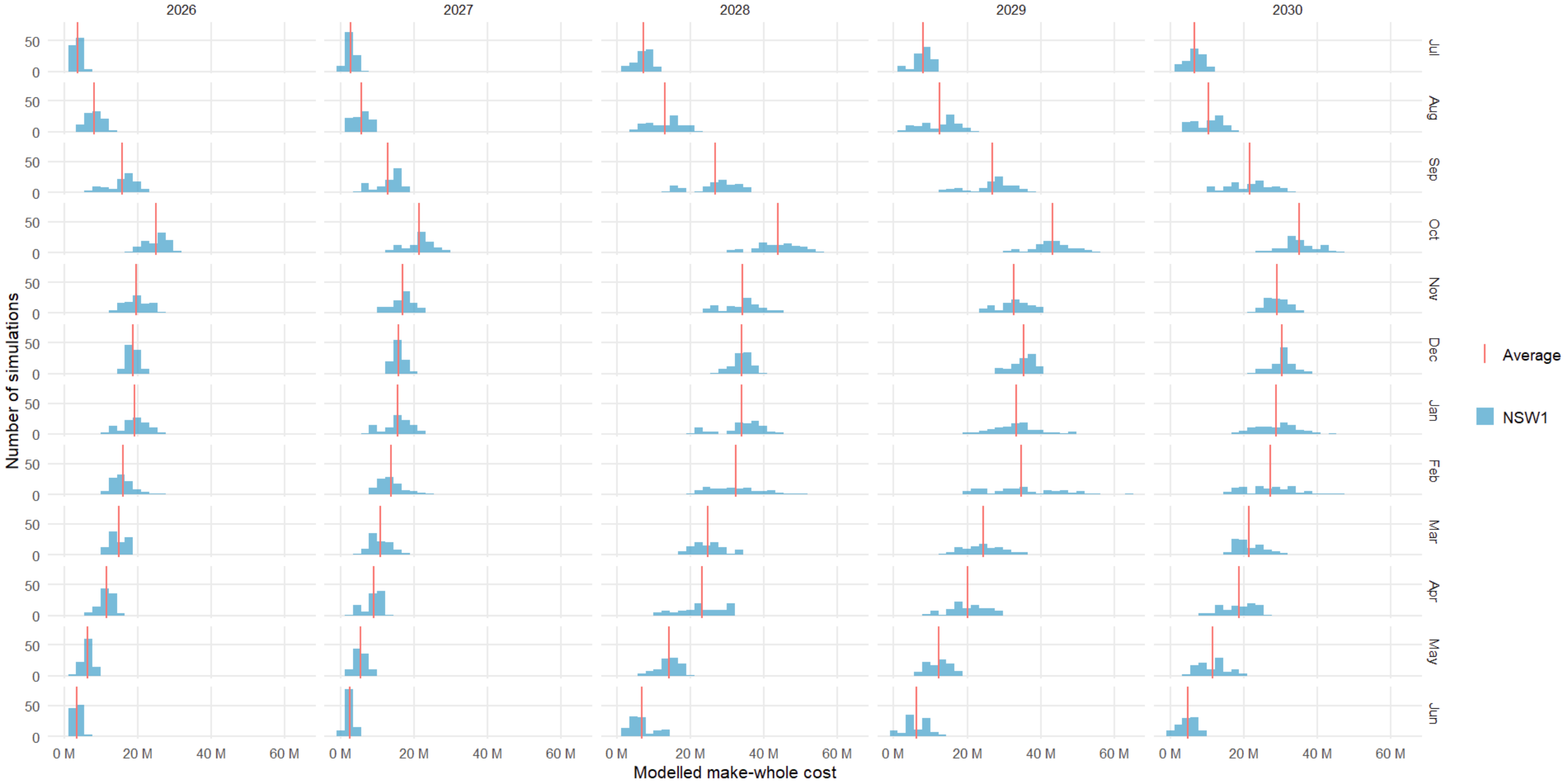
Resource run costs account for the greater share of variability in modelled cost. In the appendix, we decompose the modelled costs into the two sources of variability.

In the following slides we present the modelled make-whole cost results for QLD, NSW and SA across FY 2026 – 2030.

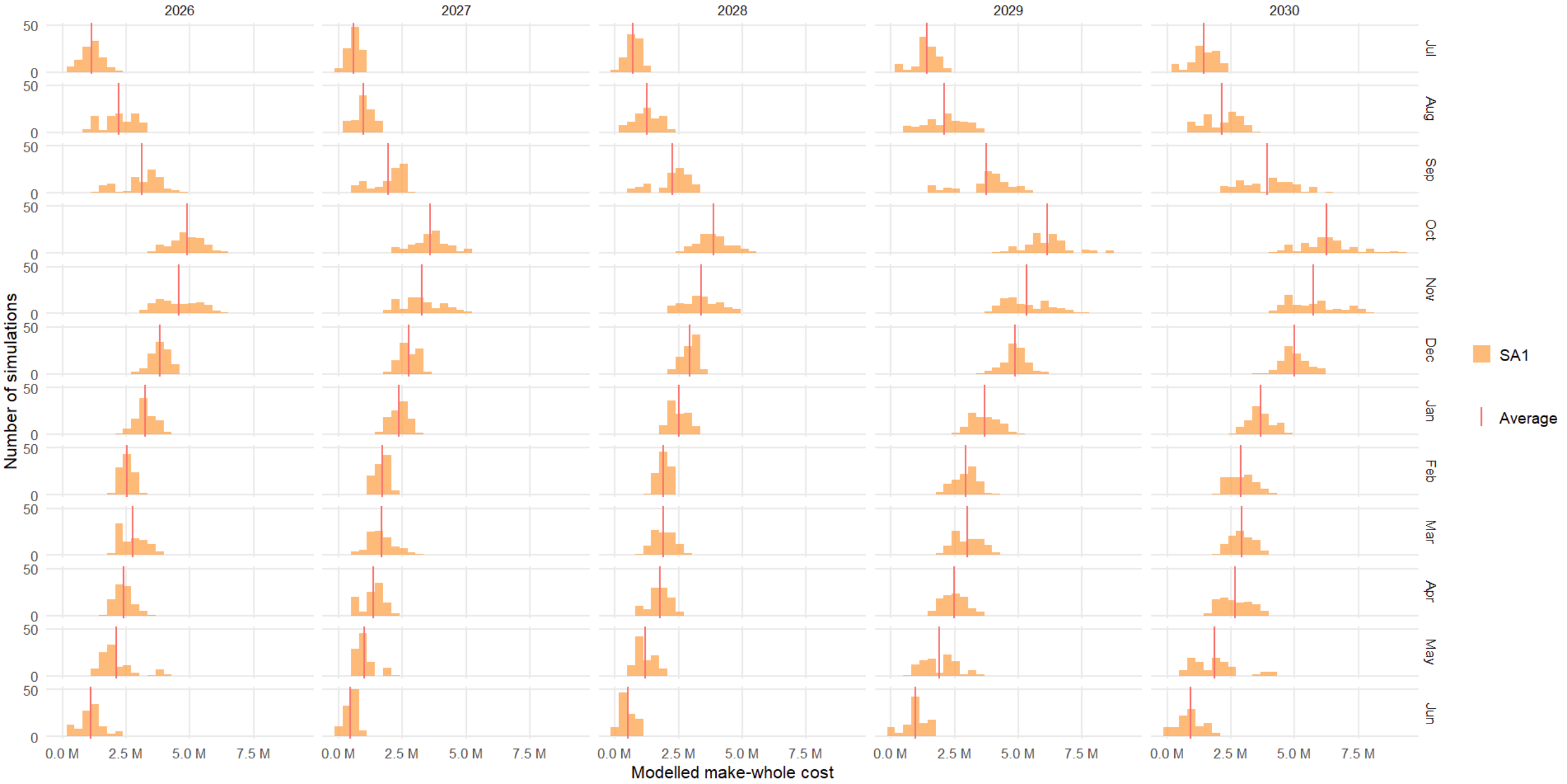
Distribution of monthly modelled make-whole costs by financial year (QLD)



Distribution of monthly modelled make-whole costs by financial year (NSW)



Distribution of monthly modelled make-whole costs by financial year (SA)



There are two sources of variability in make-whole payments

- There are two sources of variability in estimated make-whole payments for system strength enablement:

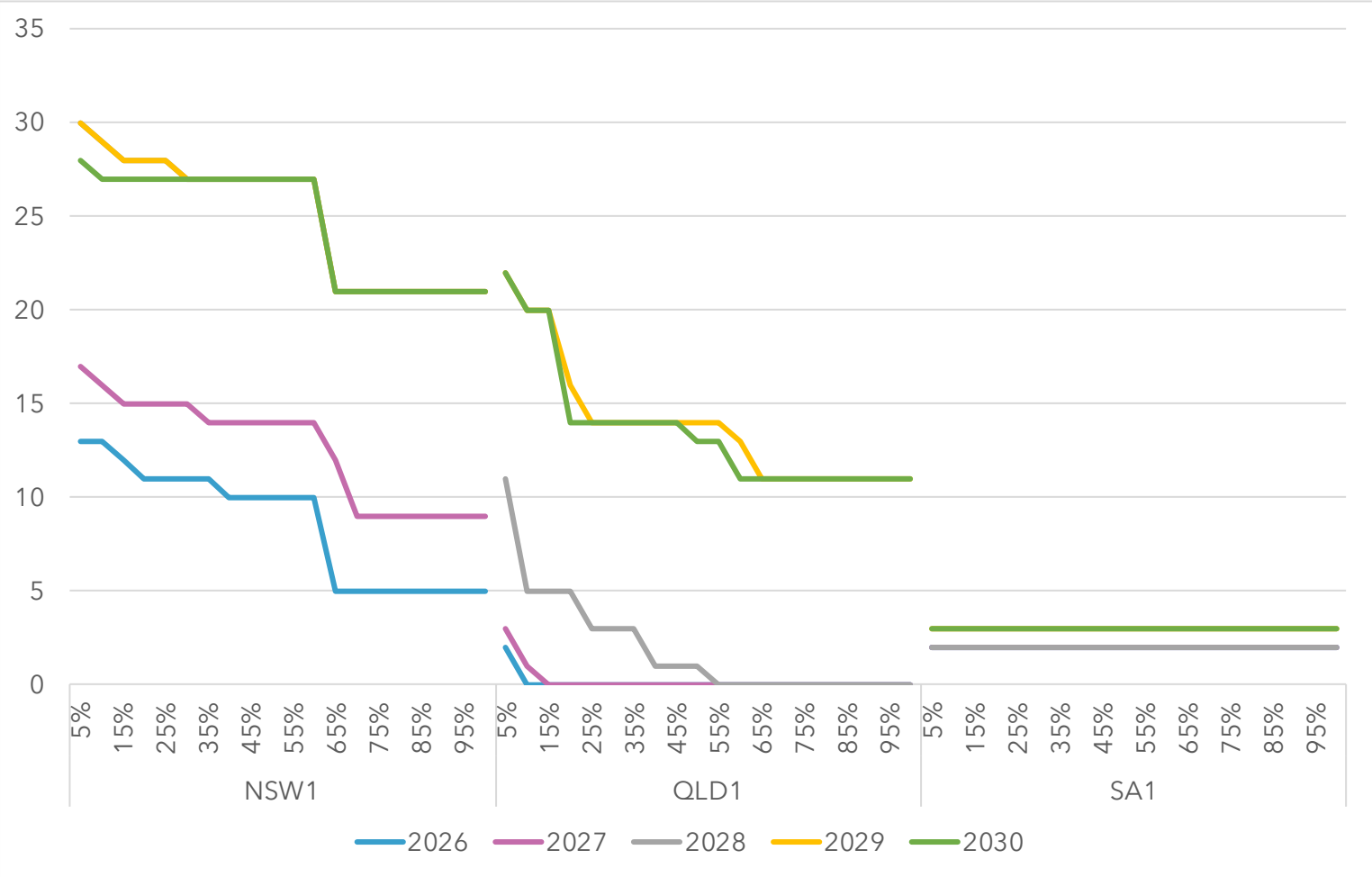
    1. An increasing system strength requirement

    2. More frequent low (and often negative) spot prices

- The following slides illustrate these two sources of variability and the appendix includes a decomposition of the modelled make-whole payments into spot revenue and enabled resource run costs.

Required system strength enablement is one source of variation in make-whole costs over time

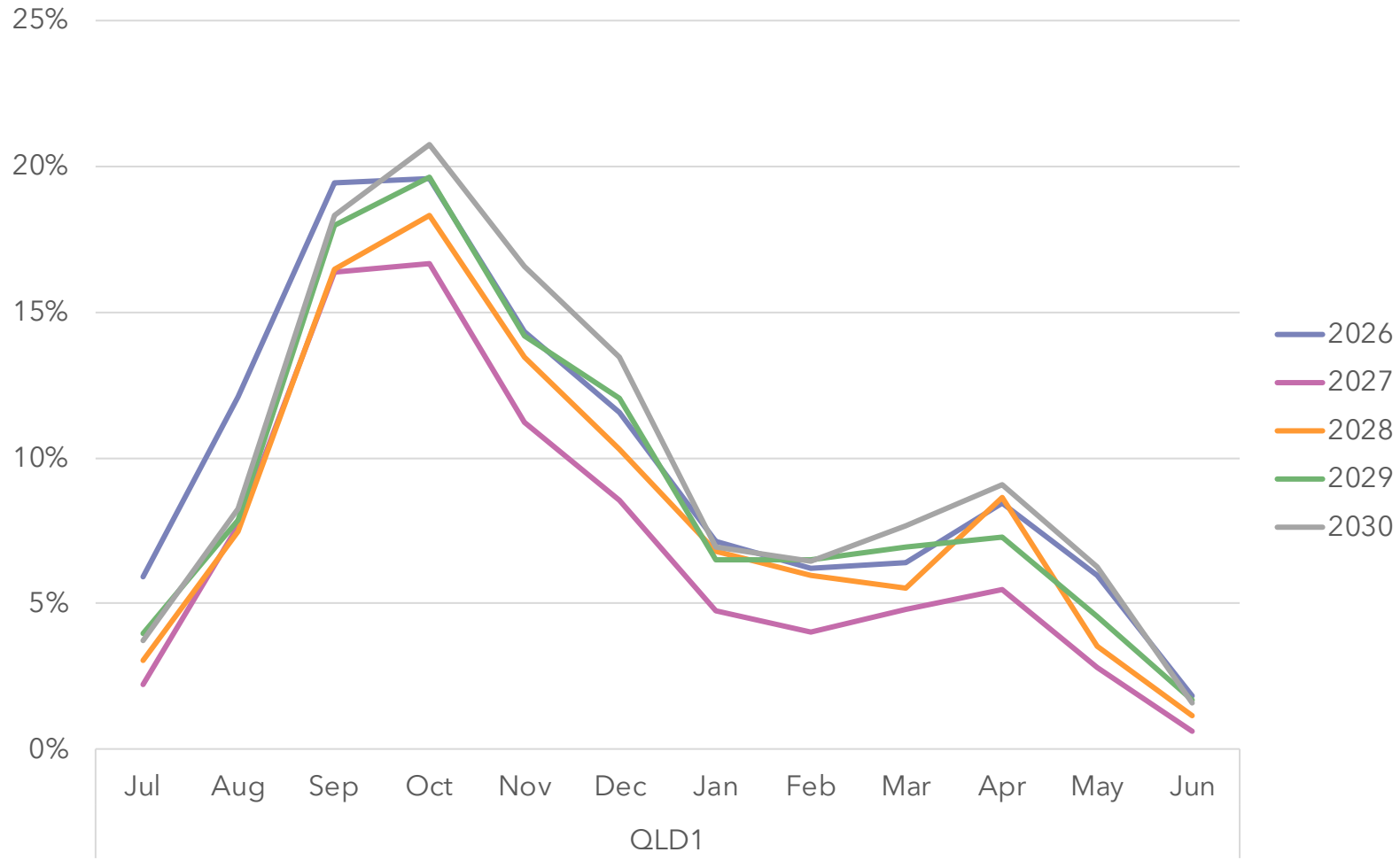
Number of required synchronous units by percentage of the financial year



- This chart shows the required number of synchronous units required to meet the efficient system strength level by percentage of year.
- For e.g. in NSW in FY 2026 13 units are required to be enabled 5% of the time and 5 units are required to be enabled 95% of the time
- Units are assumed to run at minimum generation.
- The mix of units varies by region:
  - QLD – units include coal and gas units
  - NSW – units include coal, gas and hydro units
  - SA – units include gas units only

Price is the other source of variation in make-whole costs

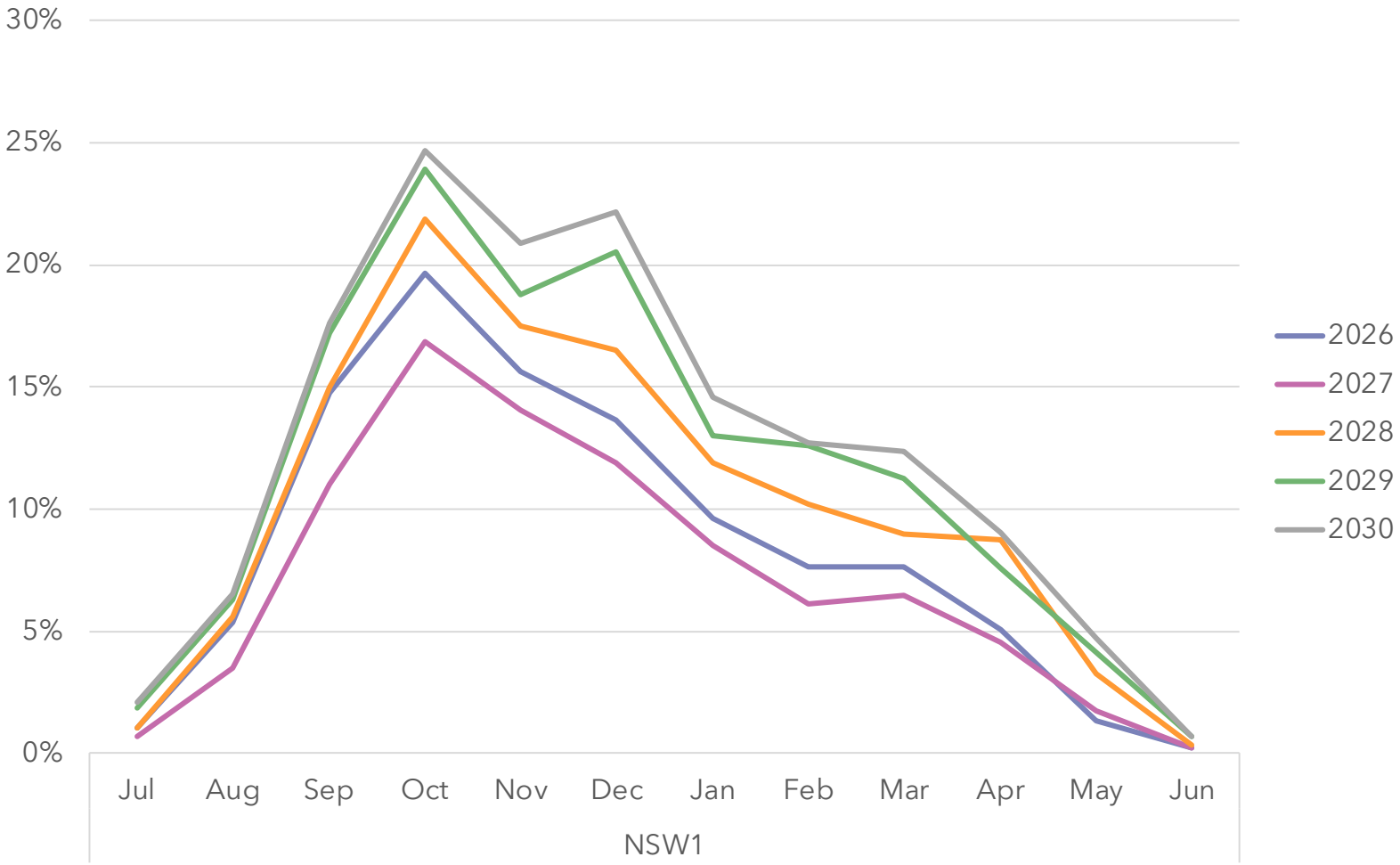
Percentage of negative prices by month in QLD



- The frequency of negative prices hits a minimum in winter when solar output is low.
- Negative price percentage peaks in spring with high VRE output and moderate demand.
- Note that this chart aggregates over 100 simulations in each financial year. The actual frequency and occurrence of negative prices varies across simulations.

Price is the other source of variation in make-whole costs

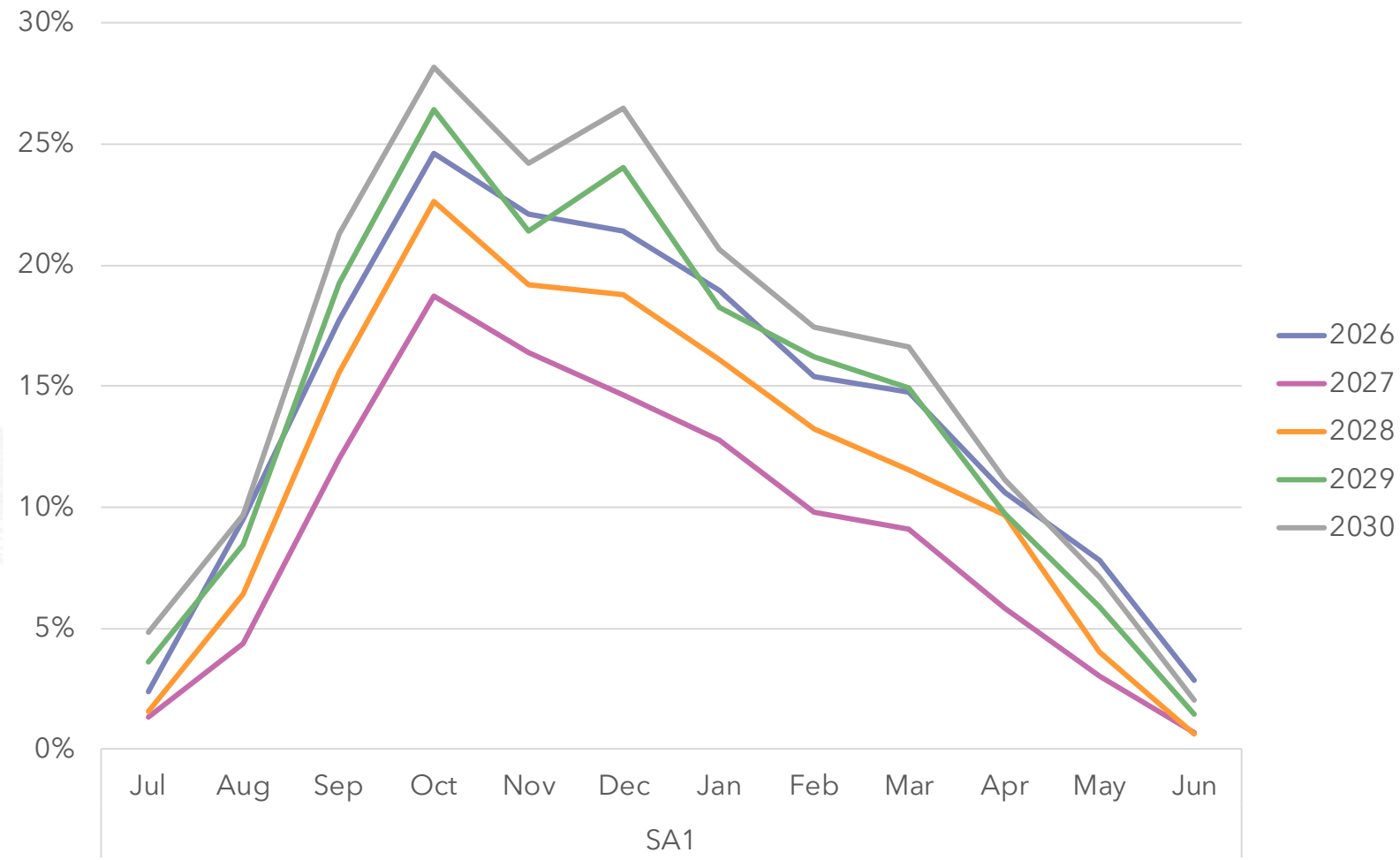
Percentage of negative prices by month in NSW



- The frequency of negative prices hits a minimum in winter when solar output is low.
- Negative price percentage peaks in October with high VRE output and moderate demand.
- The proportion of negative prices generally increases over time as more VRE generation enters the system.

Price is the other source of variation in make-whole costs

Percentage of negative prices by month in SA



- The frequency of negative prices hits a minimum in winter when solar output is low.
- Negative price percentage peaks in October with high VRE output and moderate demand.

The average price earned by enabled resources provides insight into the dynamics

Volume-weighted average price earned by enabled resources ($/MWh)

Region	FY	VWAP earned by enabled resources ($/MWh)
QLD1	2026	-35.85
QLD1	2027	-20.15
QLD1	2028	-5.82
QLD1	2029	21.64
QLD1	2030	21.12
NSW1	2026	23.08
NSW1	2027	29.50
NSW1	2028	31.40
NSW1	2029	26.59
NSW1	2030	29.86
SA1	2026	10.69
SA1	2027	4.30
SA1	2028	8.55
SA1	2029	7.67
SA1	2030	5.20

- Make-whole costs are estimated as the difference between spot revenue and short-run marginal cost of enabled resources.
- This table shows the volume-weighted average price (VWAP) earned by enabled resources across all simulations by financial year.
- There are two offsetting effects:
    1. The number of low and negative prices over time tends to increase with increasing penetration of VRE.
    2. A greater system strength requirement over time tends to increase the average price earned by enabled resources.
- In QLD, effect (2) tends to dominate due to a significant increase in the required system strength enablement after FY 2027.
- In NSW and SA the two effects are largely offsetting one another, i.e. increased occurrence of low and negative prices is offset by increasing system strength enablement.

Conclusion: modelled make-whole payments for system strength enablement are volatile

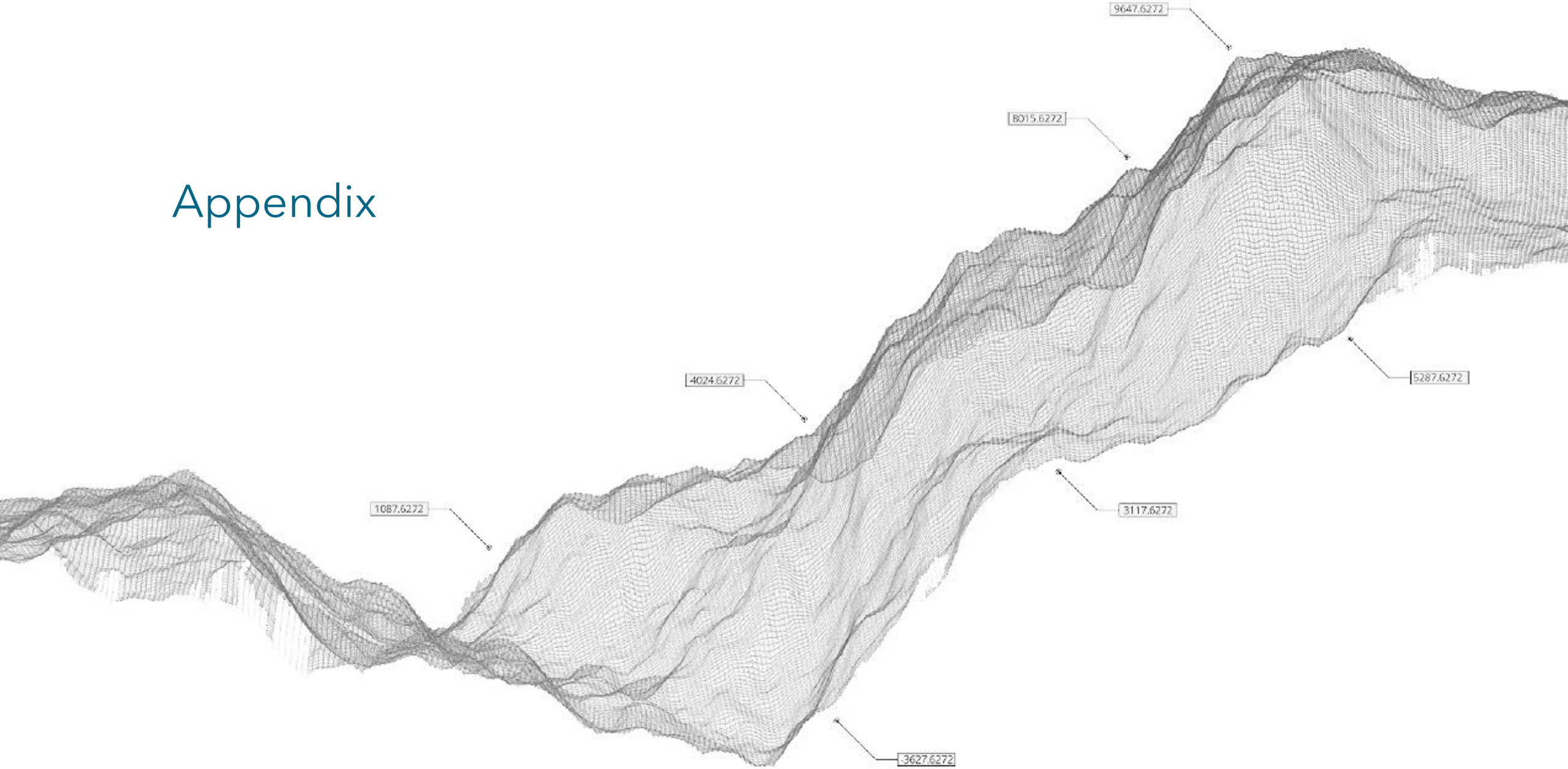
- The level and variability in modelled make-whole costs for system strength providers is increasing over time.

- This is due to two sources of variation:
  - An increasing system strength requirement as VRE generation increases and synchronous generation decreases
  - More frequent low (and often negative) spot prices

- The results suggest that if SSSPs were to contract with non-network system strength providers they may be exposed to cash flow risk.

- We have adopted a conservative approach that may understate the true cash flow variability that SSSPs may be exposed to. In practice, economic behaviour by participants may increases the system strength enablement requirement. In addition, availability payments, commercial negotiations and the potential for market power by system strength providers may increase the level and/or variability of costs.

Appendix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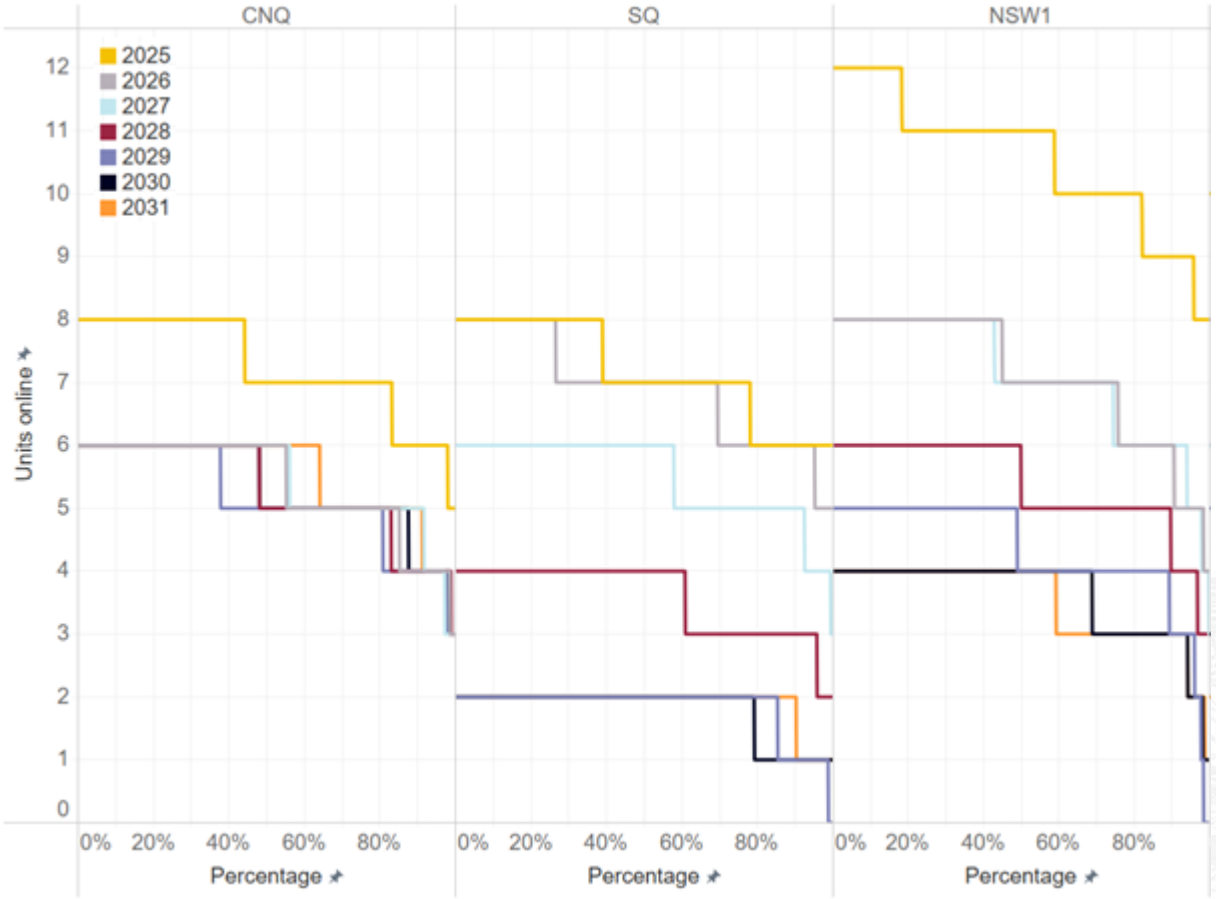
1087.6272
3117.6272
3627.6272

Quantity of system strength enablement based on dispatch

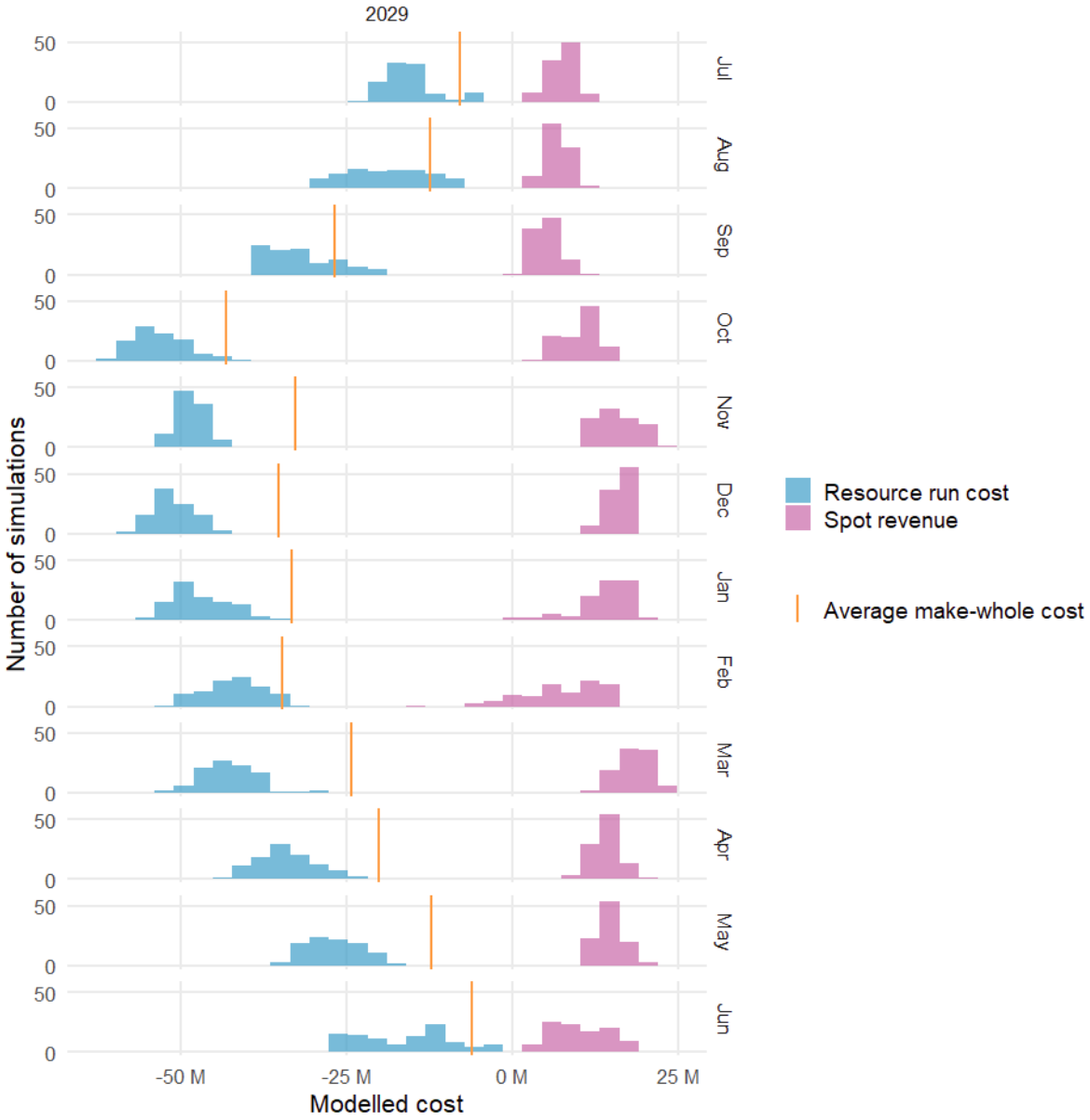
Coal unit duration curves



- The quantity of system strength enablement for each region and financial year is based on the difference between the efficient level and the level of generation from a subset of synchronous units.
- For this purpose we use generation duration curves by financial year from:
  - AEMO 2022 System Strength Report until FY 2028
  - Endgame modelling from FY 2029
- The coal generation duration curve decreases over time.
- This requires increasing enablement for system strength.
- In Queensland this leads to an increasing number of coal and gas units being enabled a greater proportion of the time.
- In NSW it relies on a combination of coal, gas and hydro units being enabled.
- Gas units are assumed in SA.

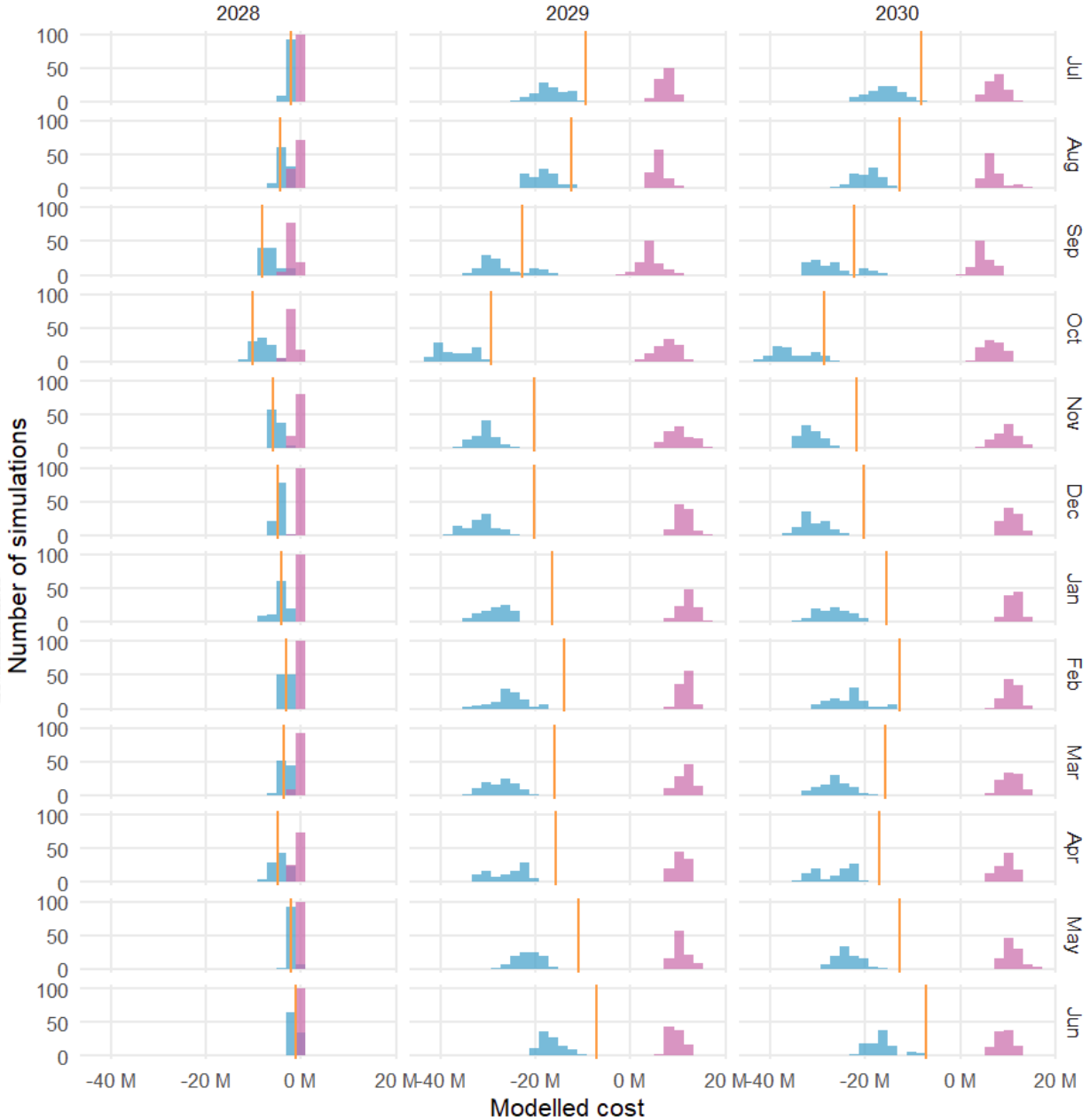
Modelled make-whole costs can be decomposed into spot revenues and resource direct costs

NSW monthly spot revenue and resource run costs (FY 2029)



- The modelled costs for each simulation can be broken down into spot revenue and resource direct costs (proxied by SRMC from the 2023 IASR).
- To clearly illustrate the relationship between the components we have presented costs in net revenue terms i.e. the orange vertical line is presented as the **negative** of the average net modelled make-whole cost presented in the main results.
- The results show that resource run costs are the greater source of variation in net modelled costs. This reflects that the SRMC of enabled resources is generally higher (in absolute terms) than the spot prices earned by these resources during enablement.
- Prices will generally be low (often negative) during periods when system strength enablement is required.

Distribution of spot revenue and resource run costs (QLD)



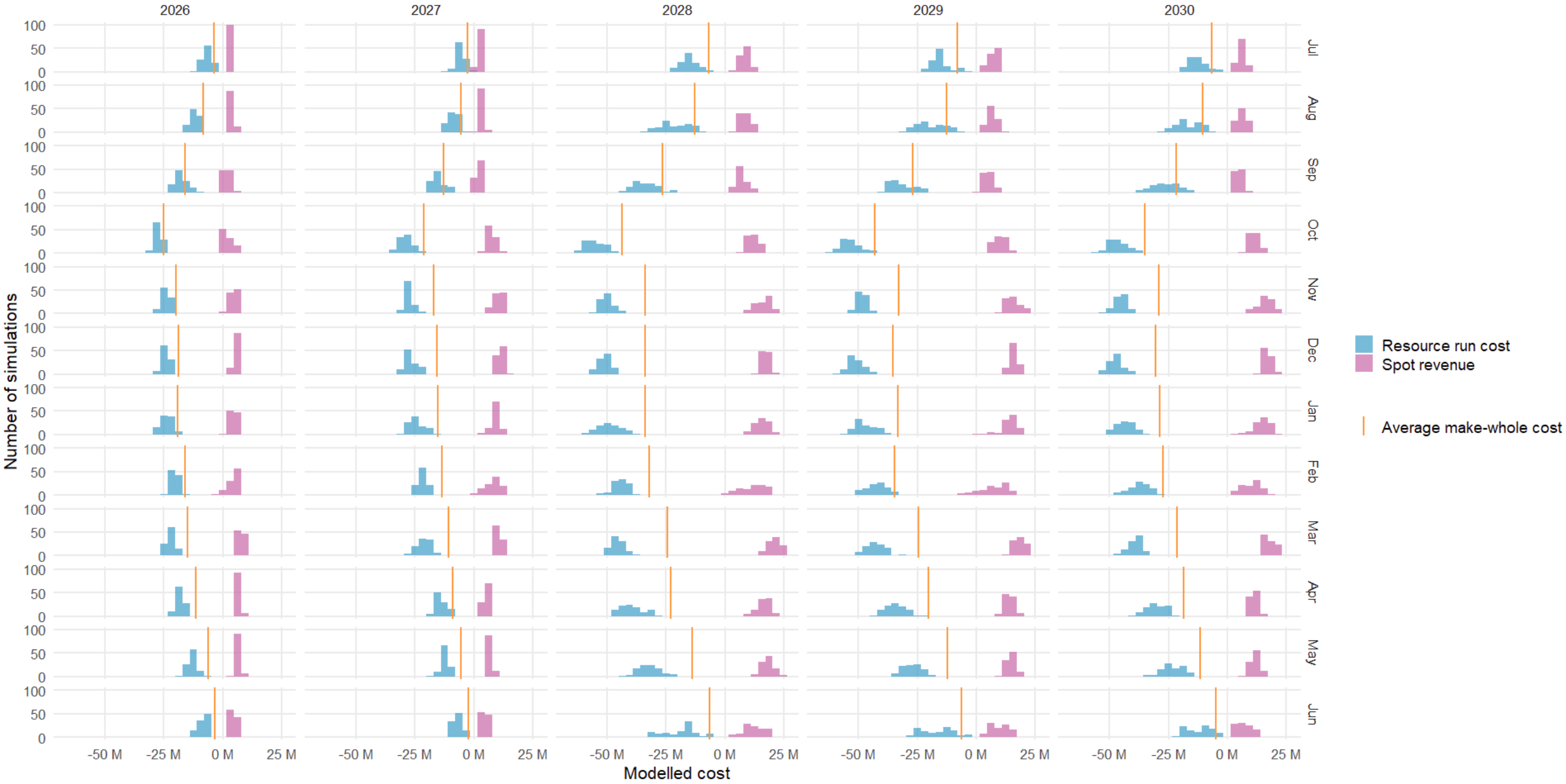
Resource run cost
Spot revenue

Average make-whole cost

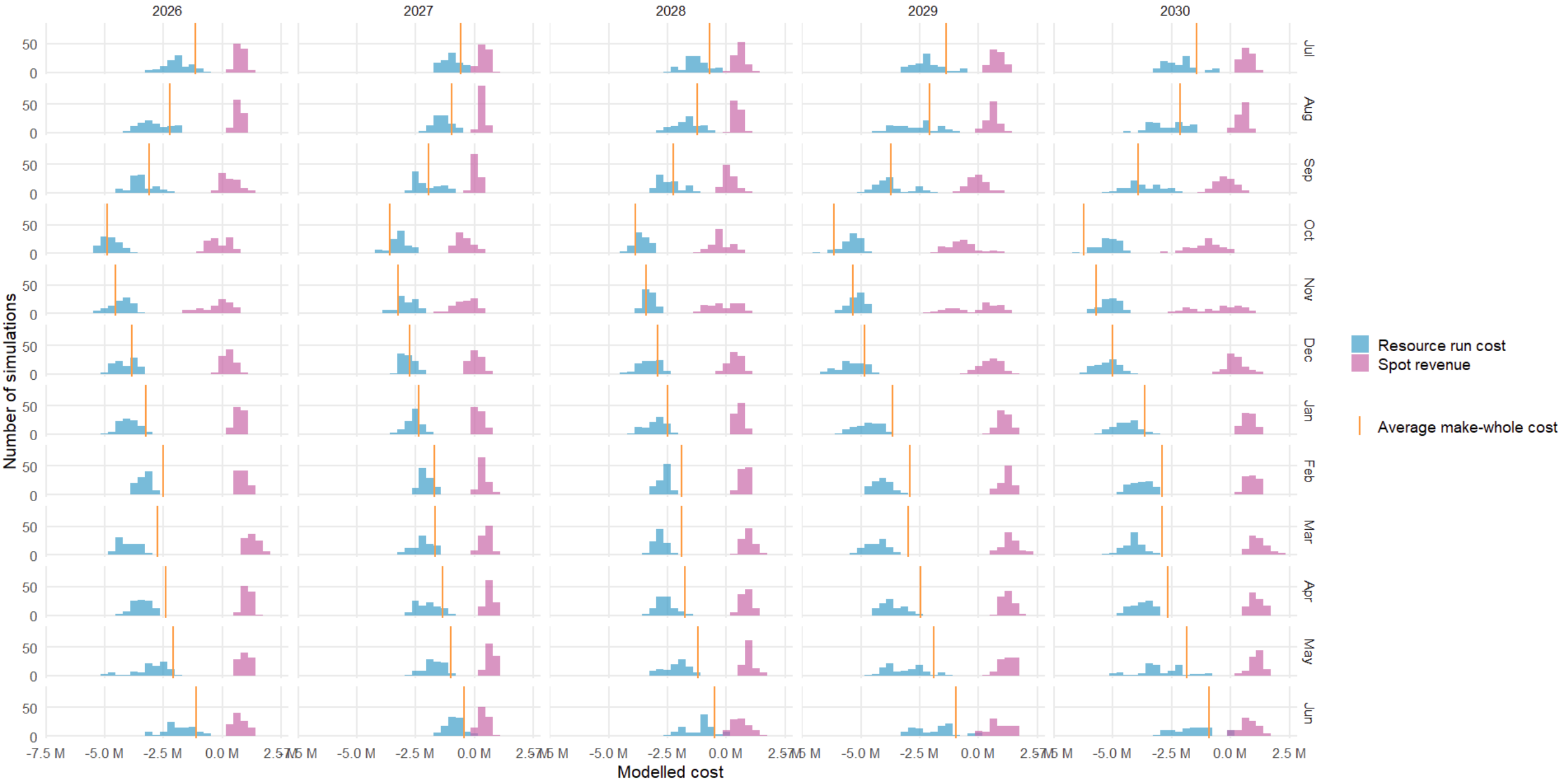
- The results show that resource run costs are a greater source of variability than spot revenues.
- These results are consistent across time and across regions.

Note: FY 2026 and 2027 omitted from QLD due to relatively low variation in costs.

Distribution of spot revenue and resource run costs (NSW)

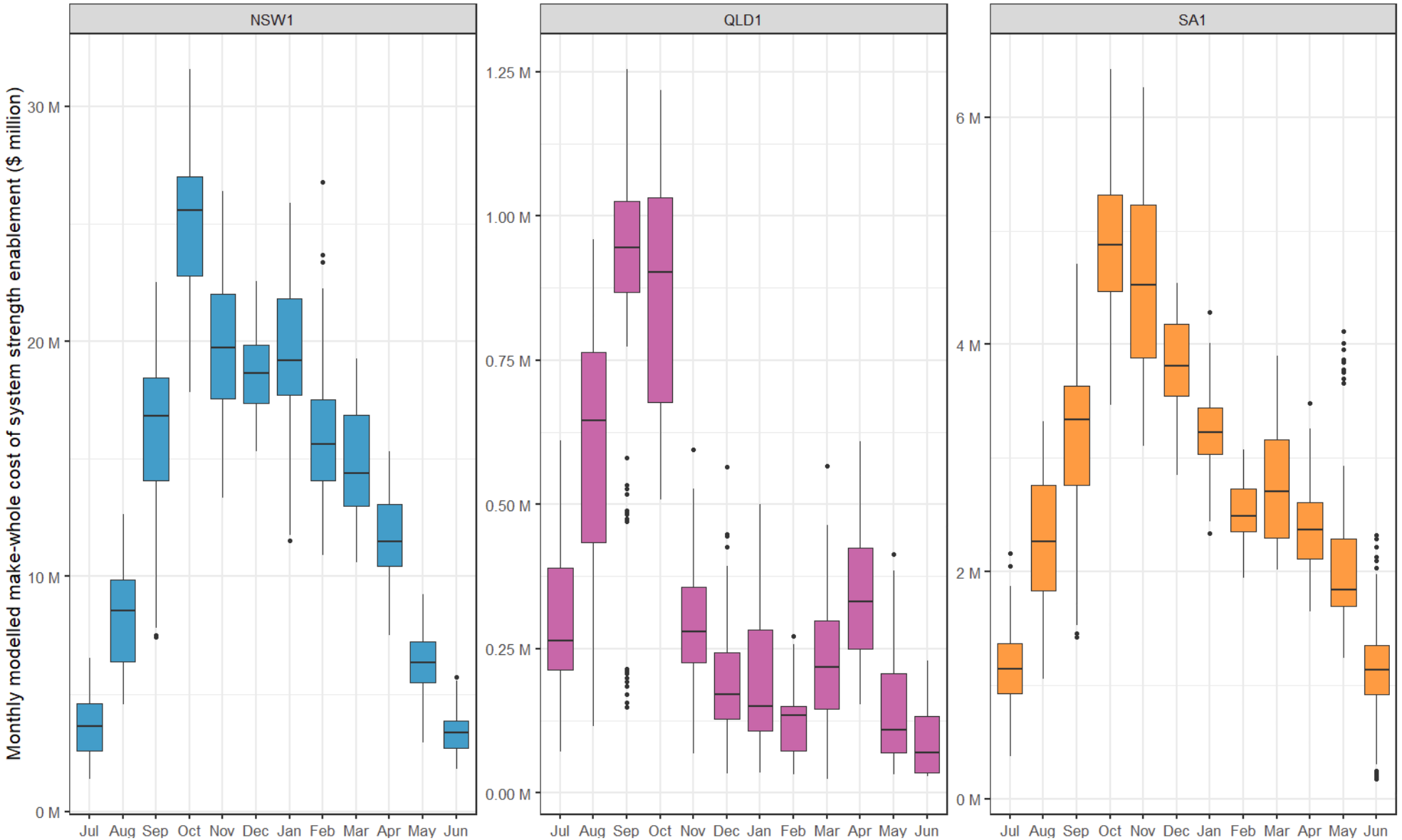


Distribution of spot revenue and resource run costs (SA)



Monthly results for all financial years

Annual modelled make-whole cost of system strength enablement in FY 2026 ($ millions, real 2023)

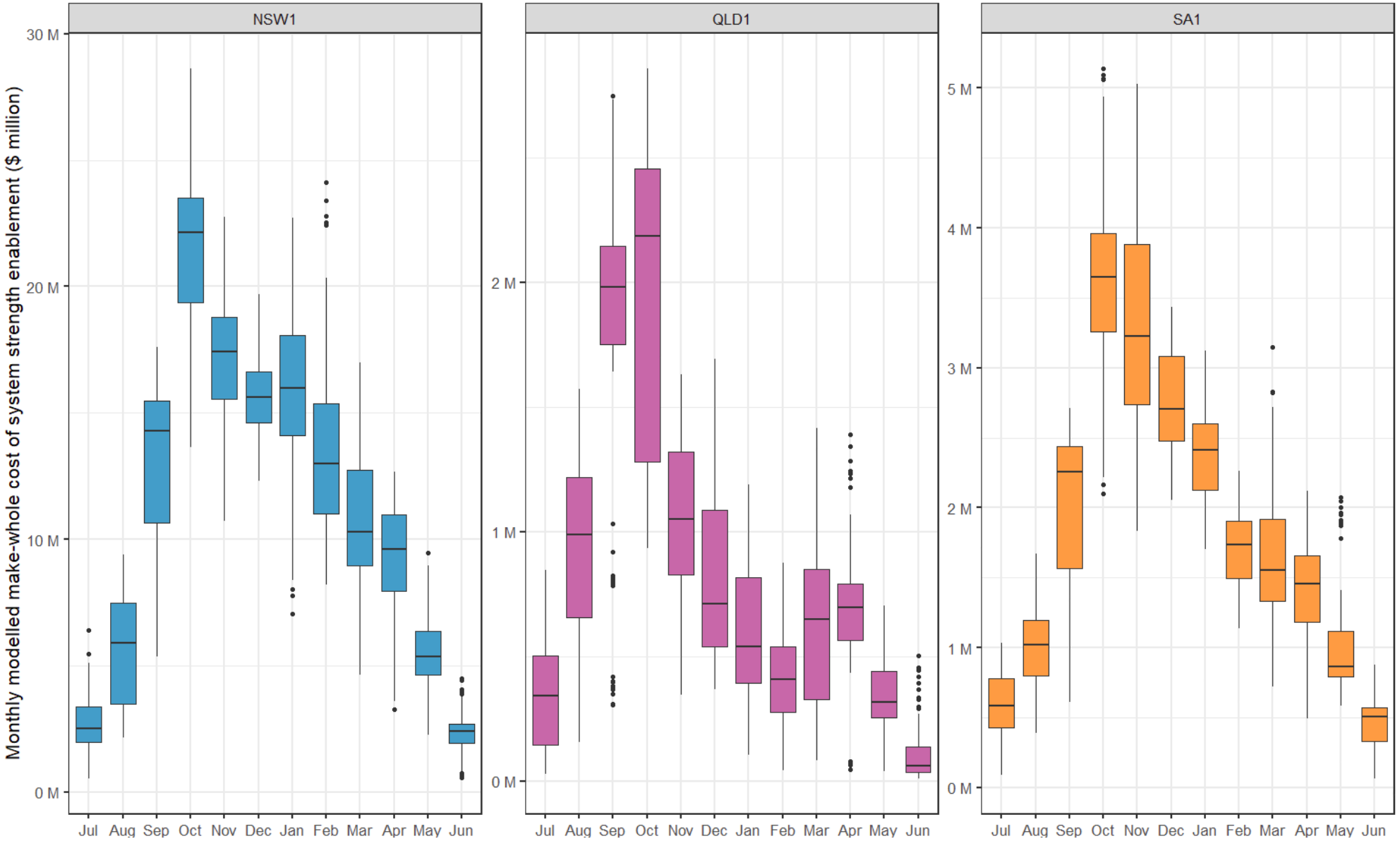


- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2026.
- The results show a high degree of variability within and across months.
- The variability is driven by different spot price outcomes under different simulations. This changes both the quantity of enablement and the make-whole cost of that enablement within a simulation.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

Monthly results for all financial years

Annual modelled make-whole cost of system strength enablement in FY 2027 ($ millions, real 2023)

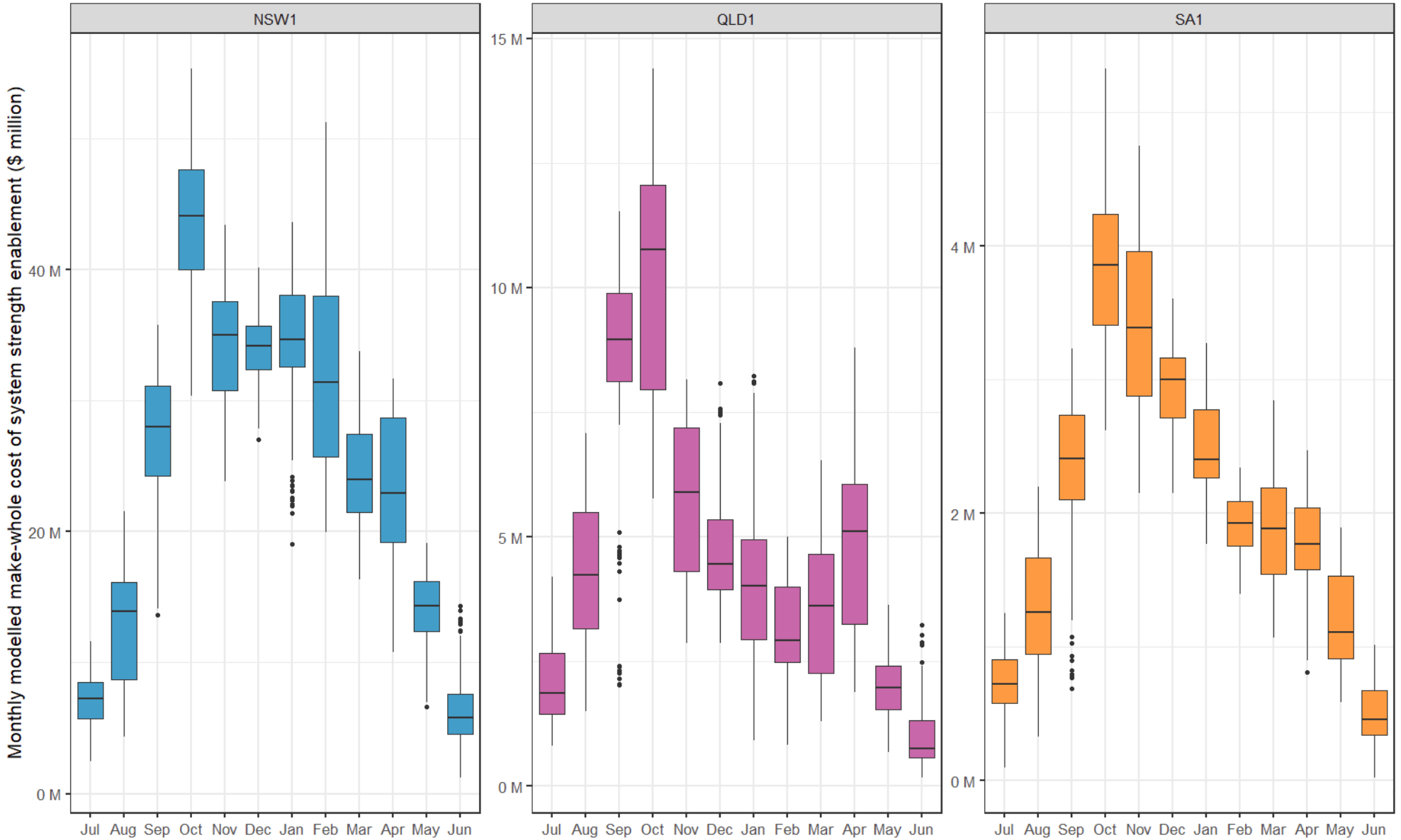


- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2027.
- The results show a high degree of variability within and across months.
- The variability is driven by different spot price outcomes under different simulations. This changes both the quantity of enablement and the make-whole cost of that enablement within a simulation.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

Monthly results for all financial years

Annual modelled make-whole cost of system strength enablement in FY 2028 ($ millions, real 2023)

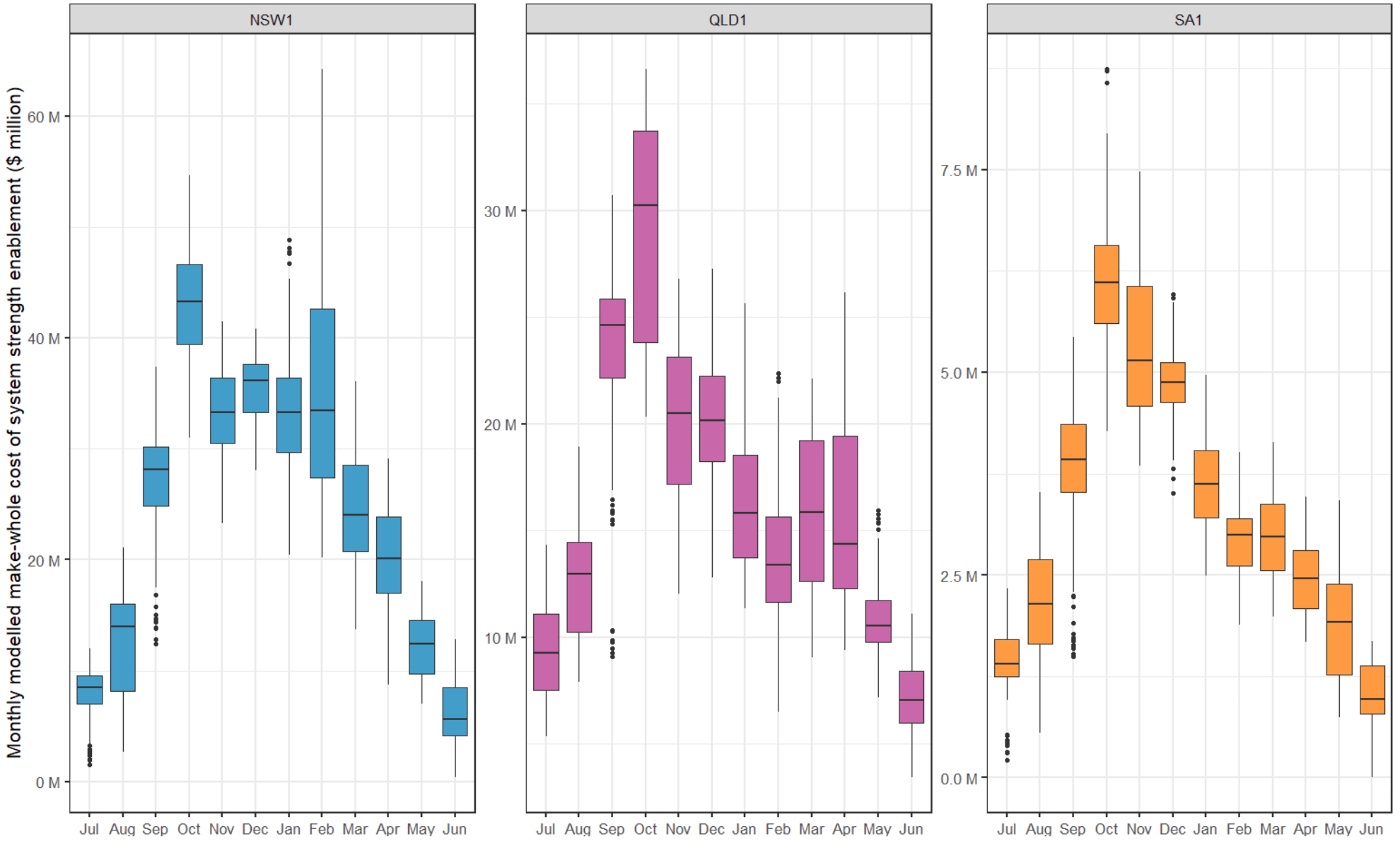


- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2028.
- The results show a high degree of variability within and across months.
- The variability is driven by different spot price outcomes under different simulations. This changes both the quantity of enablement and the make-whole cost of that enablement within a simulation.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

Monthly results for all financial years

Annual modelled make-whole cost of system strength enablement in FY 2029 ($ millions, real 2023)

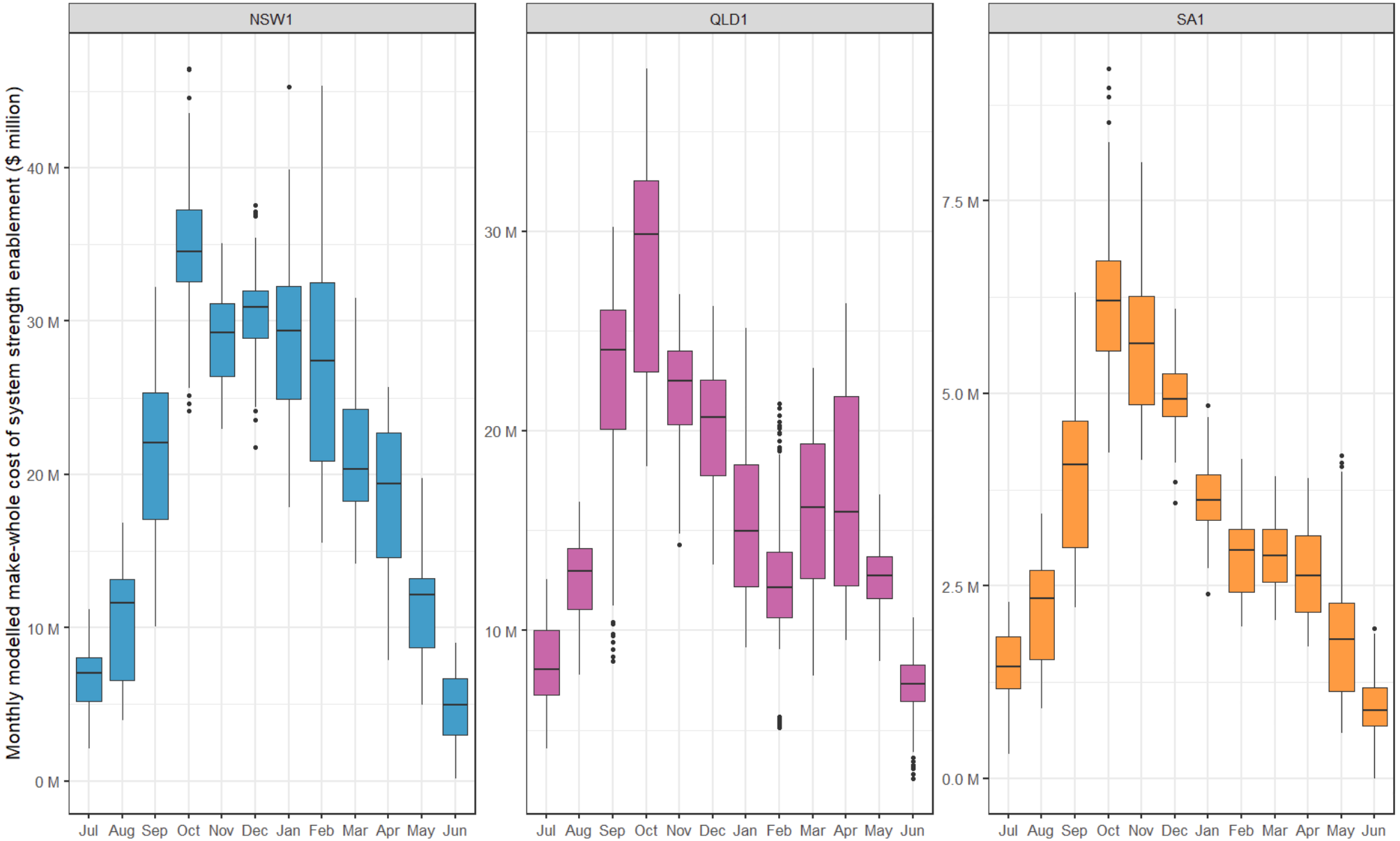


- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2029.
- The results show a high degree of variability within and across months.
- The variability is driven by different spot price outcomes under different simulations. This changes both the quantity of enablement and the make-whole cost of that enablement within a simulation.

Note: scale is automatically set by region to illustrate variability in modelled make-whole costs.

Monthly results for all financial years

Annual modelled make-whole cost of system strength enablement in FY 2030 ($ millions, real 2023)



- This chart presents the range of modelled make-whole costs across different simulations by month in FY 2030.
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