The Balance of Ancillary Services Pricing

Power Session Webinar

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ENERGEIA

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Agenda and Housekeeping

Agenda

- Ancillary Services (AS) Defined
- AS Demand and Supply
- AS Pricing
- AS Outlook
- Takeaways and Recommendations
- Next Power Session

Housekeeping

This webinar is being recorded and distributed to all registrants along with this presentation

Add your questions to the chat. My colleague, Sara, is monitoring the queue of questions for the Q&A session

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Ancillary Services

Role

Specifications

Emerging

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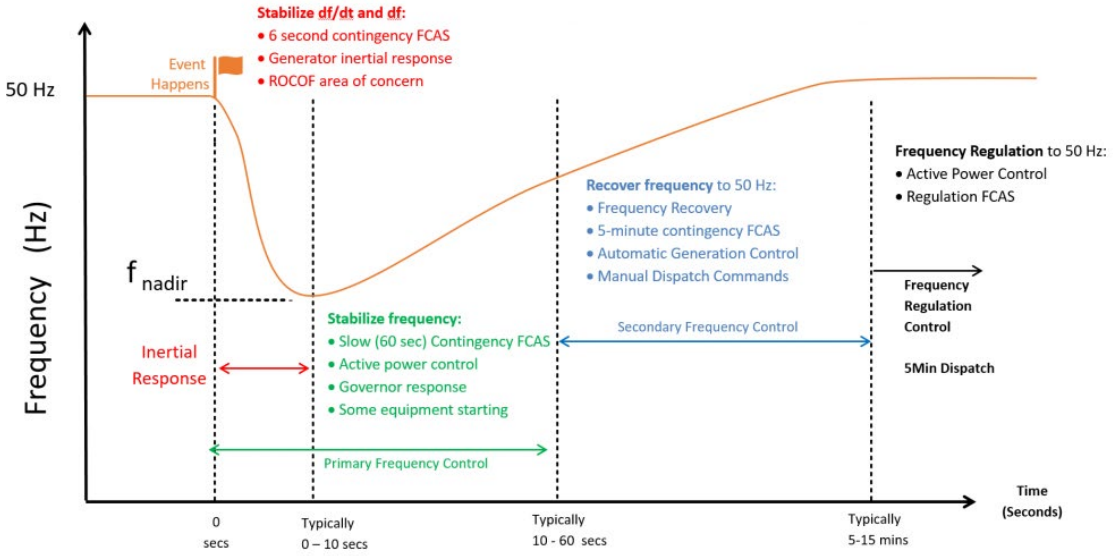
What is Frequency Control Ancillary Services (FCAS)?

Illustrative Example of a Frequency Excursion Event



Source: WattClarity - 'Let's talk about FCAS' (2017)
ROCOF: Rate of Change of Frequency
Note: The 1-second service is new (9 Oct 2024) so is not included in the diagram

- Frequency control ancillary services (FCAS) are services designed to maintain a stable frequency by balancing grid demand and supply in real time
  - When supply exceeds demand, grid frequency increases
  - When demand exceeds supply, grid frequency decreases
- There are now 10 different FCAS markets in the NEM:
  - **Regulation** – corrects minor demand/supply discrepancies and is controlled directly by AEMO
  - **Contingency** – recovers the demand and supply balance of the grid following major contingency events such as the loss of a generating unit or major industrial load. Contingency FCAS consists of 8 markets, with them being:
    - 1-second (raise and lower) - New as of 9 Oct
    - 6-second (raise and lower)
    - 60-second (raise and lower)
    - 5-minute (raise and lower)
- AEMO sets a target for capacity in each market, and registered generators and loads can bid into them
- AEMO selects the lowest-priced bids first to meet the capacity target, and then the marginal price sets the price for the market

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FCAS Specifications – Australia

NER Term	Common Name	Key Purpose	Usually Facilitated by…
Very fast raise service	1-Second Raise FCAS or R1	To arrest a change in System Frequency within the first 1s of a Frequency Disturbance and then provide an orderly transition to a Fast FCAS	• Frequency relay detecting a frequency deviation and adjusting a resource unit's output
Very fast lower service	1-Second Lower FCAS or L1		
Fast raise service	6-Second Raise FCAS or R6	To arrest a change in System Frequency within the first 6s of a Frequency Disturbance and then provide an orderly transition to a Slow FCAS	• Governor or governor-like control systems • Frequency relay detecting a frequency deviation and adjusting a resource unit's output
Fast lower service	6-Second Lower FCAS or L6		
Slow raise service	60-Second Raise FCAS or R60	To stabilise System Frequency within the first 60 s of a Frequency Disturbance, and then provide an orderly transition to a Delayed FCAS	• Governor or governor-like control systems • Frequency relay detecting a frequency deviation and adjusting a resource unit's output
Slow lower service	60-Second Lower FCAS or L60		
Delayed raise service	5-Minute Raise FCAS or R5	To return System Frequency to 50 Hz within the first 5 min of a Frequency Disturbance, and to sustain that response until central dispatch can re-schedule generation and load to balance the power system	• Governor or governor-like control systems • Frequency relay detecting a frequency deviation and adjusting a resource unit's output
Delayed lower service	5-Minute Lower FCAS or L5		
Regulating raise service	Raise Regulation FCAS or RREG	To support control of System Frequency and time error in tandem with PFR in response to variations of demand and generation within a dispatch interval	• Setpoint controllers on generating units
Regulating lower service	Lower Regulation FCAS or LREG		

Source: AEMO 'Market Ancillary Service Specification' (2023).
Note: NER: National Electricity Rules, PFR: primary frequency response

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Emerging AS Products

New Types of AS to Support the Transition to Zero Emissions Systems

Region	New Ancillary Service Product	Definition	AS Response Spec
EU	Synchronous Inertial Response (SIR)	The objective is to quickly provide an active power output and synchronizing torque during a short time to cope with disturbances	0-Second
	Dynamic Reactive Response (DRR)	The objective is to deliver a reactive current response for voltage dips in excess of 30% that would achieve at least a reactive power in Mvar of 31% of the registered capacity at nominal voltage	< 40 ms
	Fast Post Fault Active Power Recovery (FPFAPR)	FPFAPR is defined as having been provided when, for any fault disturbance that is cleared within 900 ms, a plant that is exporting active power to the system recovers its active power to at least 90% of its pre-fault value within 250 ms of the voltage recovering to at least 90% of its pre-fault value	< 250 ms
	Enhanced Frequency Response (EFR)	The objective is to deliver active power to the grid as a proportional response to a change in system frequency outside of the deadband	< 1-Second
	Ramping Margin (RM)	Ramping margin is defined as the guaranteed margin that a unit provides to the system operator at a point in time for a specific horizon and duration. There are horizons of one, three and eight hours with associated durations of two, five and eight hours respectively	1 h, 3 h, 8 h
US	Inertial Response	Inertia can be characterized as a measure of a generator's resistance to changes in its rotational speed. Unlike PFR or FFR, synchronous inertial response occurs simultaneously with loss of supply or loss of load	0-Second
	Fast Frequency Response (FFR)	Fast Frequency Response has many similarities to PFR, but typically responds more quickly and might be activated in a more controlled manner and is not limited by thermal or hydraulic processes but rather achieved through digital controls	< 0.5-Second
	Flexible Ramping	The main objective is for optimisation software to make available additional upward and downward flexible ramping capability to address uncertainties driven by load changes, intermittent output changes, and/or forecasting errors	X/5 min

Source: Energeia Research

- Energeia analysed US and EU market operator documentation to identify new types of ancillary services
- Key findings include
  - Instantaneous / inertial response (EU)
  - Sub-second FCAS (EU)
  - Sub-second reactive power for voltage (EU)
  - Fault recovery rate (EU)

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Market Fundamentals

Demand

Supply

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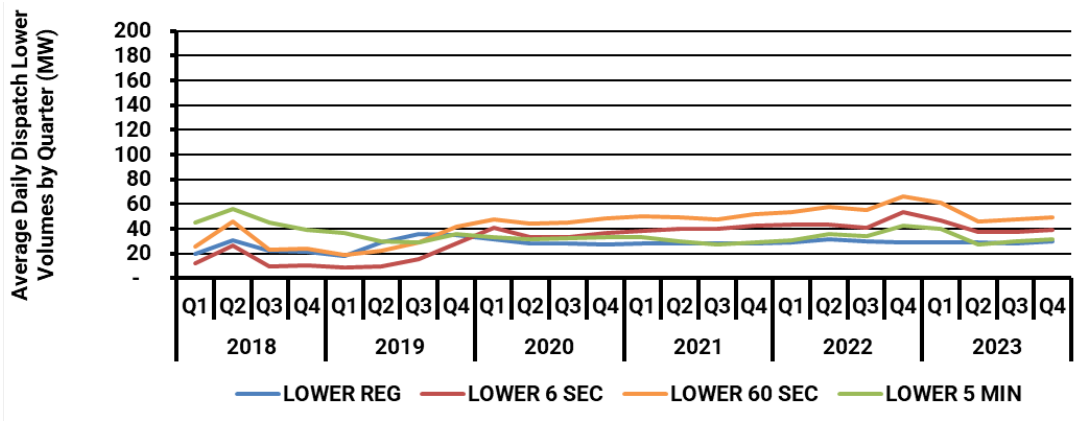
FCAS Lower Market

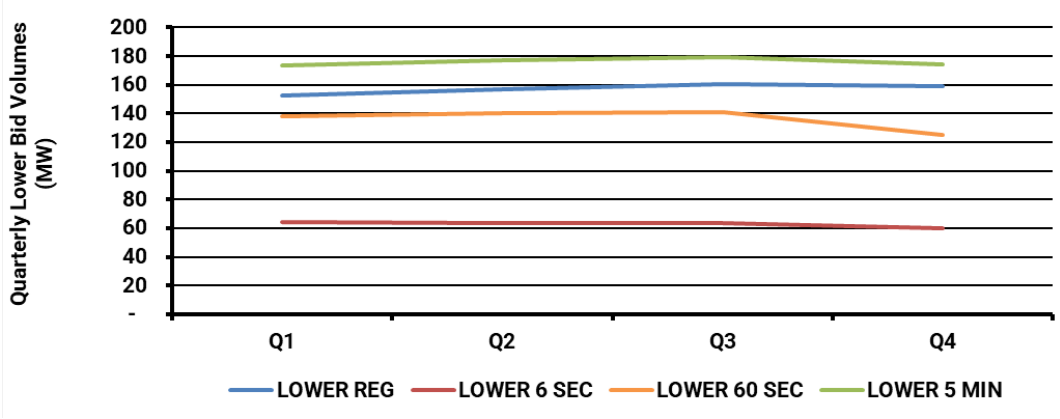
Average Demand for Lower FCAS



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

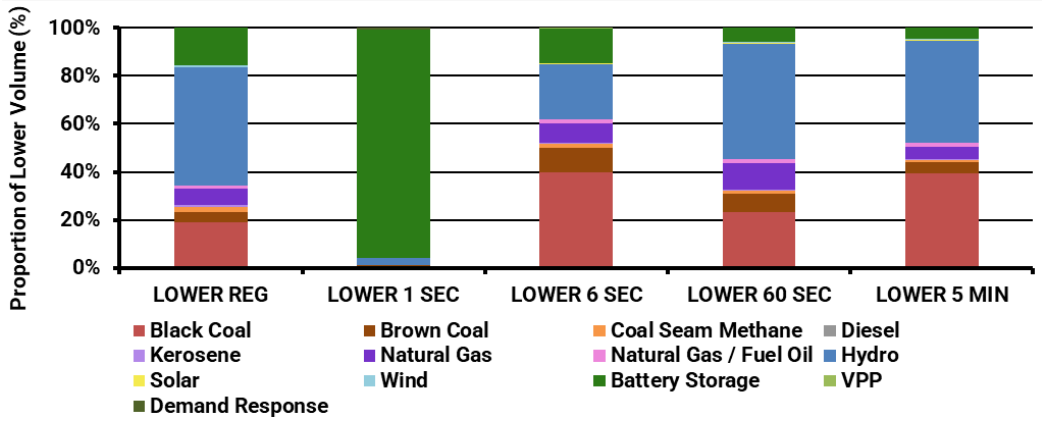
- The figures show the supply and demand of FCAS by product:
  - **Demand** – the dispatched volume of FCAS in MW
  - **Supply** – the total bid volume of FCAS in MW
- Overall trends show:
  - FCAS lower is the smaller market compared to FCAS raise, however overall increases in volume over the last 5 years
- FCAS demand driven by system conditions:
  - Underlying stochastic variation in load or generation
  - Contingency events, including interconnector outages

Average Supply of Lower FCAS – 2023



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

Lower FCAS Supply by Fuel Source – 2023



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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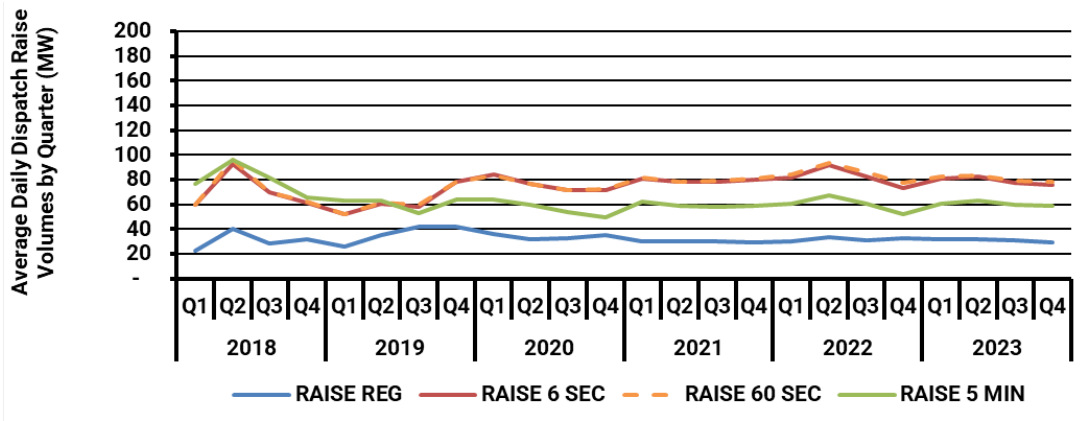
FCAS Raise Market

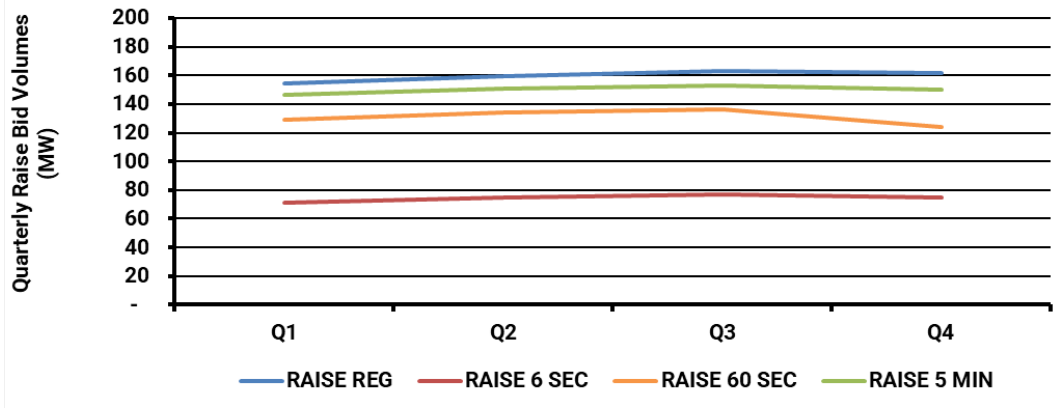
Average Demand for Raise FCAS



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

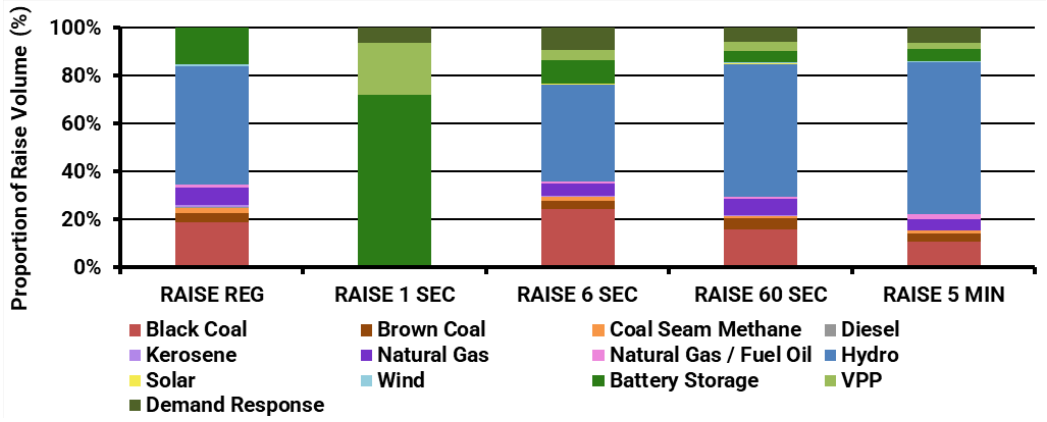
- Overall trends show:
  - FCAS raise is the larger market, however trend is flat
- According to the State of the Energy Market Report (2023) in Q2 2023 FCAS consisted of record non-traditional sources:
  - 40% batteries
  - 13% demand response

Average Supply of Raise FCAS – 2023



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

Raise FCAS Supply by Fuel Source – 2023



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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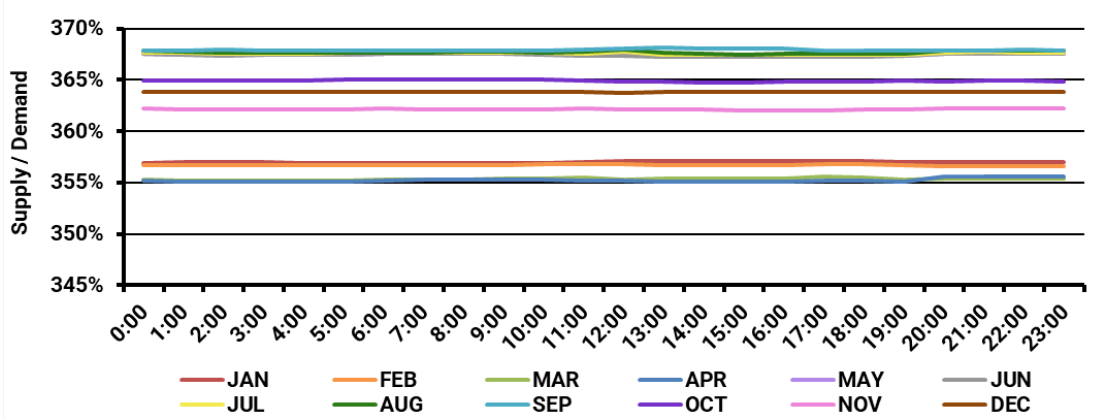
Demand and Supply Balance by Hour and Month – FCAS Raise

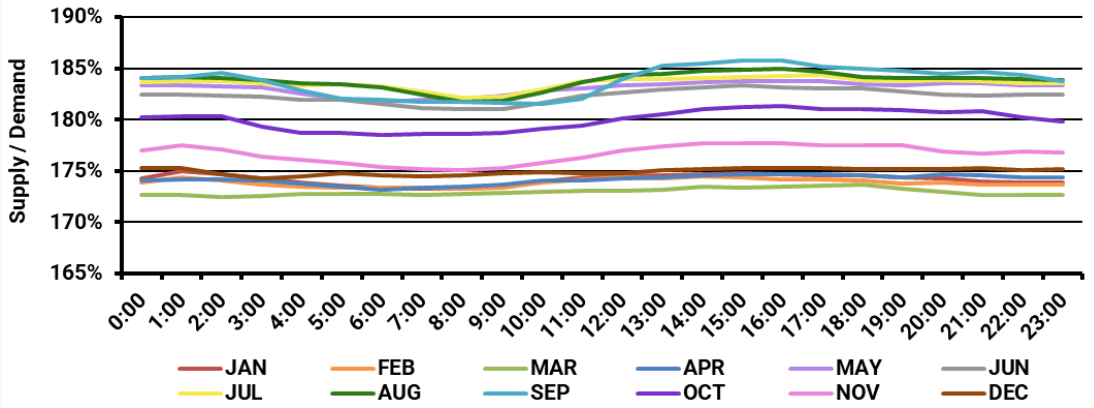
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

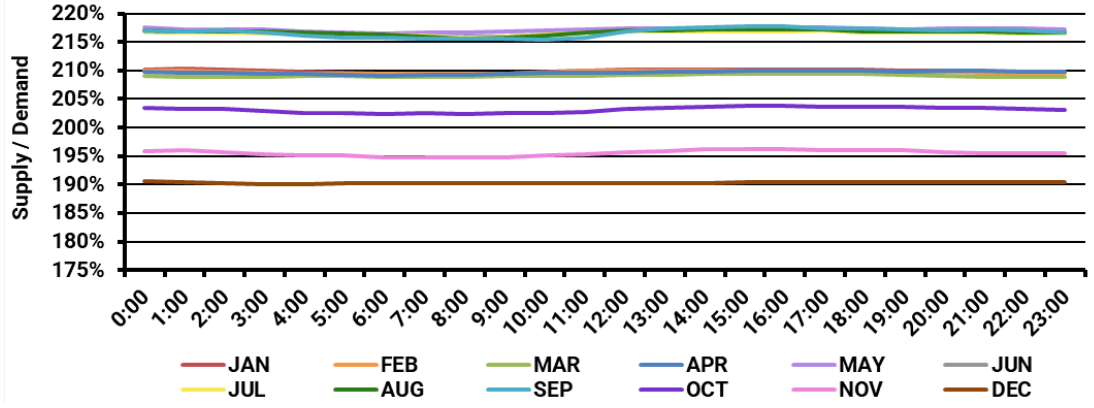
- The charts show the ratio of supply to demand by month in 2023
  - Regulation shows a 3-4x greater magnitude of supply to dispatch
  - 6-second shows the lowest ratio of just under 2x the dispatch volume on average

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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Pricing

Trends

Drivers

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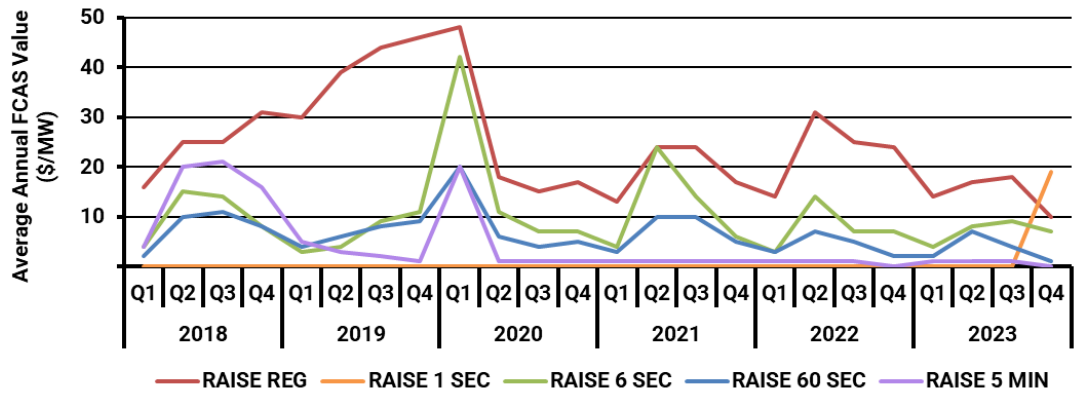
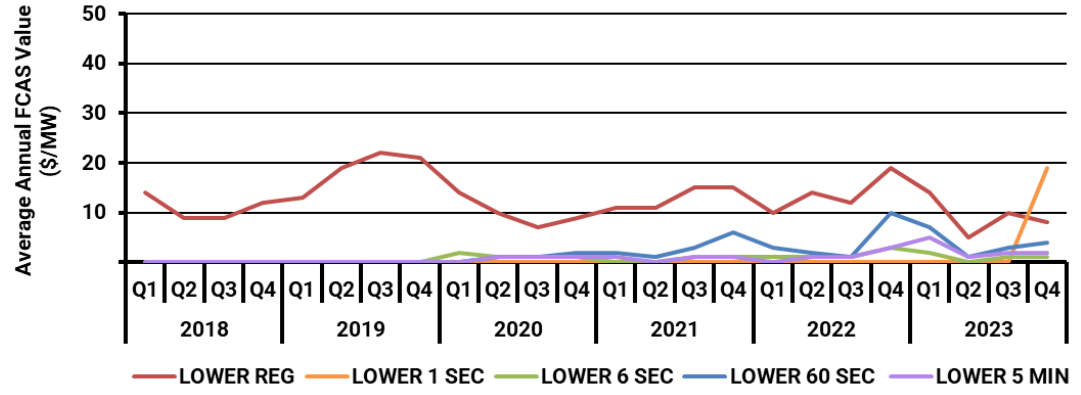
Pricing Trends – Quarterly by Year

Average Quarterly Raise Price



Source: AER (2024)

Average Quarterly Lower Price



Source: AER (2024)

- Raise prices are typically higher as generators must reserve operating headroom in the wholesale market to supply it
  - Prices must recover the foregone revenues in the energy market, resources are paid the same price if dispatched
- FCAS prices are susceptible to changes in the market:
  - Q1 2020: SA islanding drove high local FCAS prices
  - Q2-Q4 2021: QLD-NSW interconnection separation and constraints drive high local FCAS prices in QLD
- Recently, new entrants are providing new sources of FCAS with the exit of thermal plants:
  - Grid-scale batteries
  - Virtual power plants
  - Demand response aggregators

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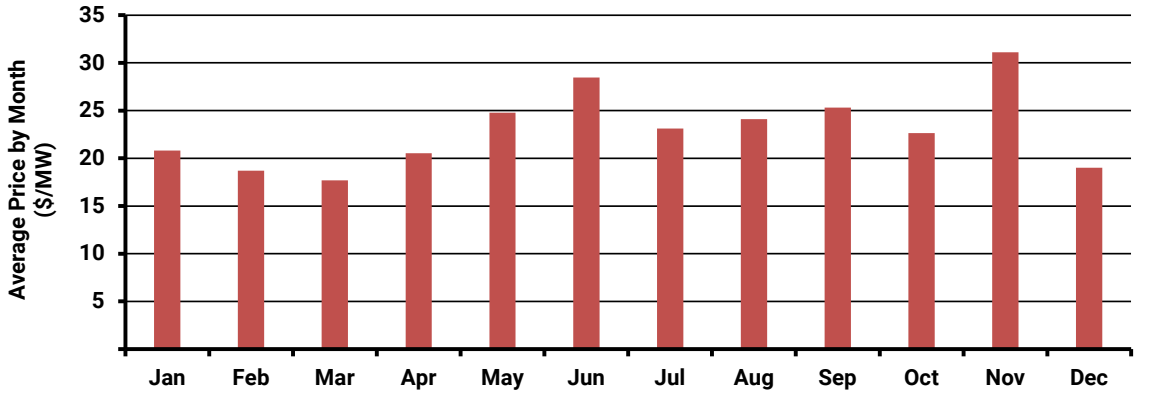
Seasonal Variance in Pricing - Raise

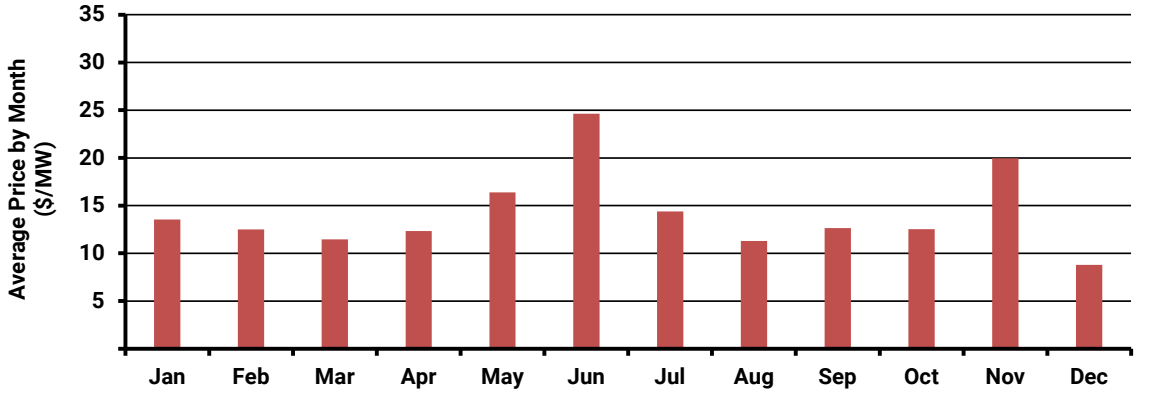
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

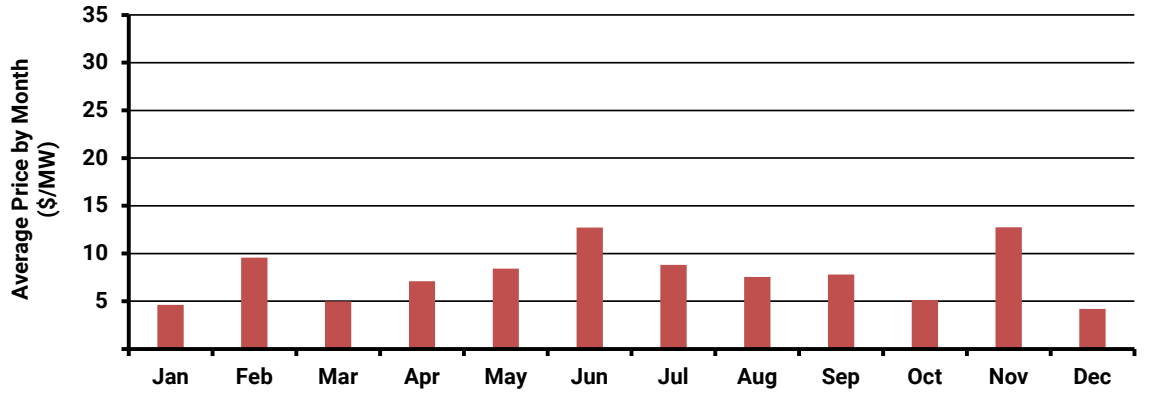
- Average dispatch price over each month is shown for 2017-2024
- Some seasonal variance is present, with higher prices during the coldest and hottest months
- More responsive markets see higher prices, with regulation the highest as requires continuous dispatch

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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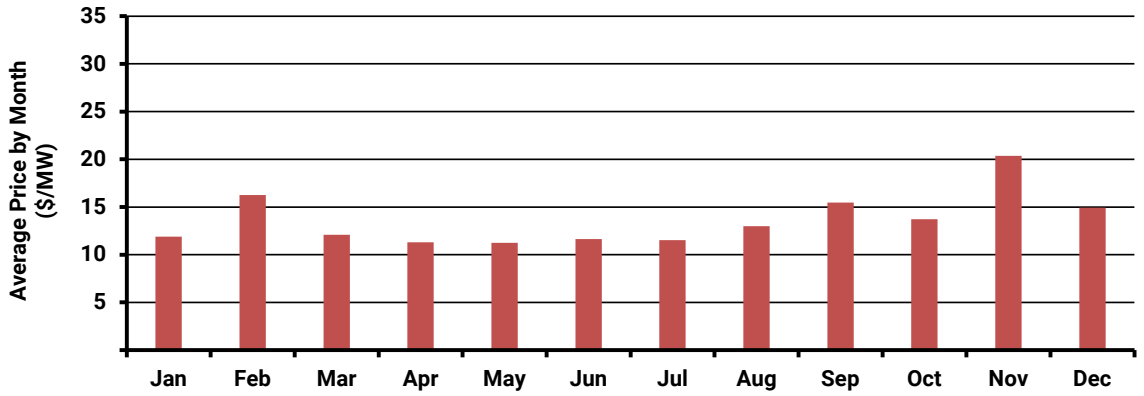
Seasonal Variance in Pricing - Lower

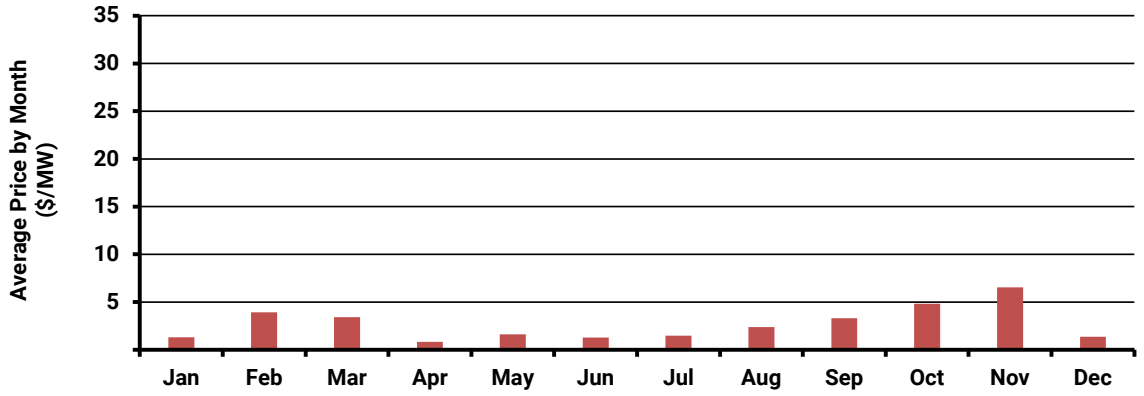
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

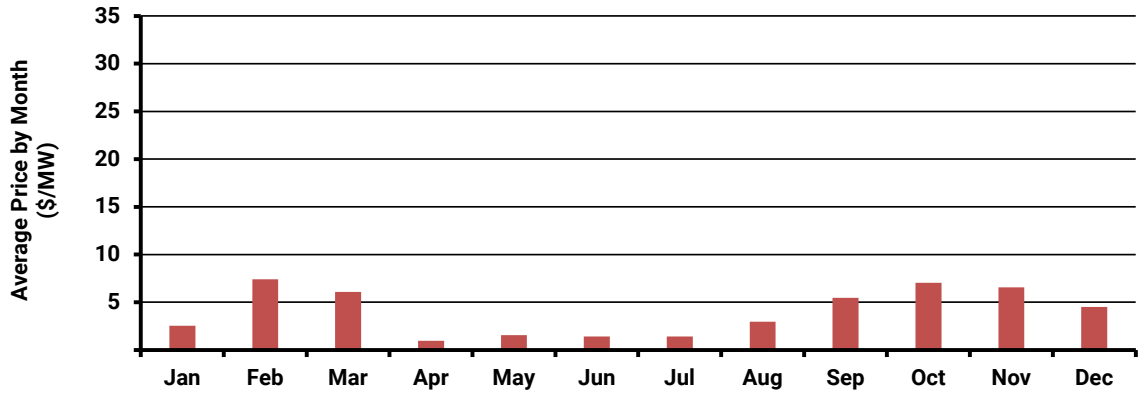
- Average dispatch price over each month is shown for 2017-2024
- Seasonal price variance here is the **inverse** of raise, i.e., highest in spring and autumn months
- Again, more responsive markets see higher prices, with regulation the highest as requires continuous dispatch

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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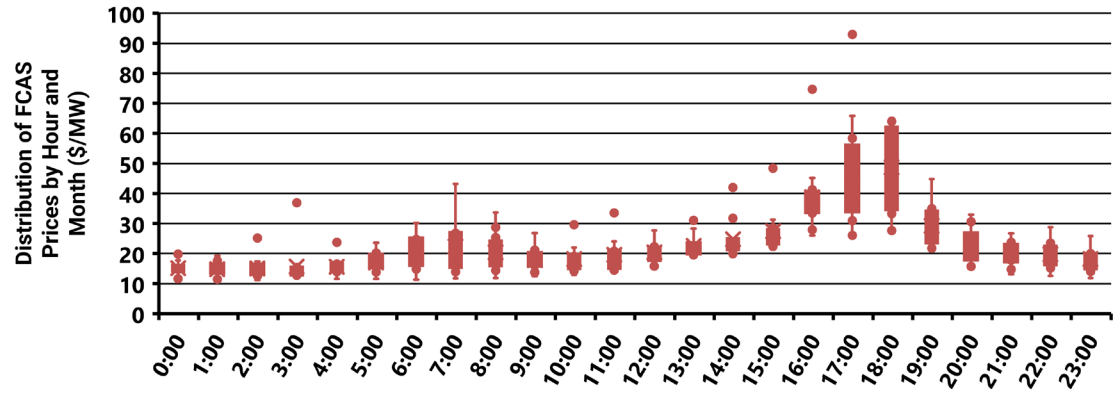
Pricing by Hour and Month - Raise

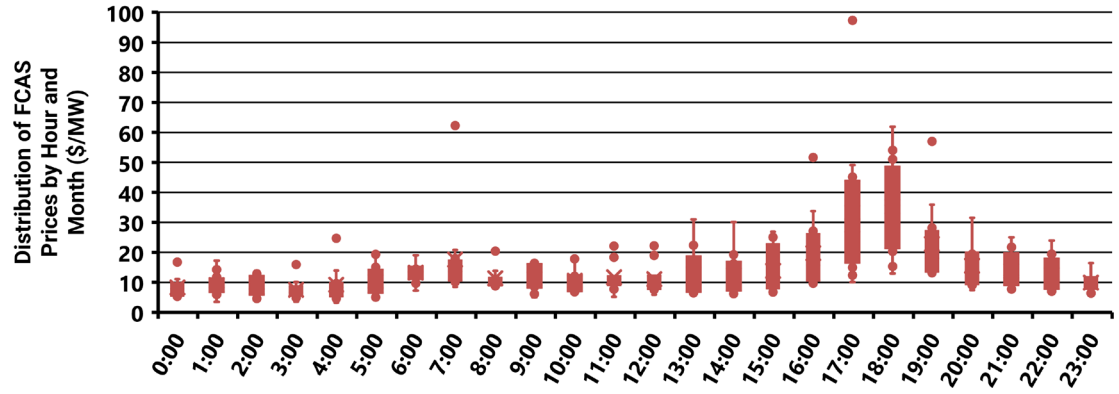
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

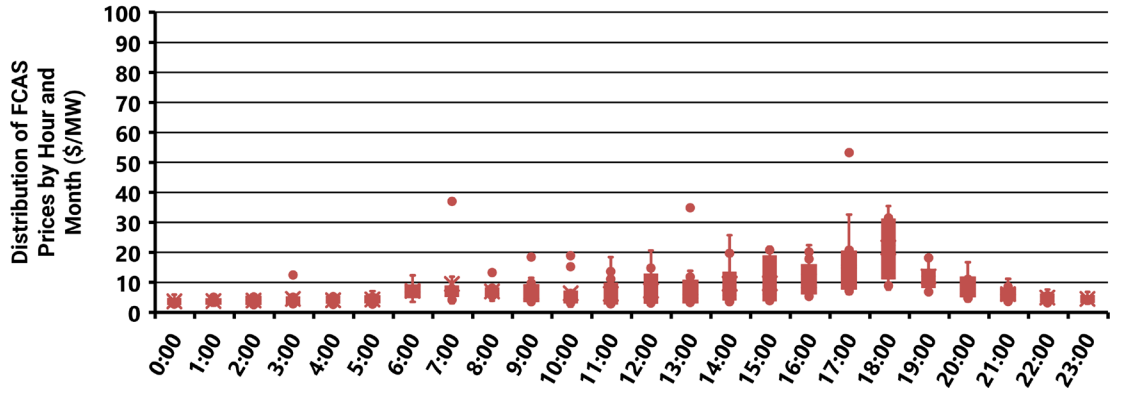
- Average dispatch price over each month is shown for 2017-2024
- Hourly breakdowns of dispatch prices show that the prices spike during evening periods
  - Average prices are correlated with demand
- Faster response markets show higher prices at the hourly level

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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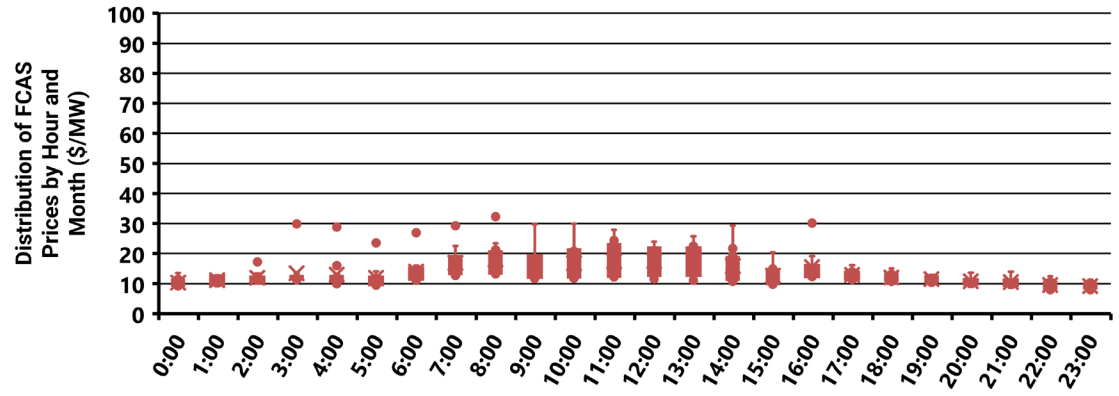
Pricing by Hour and Month - Lower

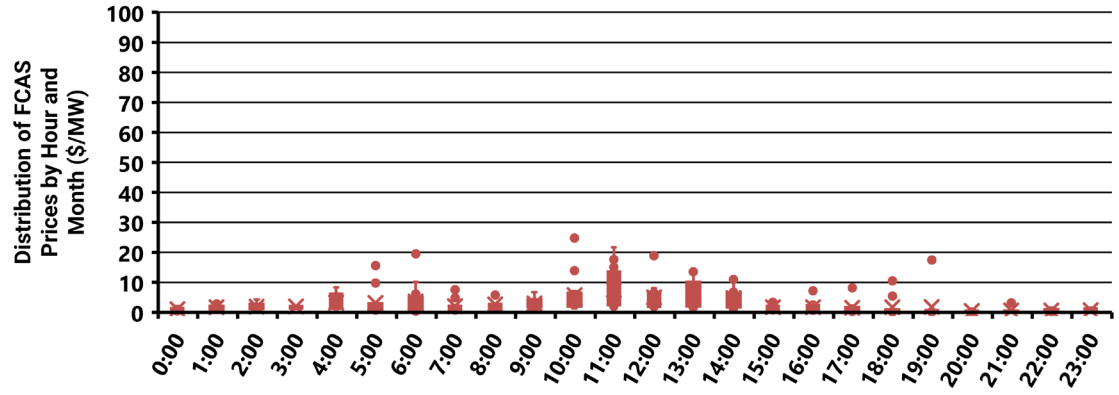
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

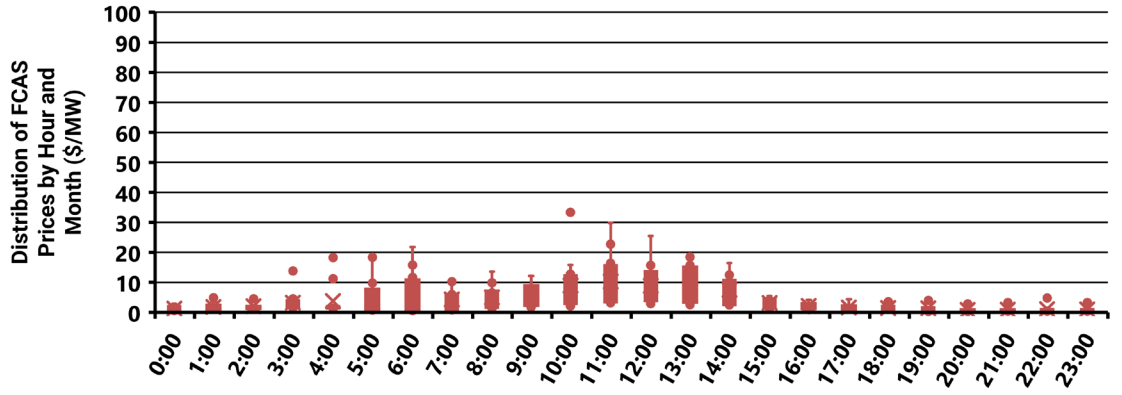
- Average dispatch price over each month is shown for 2017-2024
- Hourly breakdowns of dispatch prices show that the prices spike during midday periods
  - Regulation is consistently higher than other lower markets over all hours of the day

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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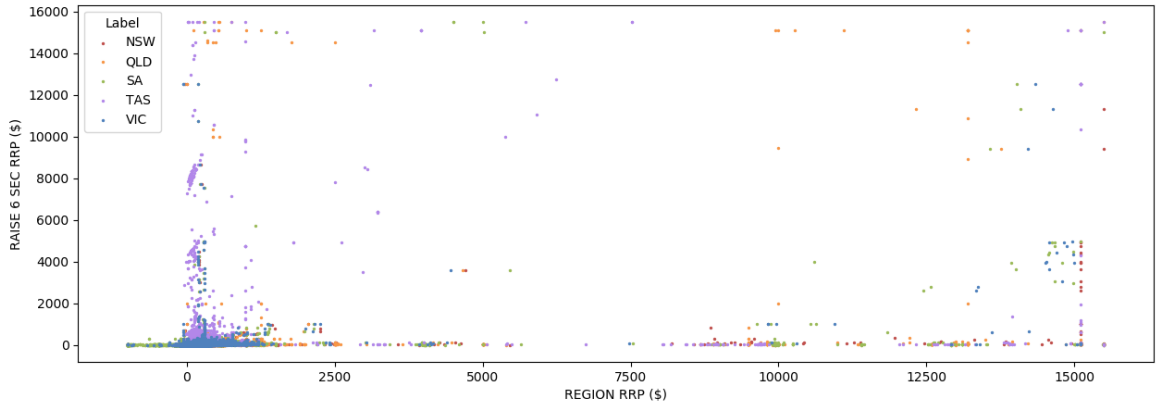
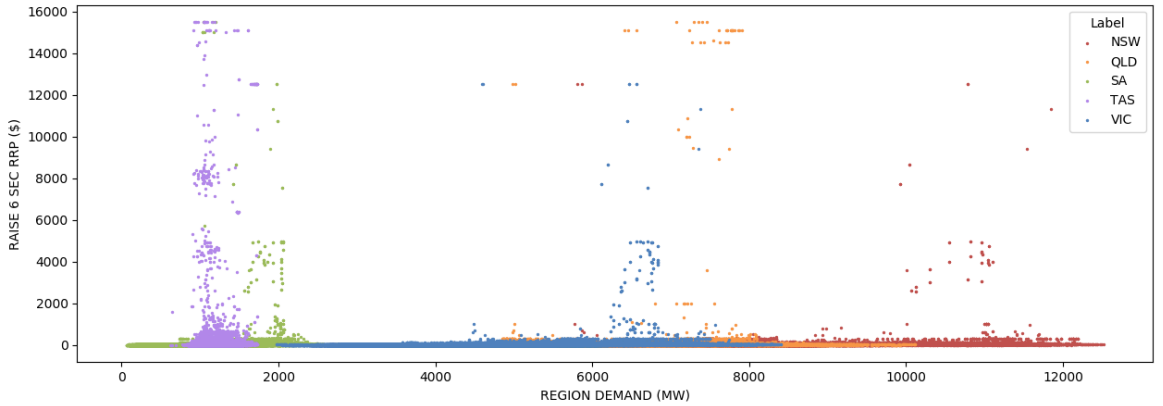
Pricing Driver Analysis – 2022 RRP and Demand vs. 6 Sec Raise

Correlation Between FCAS Price and RRP Price



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

Correlation Between FCAS Price and Demand



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

- Raise 6-second prices are shown vs. energy prices (RRP) and demand in each state in 2022
- The results show there is no noticeable correlation between FCAS 6-second raise price spikes and:
  - Energy prices
  - System demand
- There may be a weak correlation between 6-second raise prices and demand at the high and low ends of demand
  - Most of the exceptionally high FCAS raise price events tend to occur toward the medium to high end of demand

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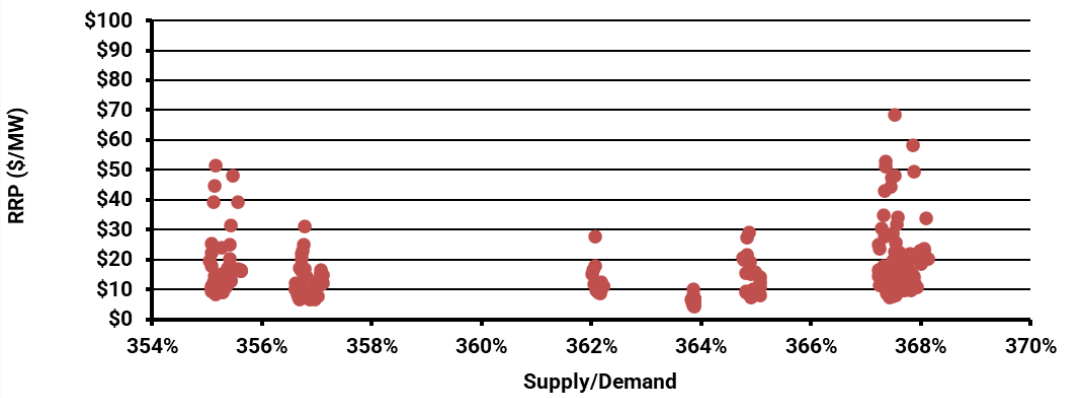
Raise Pricing Driver Analysis – Demand and Supply

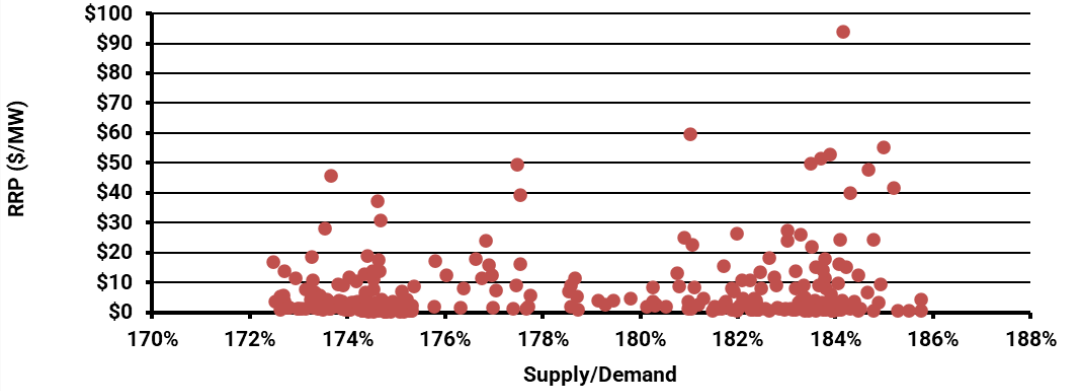
Regulation



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

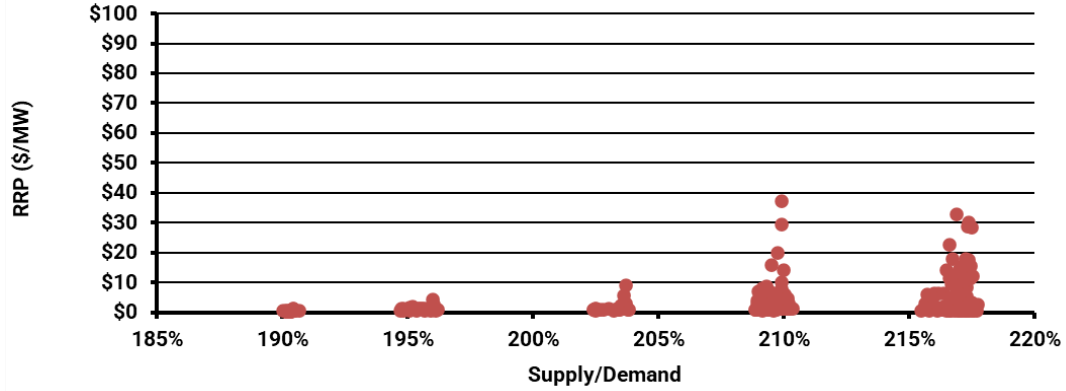
- This analysis shows the relationship between average prices and the supply and demand balance in 2023
  - Pattern appears to reflect differences in monthly demand and supply balances for regulation and 60-second
  - 6-second pricing is less grouped, potentially due to the demand and supply balance being tighter
- The supply and demand balance is relatively constant, and we were not able to identify an expected correlation between lower reserve margins and higher average prices
  - This may be due to higher prices drawing more supply into the market

6-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

60-Second



Source: Energeia, AEMO, NEMOSIS (CEEM, UNSW)

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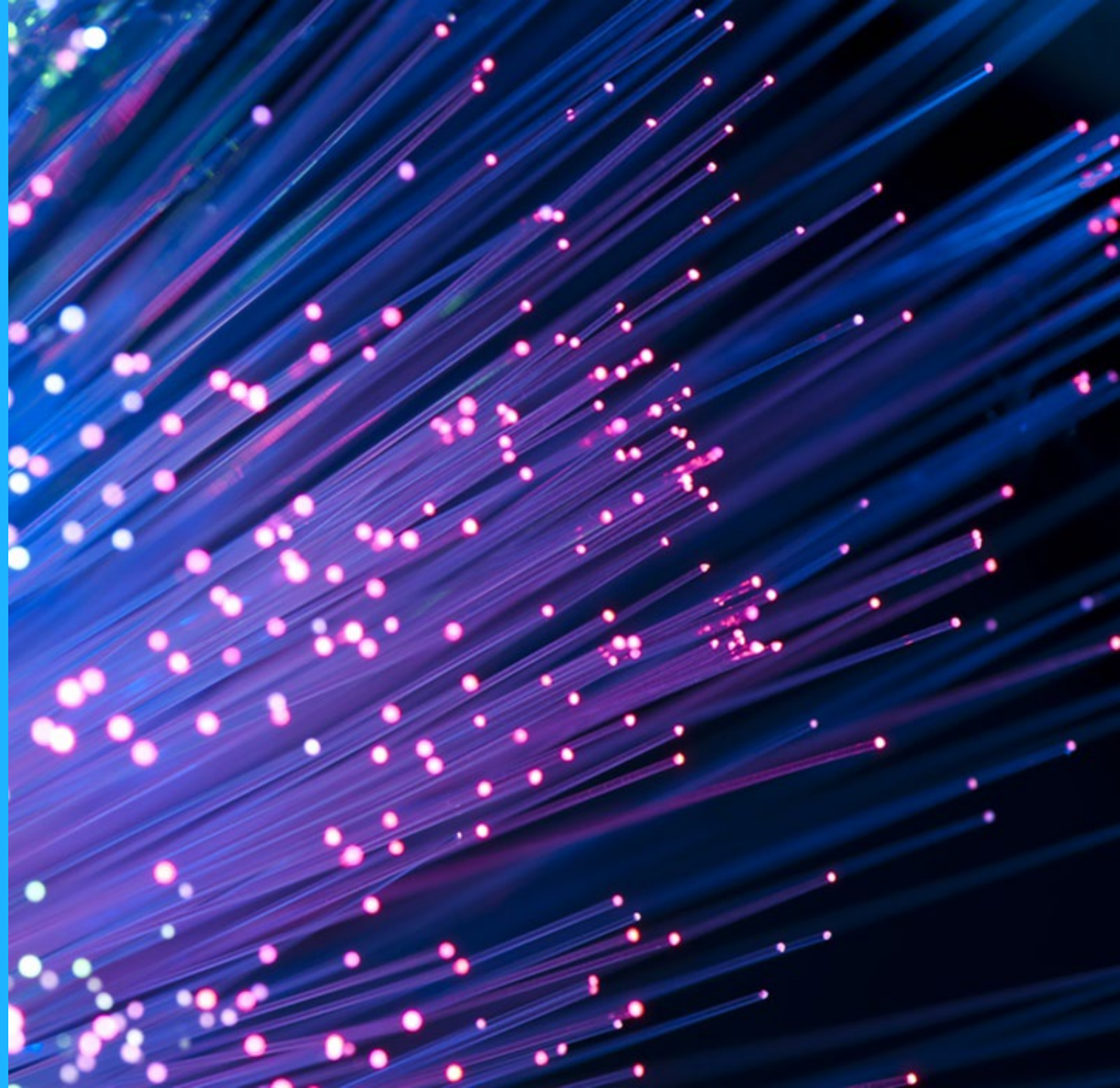
Outlook

Resource Mix

Demand

New Entry Prices



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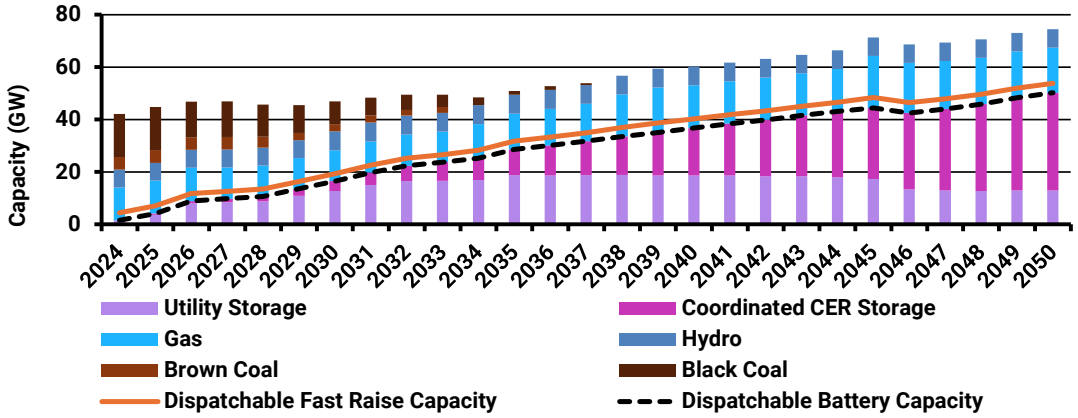
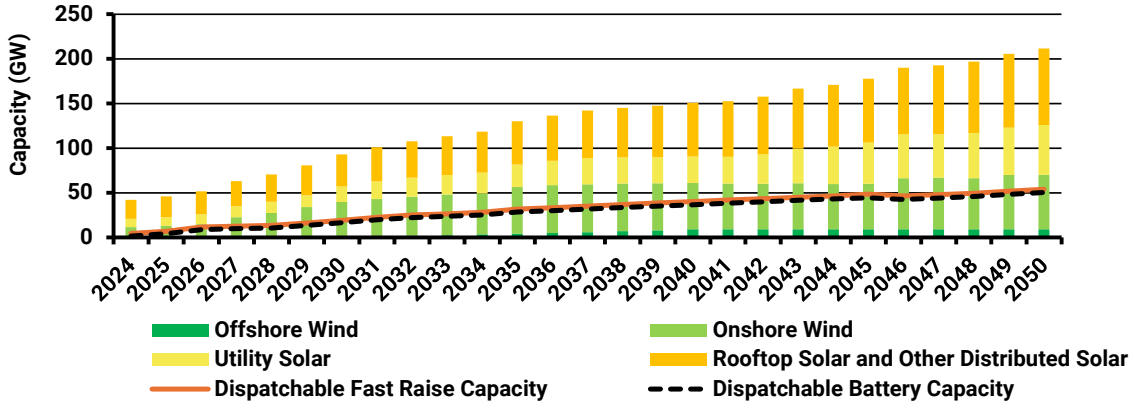
NEM Resource Mix Outlook

Dispatchable Capacity by Type (Firm Capacity)



Source: AEMO ISP Draft (2024)

Generator Capacity by Fuel Type (Intermittent Capacity)



Source: AEMO ISP Draft (2024)

- These graphs from AEMO's 2024 draft ISP report forecast firm and intermittent generation type under the Step Change scenario
- Energeia has added in the amount of fast response dispatchable generation over time, mainly batteries and battery VPPs
- This is compared to the level of intermittent resources in the bottom left graphic
- AEMO's notes appear to say that generation FCAS market activity is not factored into the energy market – is that an issue?

AEMO FCAS Outlook

[25] Synchronous condensers are synchronous machines, specially built to supply only reactive power.

[26] Note that the ISP modelling is an energy-only model and does not consider the co-optimisation of batteries for both their energy dispatch and system service roles. AEMO takes this conservative approach as it expects FCAS markets to remain of finite depth and quickly saturate as more battery projects connect.

[27] AEMO has contracted the Waratah Super Battery, Victorian Big Battery, Hornsdale Power Reserve and the Dalrymple Battery Energy Storage System in the System Integrity Protection Scheme (SIPS).

Source: AEMO ISP Draft (2024)

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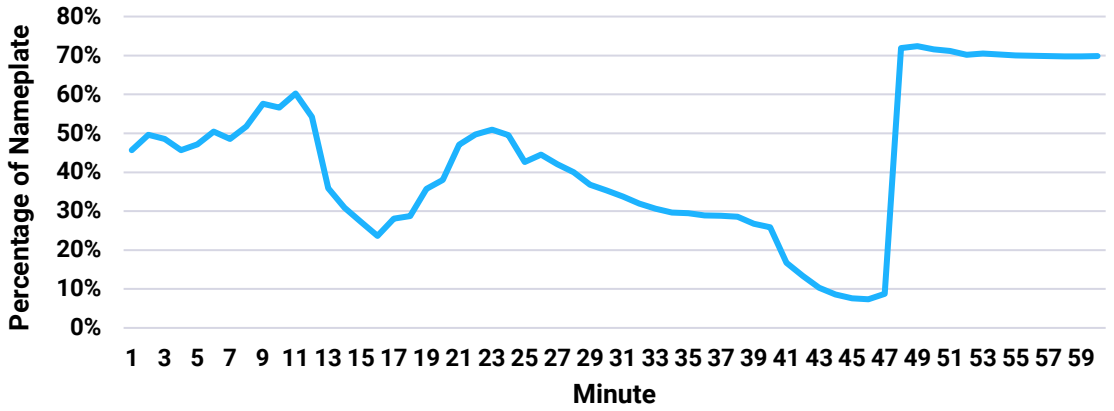
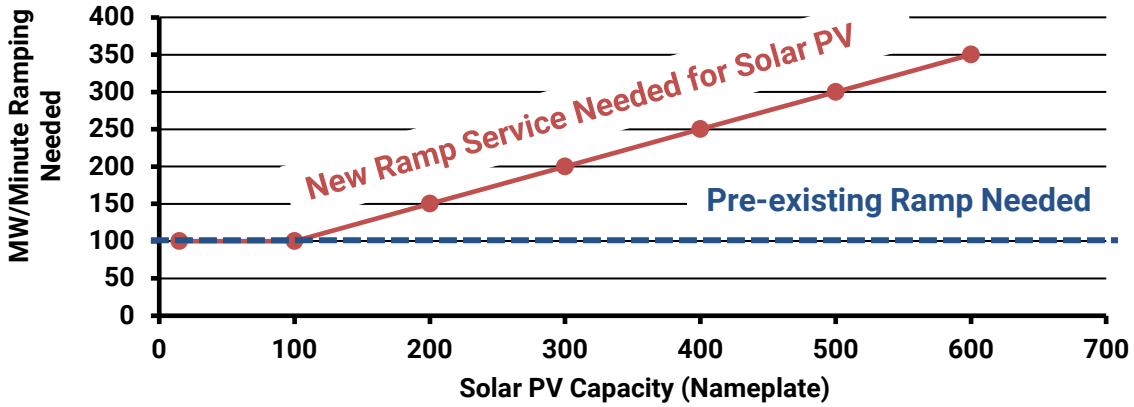
Forecasting NEM FCAS Demand vs. Solar PV Capacity

Example Solar PV Resource Ramp Rate (1 min intervals)



Source: Energeia analysis

Ramp Events by PV Capacity and Type



Source: Utility solar PV data

- Solar PV can rapidly rise and fall due to cloud cover, as shown in the top left graphic
- The bottom left chart shows the estimated amount of min/MW FFR needed, which levels out at around 55% of solar PV nameplate
- Importantly, this effect is hidden by existing noise until it becomes the largest driver of demand for FFR

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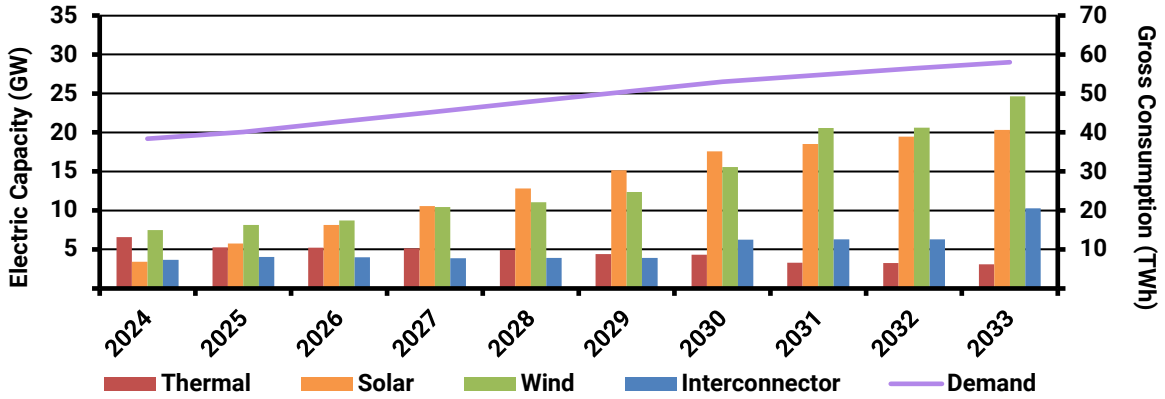
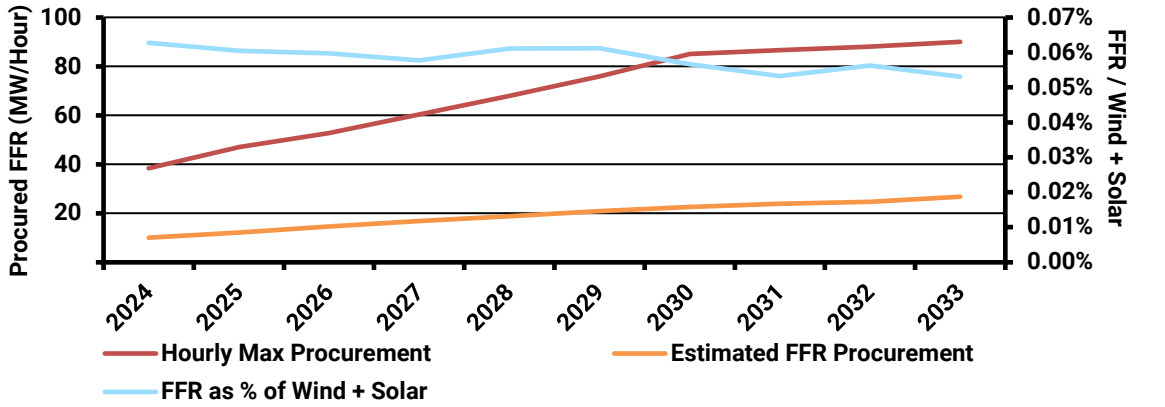
Forecasting FCAS Demand – Intl. Benchmarking (Denmark)

Danish Demand Forecast



Source: Energinet (2023)

Danish FCAS (FFR) Forecast



Source: Energinet (2023), Energeia analysis

- A case study from Energinet provides the outlook for FCAS to 2033 in Denmark
  - Fast Frequency Response (FFR) a similar service to FCAS
- Model results on an hourly basis for 2025, 2030, and 2033 have been used to estimate electricity production
- Linear extrapolation has been used between the calculation years 2025, 2030, and 2033
  - Linear extrapolation is a simplistic method of forecasting
  - FFR forecasts are a current gap in the public domain
- The analysis shows that max procurement increases with solar PV over time but then plateaus in 2030
- Estimated procurement is more linear, representing a percentage of the solar and wind capacity over time
  - It is a fraction of Energeia's estimate of solar PV's potential impact

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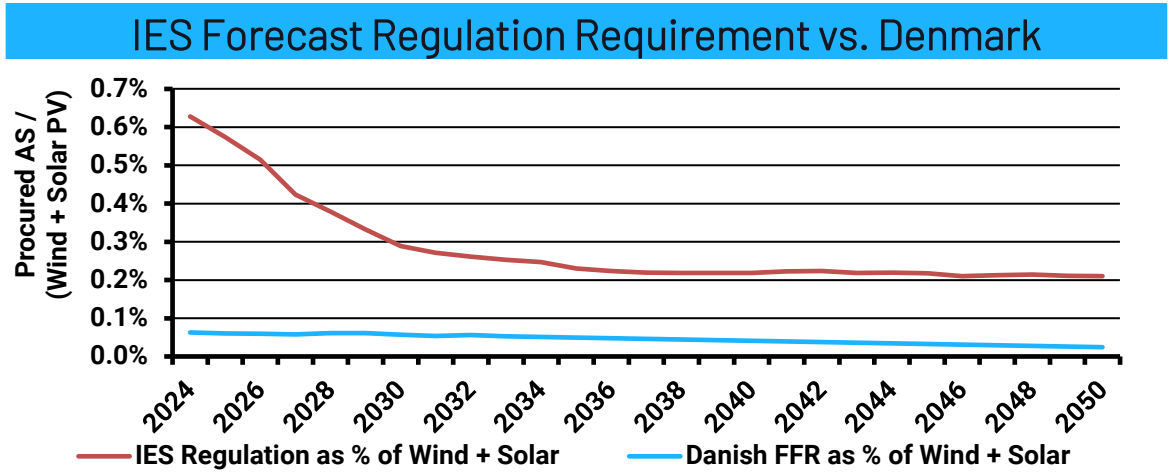
Australian Regulation Requirement Forecast



Source: IES (2024), Energinet, Energeia

- In this figure, the NEM's baseline 'regulation' requirement has been estimated by scaling **current** levels of raise regulation
  - Actual FCAS requirements are influenced by underlying demand forecasting and generator non-conformance errors
  - Replicating these requirements in PLEXOS modelling poses challenges due to their complexity
  - A 2 GW cap on single greatest contingency has been assumed in this report
  - Forecasting errors resulting from AEMO's "lack of visibility of VPP operations" are expected to lead to additional regulation procurement to address frequency fluctuations
- It is a higher level of AS product procurement than the Danish estimate
  - It is important to note that this analysis is normalised by the level of wind and solar PV in the market, which it is not sensitive to
  - Also important to note that the Danish forecast is of FFR, a contingency service, while IES is a regulation service
  - Regulation is typically smaller than contingency services like 1-second and 6-second, etc.
- Could solar PV ramping be another potential risk that is as yet not widely understood?

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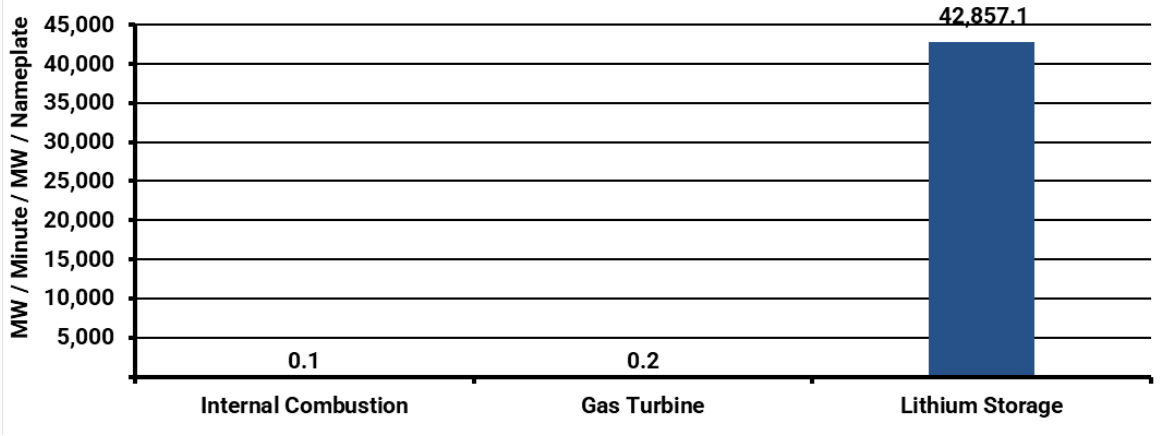
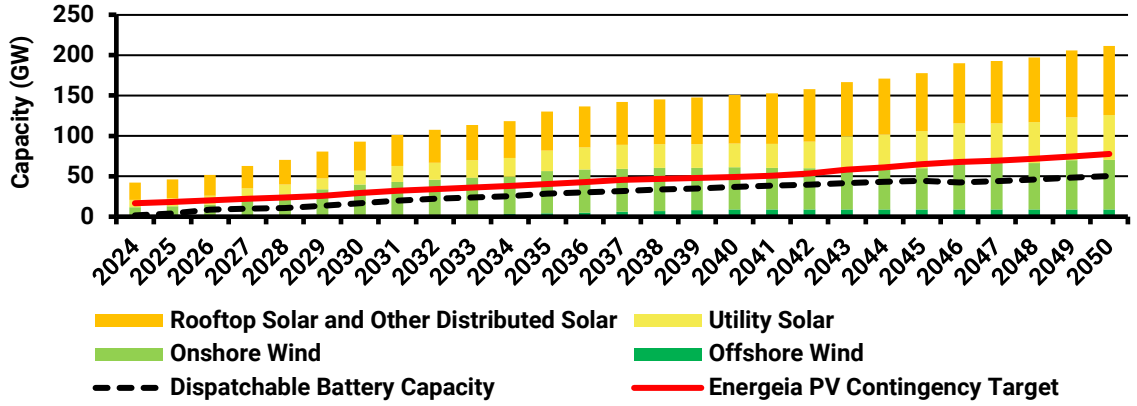
Resource Response Rates and Impact on Capacity Requirements

Batteries are 5 Orders of Magnitude Faster than Gas Turbines



Source: AEMO, Energeia analysis

AEMO Battery Forecast May be Insufficient for FCAS



Source: Energeia analysis

- Resource FCAS/FFR capacity depends on their rate of change
- Convention resources not able to change output quickly, compared to battery storage
  - Energeia notes that the kinetic energy in the rotating machine can deliver limited amounts of nearly instantaneous response
- Bottom left chart shows battery capacity vs. Energeia's solar PV ramping target

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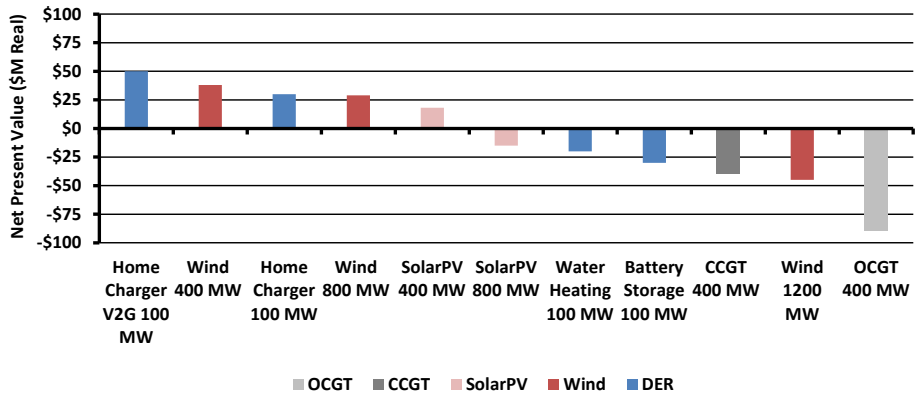
New Entry Prices for FCAS Services

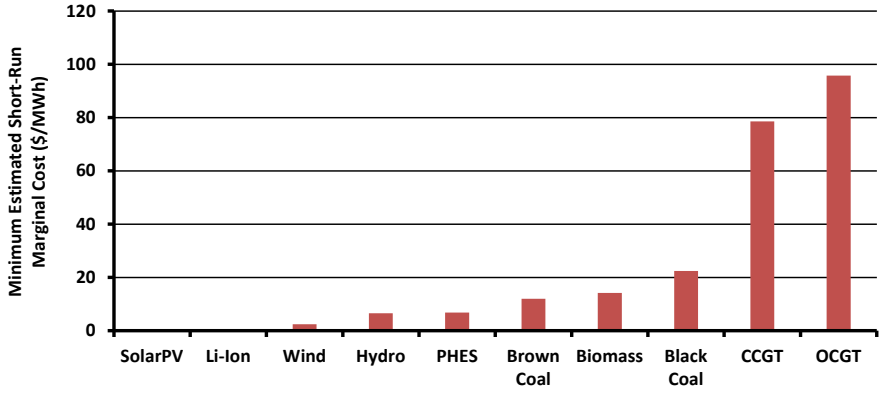
Net Present Value by Technology Type (NSW 2026)



Source: Energeia, AEMO

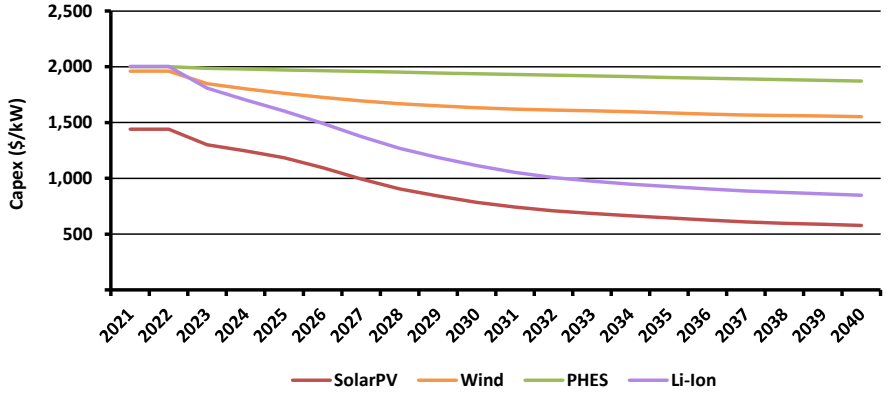
- In levelised cost terms, renewables, and Customer Energy Resources (CER) are least cost
- In terms of the cost of delivering fast ramping FCAS, batteries are much, much cheaper
- Energeia expects FCAS shortfalls to generally be addressed by investment in battery capacity
- In terms of price setting, batteries are also expected to set prices over time based on the opportunity cost of the energy

Short-run Marginal Cost (NSW 2026)



Source: CSIRO GenCost 2022

Capacity Expansion Generation Capex Cost by Fuel Type



Source: CSIRO GenCost 2022

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Key Takeaways and Recommendations

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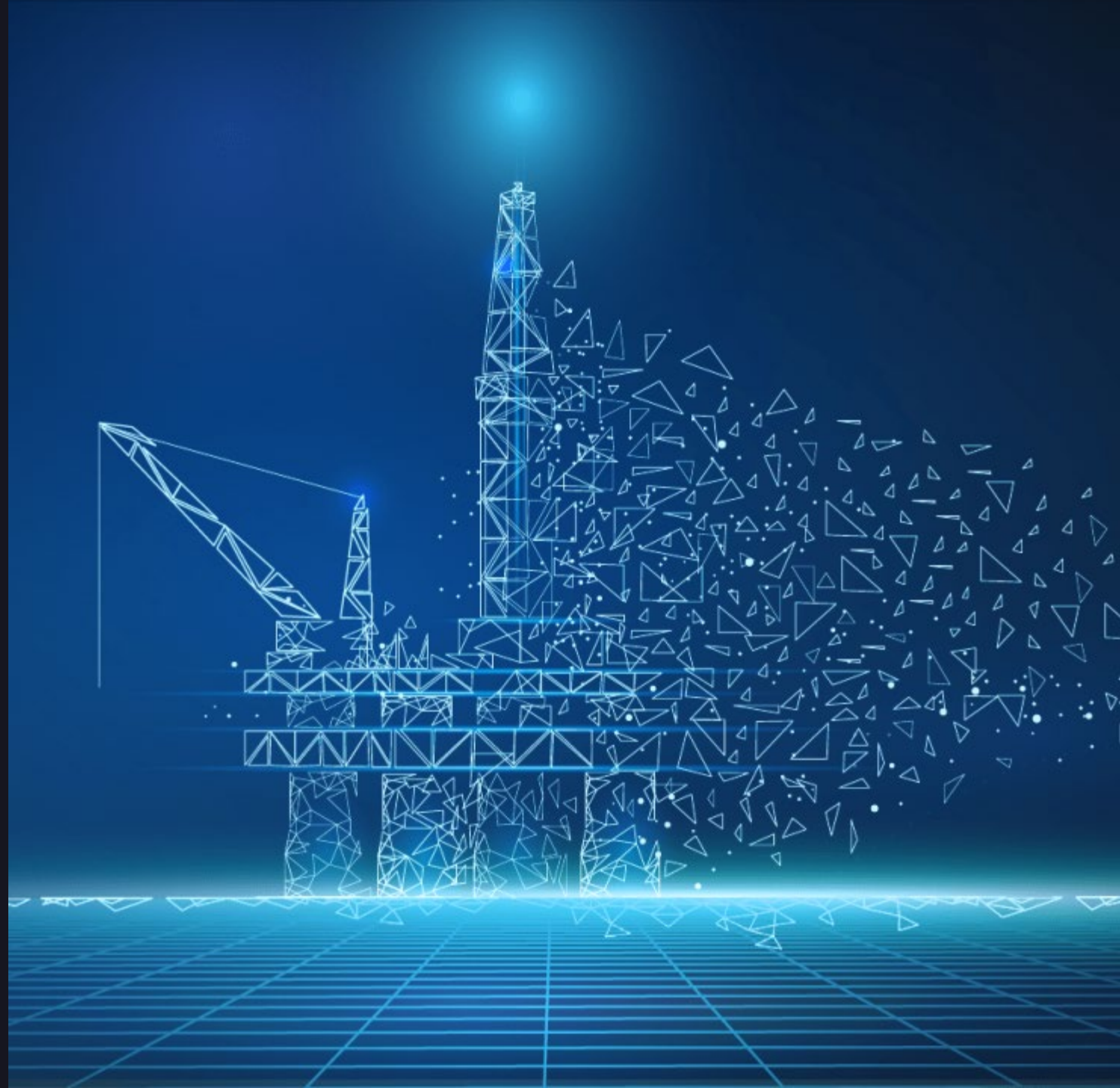
Key Takeaways and Recommendations

- Key Takeaways
  - FCAS ensure the secure operation of the NEM by providing a series of interwoven, fast response services to keep demand and supply in balance at all times
  - FCAS prices are currently driven by interconnector events, higher for raise than lower and higher for faster services, with raise regulation the highest value service
  - Increasing intermittent solar PV and wind resources is expected to require an increasing amount of FCAS, once they become the single largest contingency
  - This could change the nature of prices spikes and pricing behavior in FCAS markets from today's random but infrequent major contingency events
  - Overseas market operators are also forecasting solar PV and wind to be the key driver of demand for FCAS
  - AEMO's ISP may not include sufficient battery storage to meet the forecast penetration of intermittent renewable energy
- Key Recommendations
  - Pricing dynamics in the FCAS market could change as solar PV and wind become the single largest driver of FCAS events and batteries lag behind
  - Examination of the correlation of solar PV and wind resources will be critical to identifying system needs and the timing of this new market factor
  - Additional work may be needed to ensure there is sufficient ramping capacity in the NEM to keep demand and supply in balance at all times

Energeia Power Sessions

Q & A

Next Power Session Topic



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Energeia's Power Sessions

- Q&A
  - Add your questions in the chat
  - Unanswered questions will be answered via email.
- Vote for the next Power Session webinar topic
  - Best Practice Grid Planning for Transport Electrification's S-Curve
  - The Coming Consumer Investment in Reliability and Microgrids
  - Optimising Tariffs and Incentives for Building Electrification
- Next Steps
  - Follow the link at the end of the webinar for the next one
  - Request an exploratory meeting with Energeia
  - Easy access links to previous webinars

Reserve your place at the next **Power Session** discussion

Natural Gas Decommissioning Strategies and Implications

24 July 2024
9:30 AM – 10:00 (AEST)

Where to find Energeia and Ezra Beeman

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  - Energeia-USA.com

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Watch for a follow-up email with recording and presentation links to share

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