The Value of Dispatchability and Earnings-at-Risk of Electricity Generators under Energy Transition

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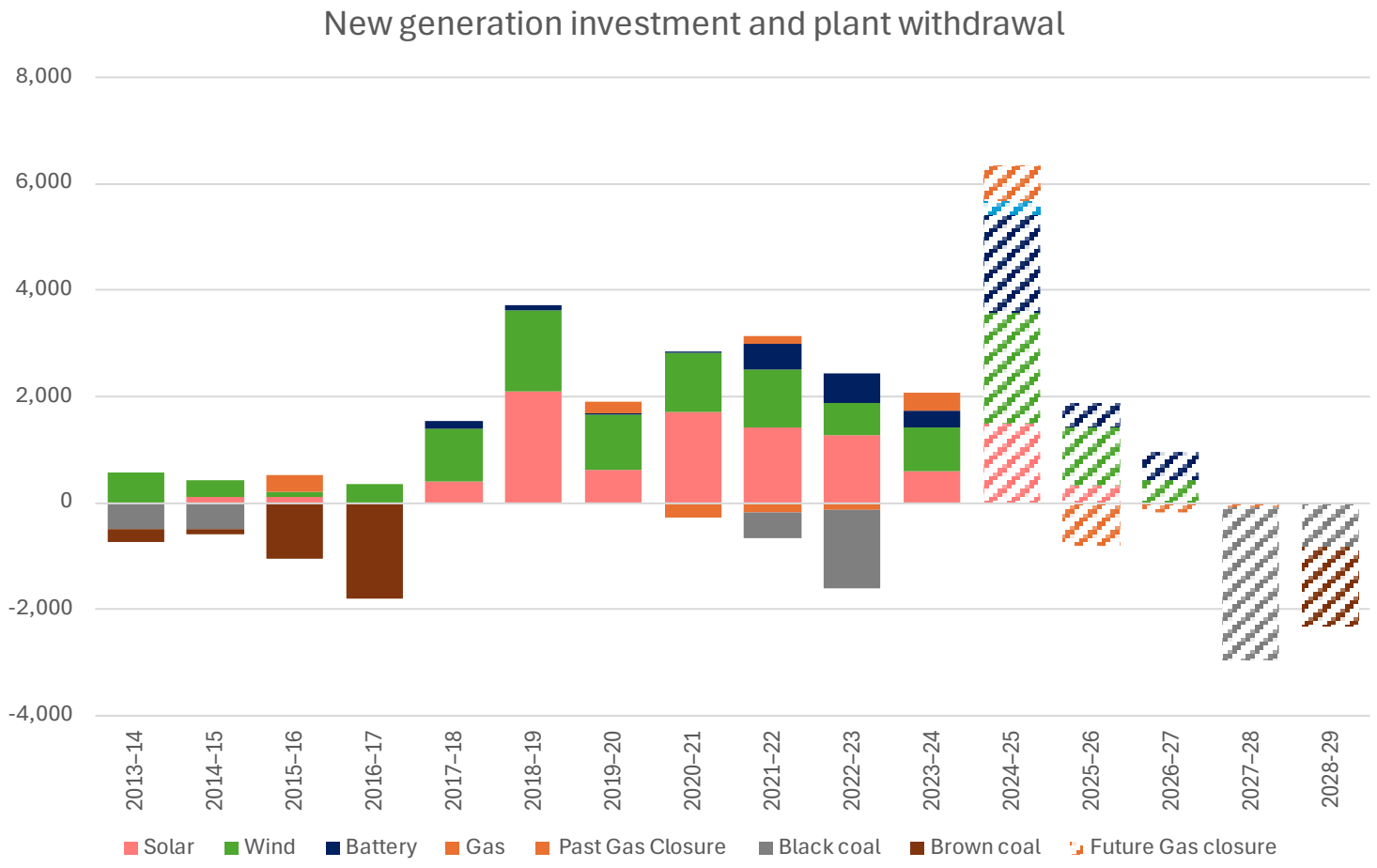
The Energy Transition



SOURCE: AER (2024)

Motivation

- Dispatchable generators such as coal and gas fired stations
  - high volatility of VRE production substantially influences wholesale prices and the residual demand for other generators
  - decision-making on entering or exiting the market
  - "*Investment is needed urgently. New generation, storage and firming must be in place before coal power stations retire, and to meet Australia's growing demand for electricity*." (AEMO, 2024)

- Non-dispatchable VREs
  - evaluating the uncertainty and profitability of new investment
  - appropriate pricing of long-term contracts such as Power Purchase Agreements

Objectives

- This study aims to provide a comprehensive understanding of profitability and risk profiles for different generation assets and technologies

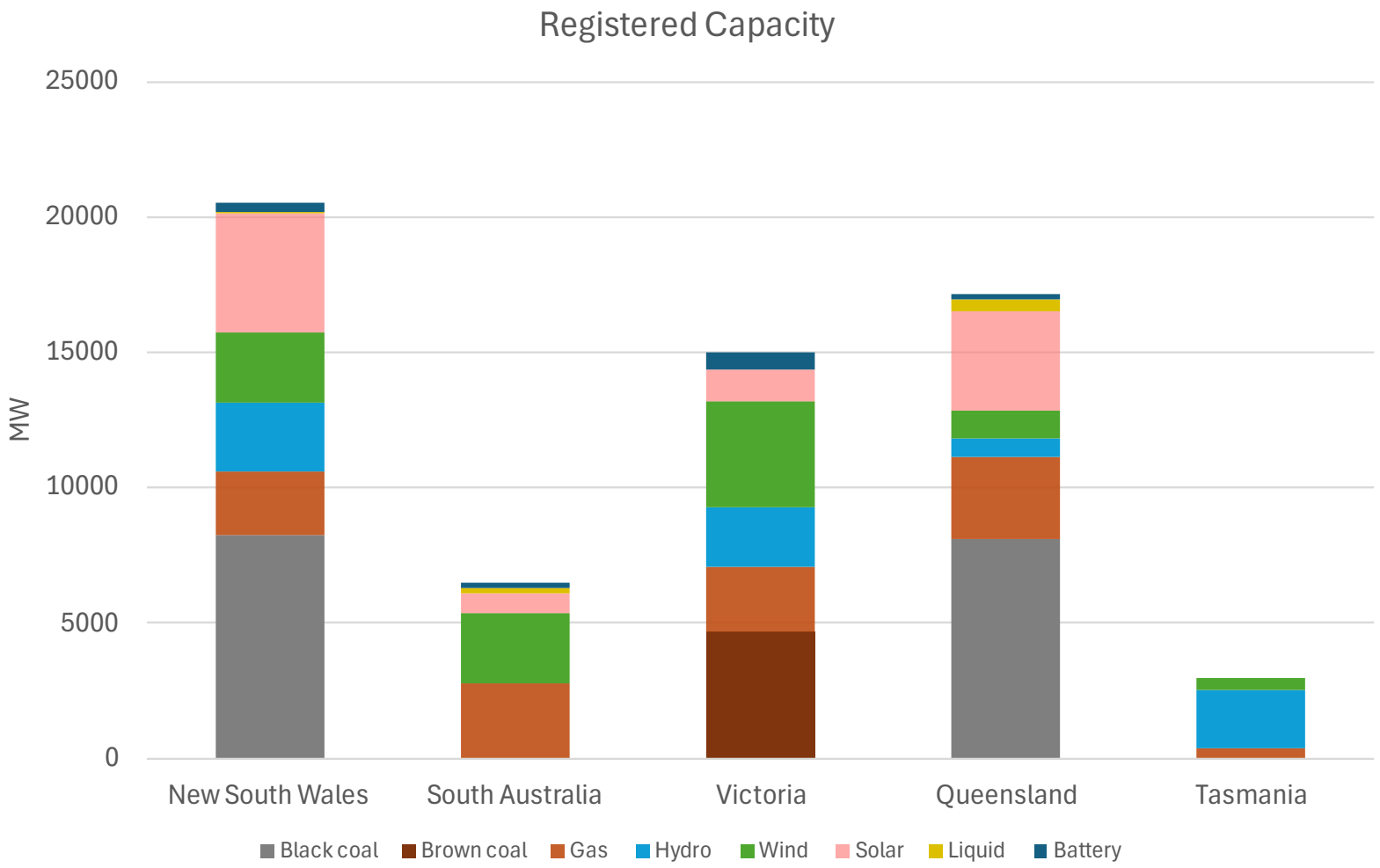
- We evaluate the profitability of each generation technology regarding
  - **dispatch-weighted price (DWP)** it receives
  - the **upside potential of earnings** it can achieve

- We quantify and compare investment risks for different generation technologies
  - **earnings-at-risk (EaR)**: it places an emphasis on measuring the variability in the accumulated revenues obtained by a power plant over a defined time period

The Australian National Electricity Market (NEM)

- One of the world's longest interconnected power systems, containing 5 states
- **Trading:** generators **offer** to supply the market with specified amounts of electricity at specified prices for each **5 minutes** and can re-submit the offered amounts at any time.
- **Non-storable nature of electricity**: supply and demand have to be instantaneously balanced 24/7
- **Volatile market**: prices are capped at a maximum of $17,500/MWh, with a price floor of –$1,000/MWh.
- **Risk management**: NEM participants typically manage the financial risk associated with the significant degree of spot price volatility by using different financial contracts (exchange-traded or OTC).

Institutional Background (cont.): Generation technologies in the NEM

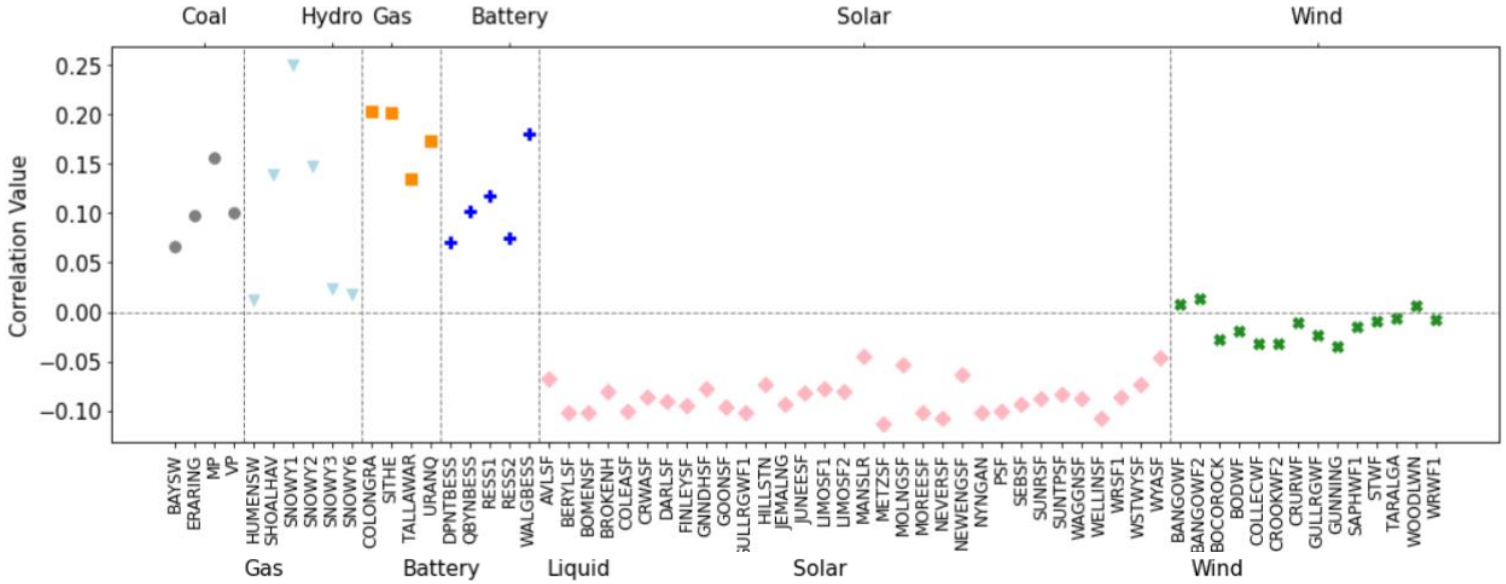


SOURCE: AER (2024)

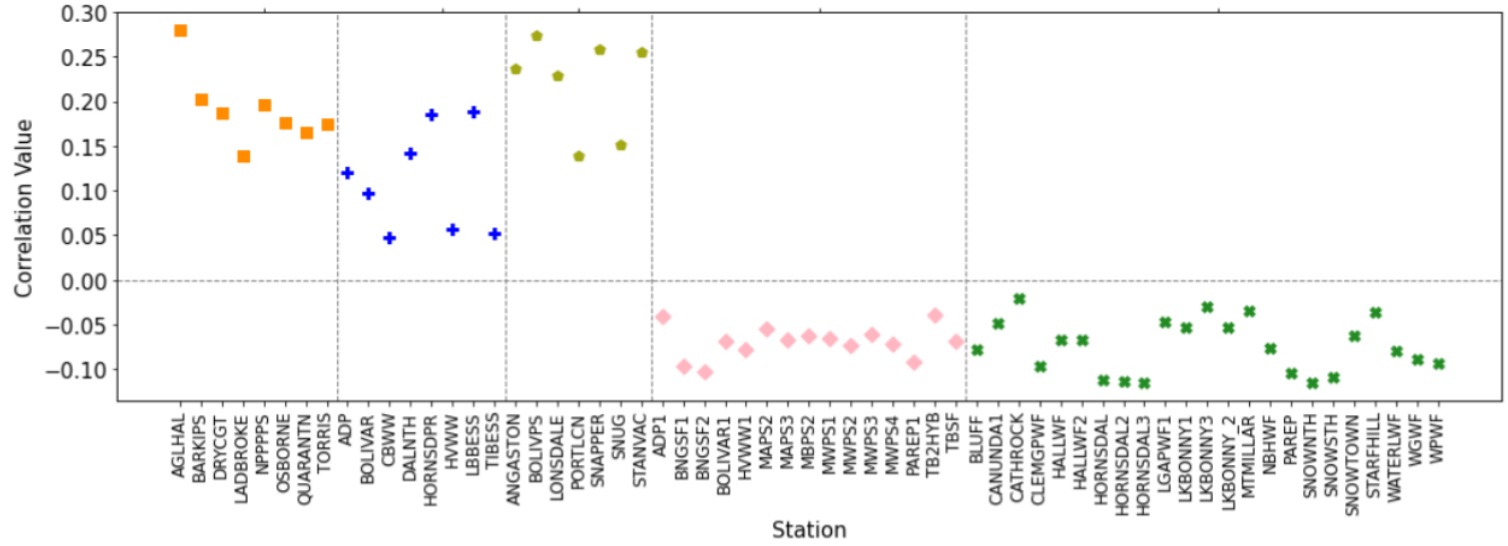
The Australian National Electricity Market (cont.):

Generation technologies – correlation with spot price

(a) NSW



(b) SA



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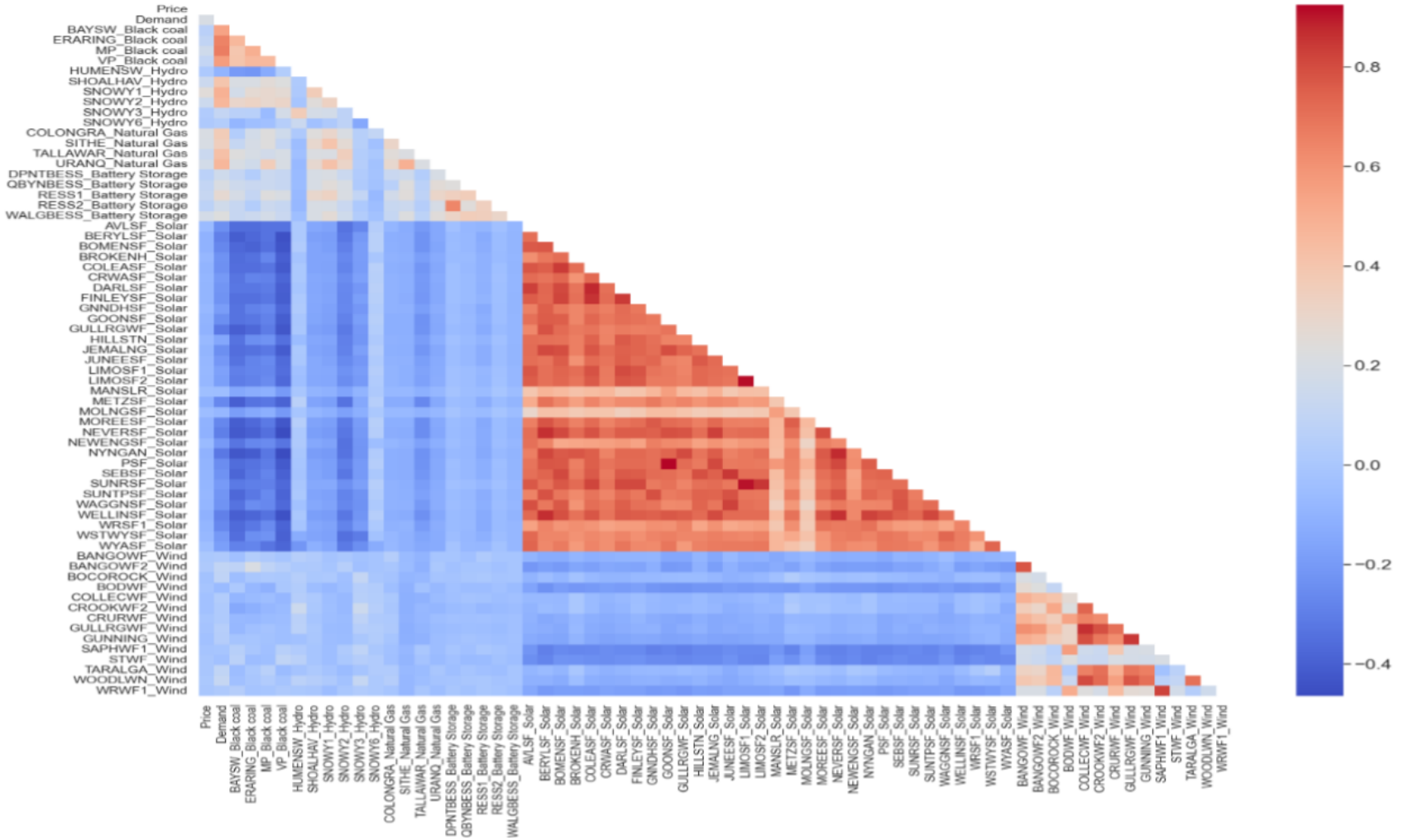
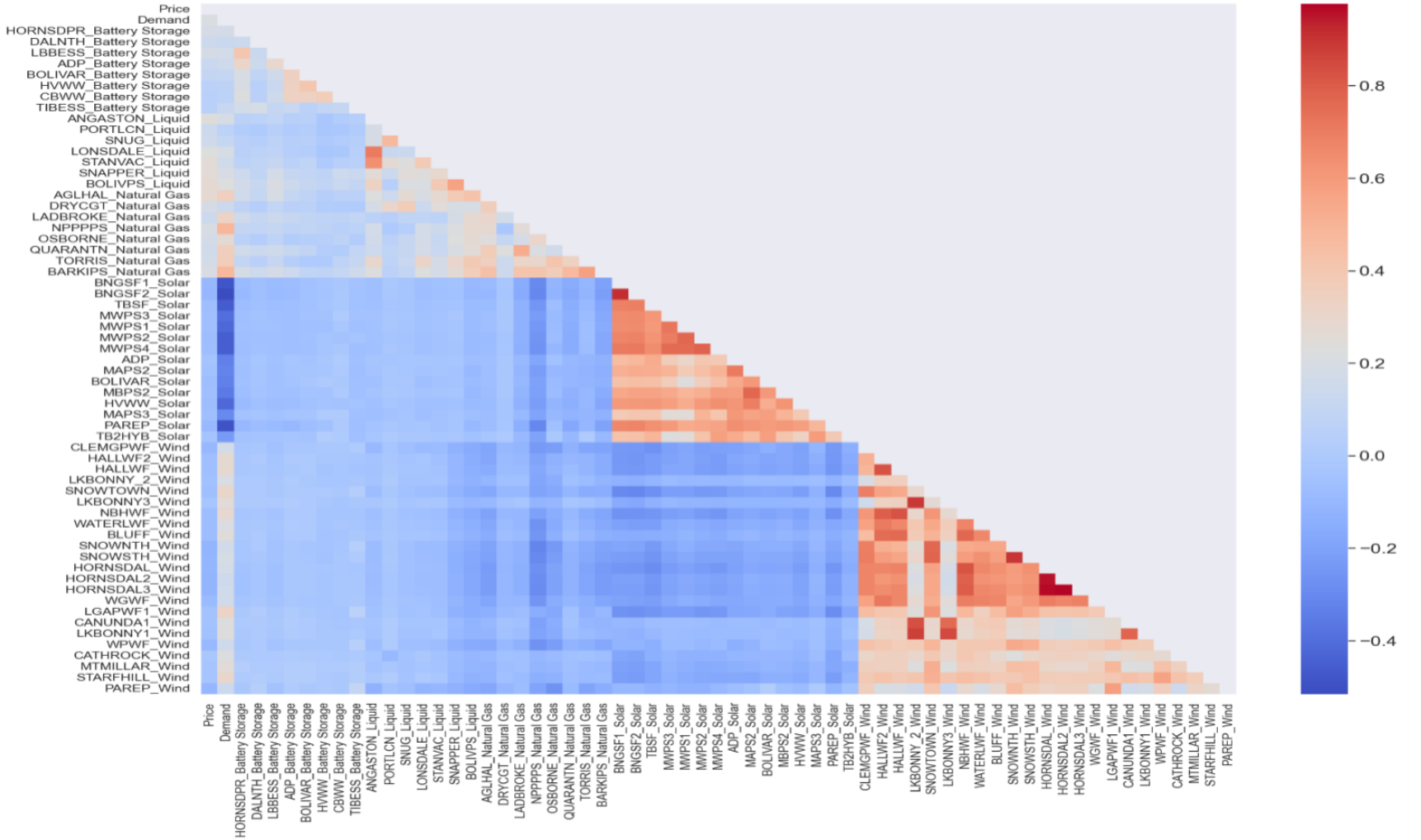
The Australian National Electricity Market (cont.):

Correlation between generators (NSW)



The Australian National Electricity Market (cont.):

Correlation between generators (SA)

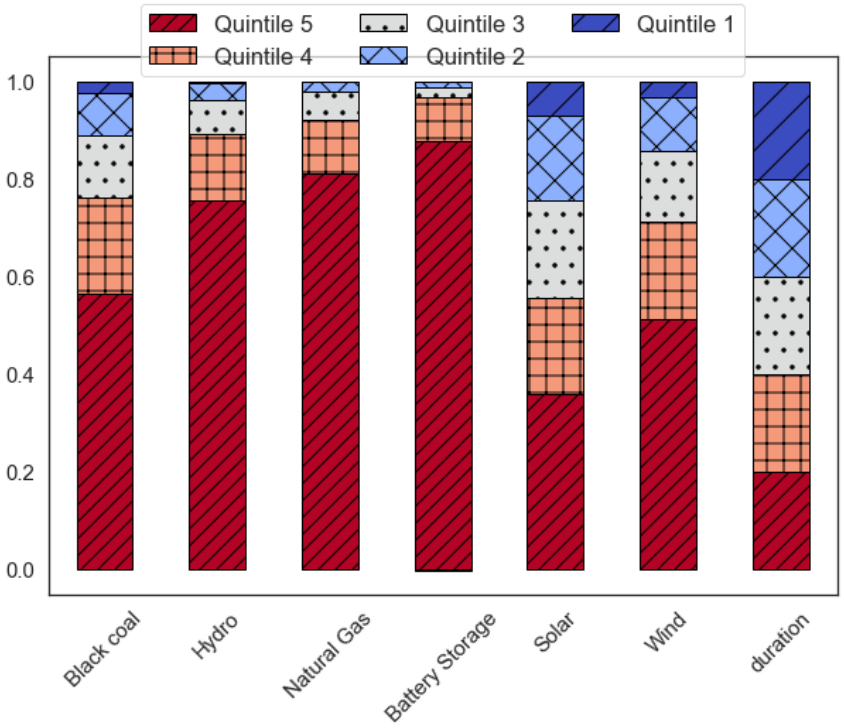


The Australian National Electricity Market (cont.):

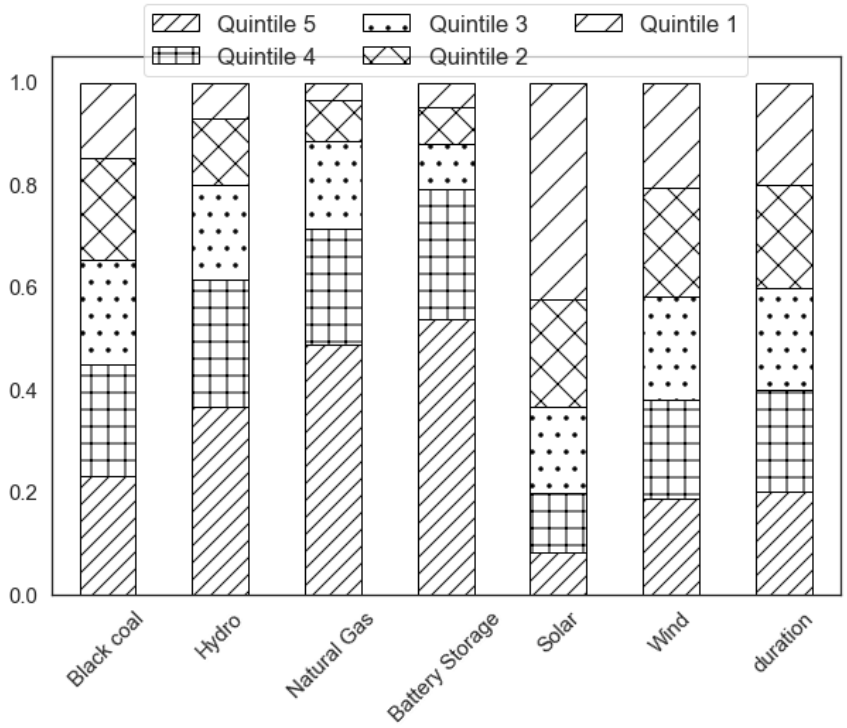
Generation technologies – source of earning (NSW)

- **Price quintiles: $53.55 (Q1) $72.84 (Q2) $100.81 (Q3) $158.99 (Q4) $16,600 (Q5)**

(a) Earnings at different price levels



(b) Dispatch at different price levels

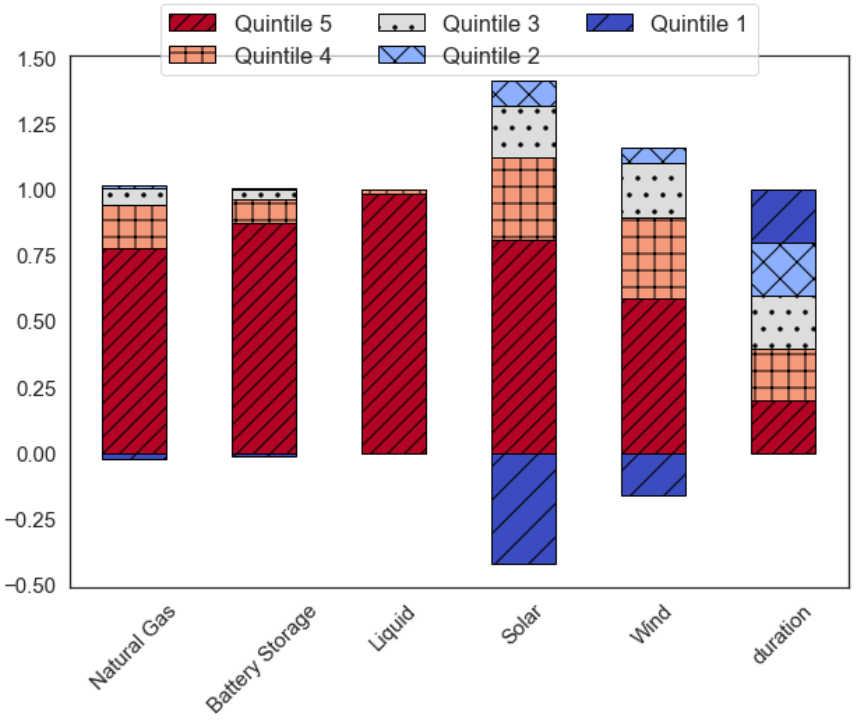


The Australian National Electricity Market (cont.):

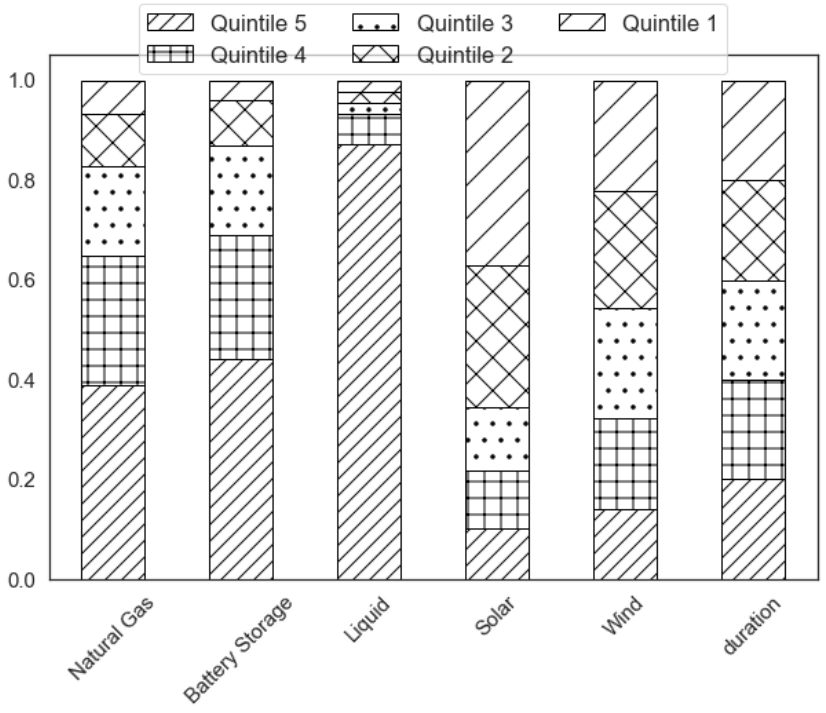
Generation technologies – source of earning (SA)

- **Price quintiles: -$7.11 (Q1) $47.04 (Q2) $92.44 (Q3) $168.51 (Q4) $16,600 (Q5)**

(a) Earnings at different price levels



(b) Dispatch at different price levels



Related Literature

1. NPV, IRR and LCOE estimates for energy investment evaluation
   - Different risk factors are simulated
   - Policy uncertainty (Williges et al. , 2010; Yang et al., 2010; Kitzing, 2014; Kitzing and Weber, 2014; Gatzert and Vogl, 2016)
   - Geographies, weather factors (Kaldellis and Gavras, 2000; Montes and Martín, 2007; Cutler et al., 2011; Biggins et al., 2023)

2. Optimising a portfolio of energy plants (Muñoz et al., 2009; Westner and Madlener, 2010; Arnesano et al., 2012; Lynch et al., 2013; Cucchiella et al., 2017; Zhang et al., 2018; Gallardo et al., 2020)

3. Market value of different types of power plants; impacts on market outcomes
   - Flexibility premium (Hirth, 2013, 2016; Hirth and Radebach, 2016; Eising et al., 2020; Prol et al., 2020; Rai and Nunn, 2020)
   - Cannibalization effect (Prol et al., 2020; Gonçalves and Menezes, 2022; Csereklyei et al., 2023; Reichenberg et al., 2023)

Methodology - dispatch-weighted price (DWP)

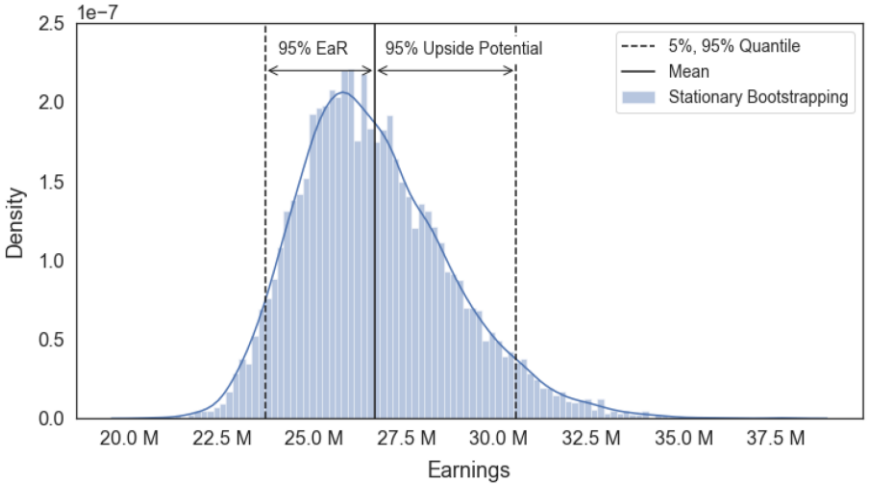
$$DWP_T^s = \frac{\sum_{t=1}^{T} P_t \times Q_t^s}{\sum_{t=1}^{T} Q_t^s}$$

- DWP_T^s denotes the dispatch-weighted price for station *s* over time *T*
- P_t denotes the regional spot price at time *t*
- Q_t^s denotes the dispatched load of station *s* at time *t*

Methodology - EaR and Upside Potential

$$EaR_T^s = \frac{\mathbb{E}(E_T^s) - q_\alpha^s}{\mathbb{E}(E_T^s)}$$

$$Upside\ Potential_T^s = \frac{q_{1-\alpha}^s - \mathbb{E}(E_T^s)}{\mathbb{E}(E_T^s)}$$

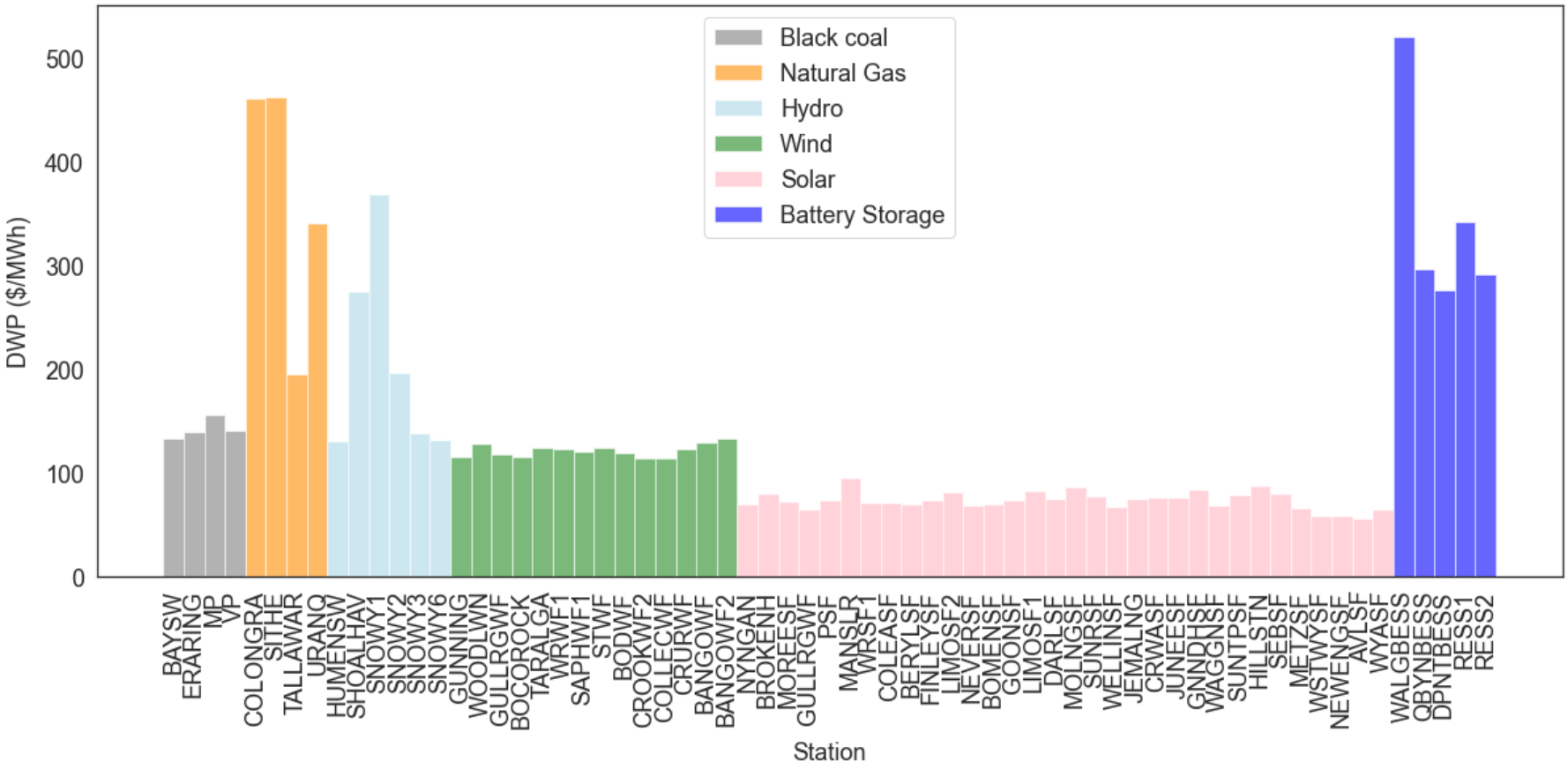


- EaR_T^s denotes the earning-at-risk for station *s* over time *T*
- E_t denotes the earnings of station *s* over time *T*
- q_α^s and $q_{1-\alpha}^s$ denote the quantiles corresponding to the selected confidence level $(1-\alpha)$
- A stationary bootstrap procedure (Politis and White, 2004; Patton et al., 2009) is applied to simulate the price-load pair

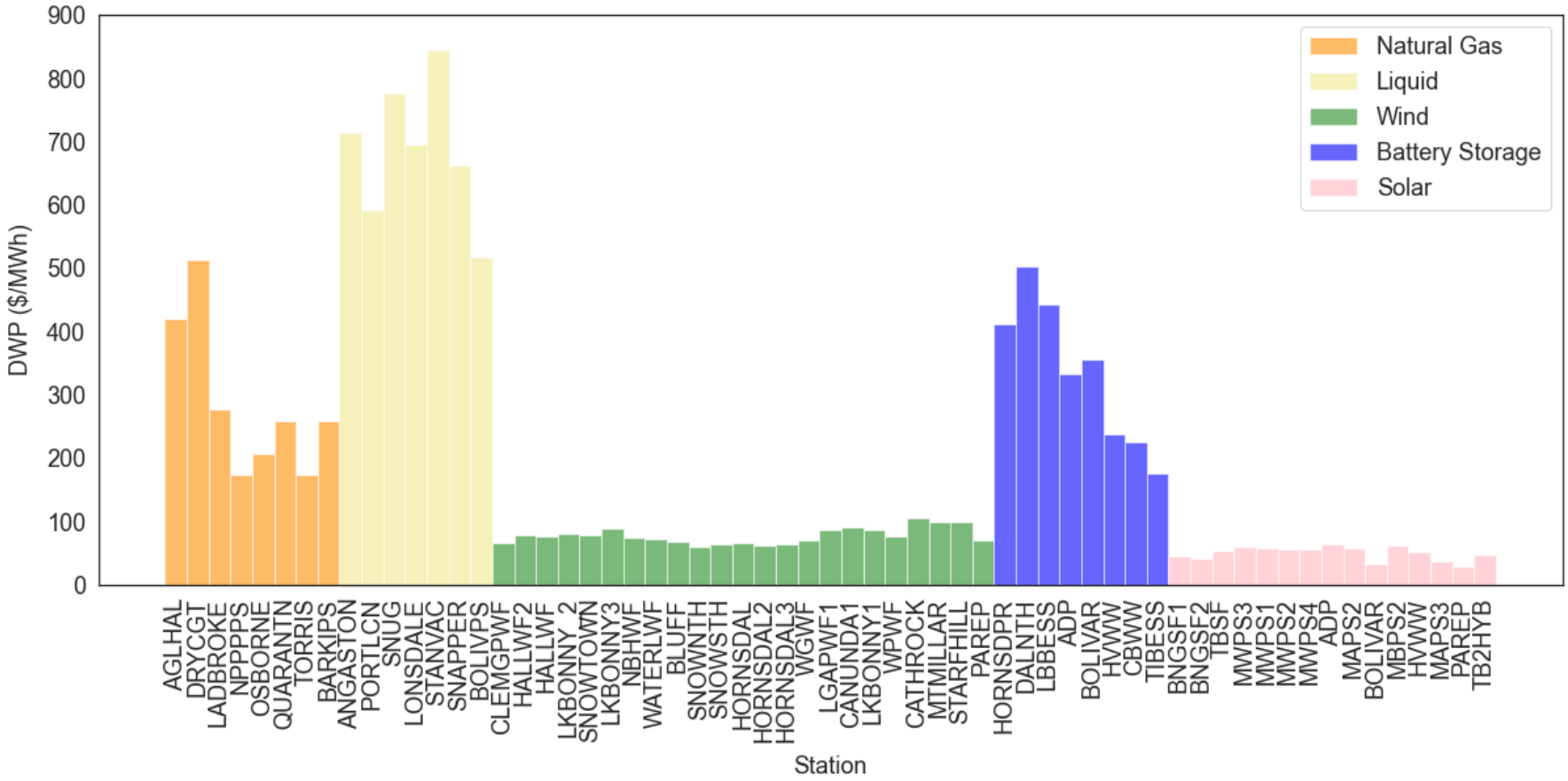
The Data

- Intra-day spot prices and dispatched load by station
  - Frequency: 5-Minute
  - Markets: NSW and SA
  - 126 Stations: 65 in NSW and 61 in SA
  - Time period: 01/07/2021 – 30/06/2024
  - Data source: Australian Energy Market Operator (AEMO)
  - We simulate full-year, spring, summer, autumn and winter DWPs and earnings for each station

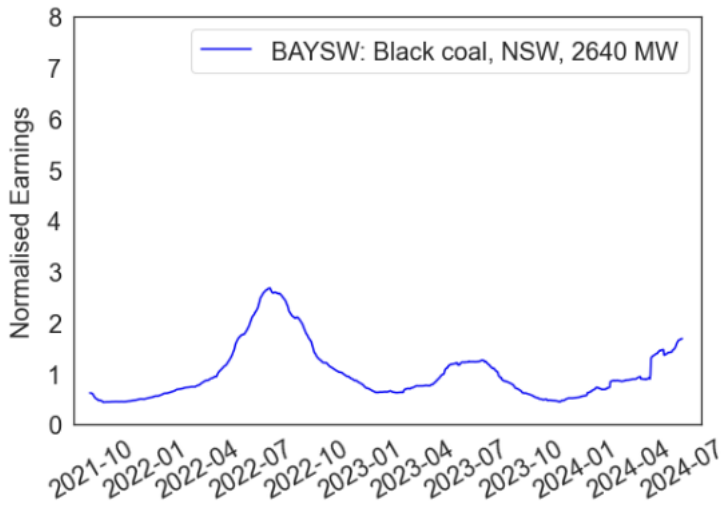
Empirical results:
Actual DWPs for stations in NSW

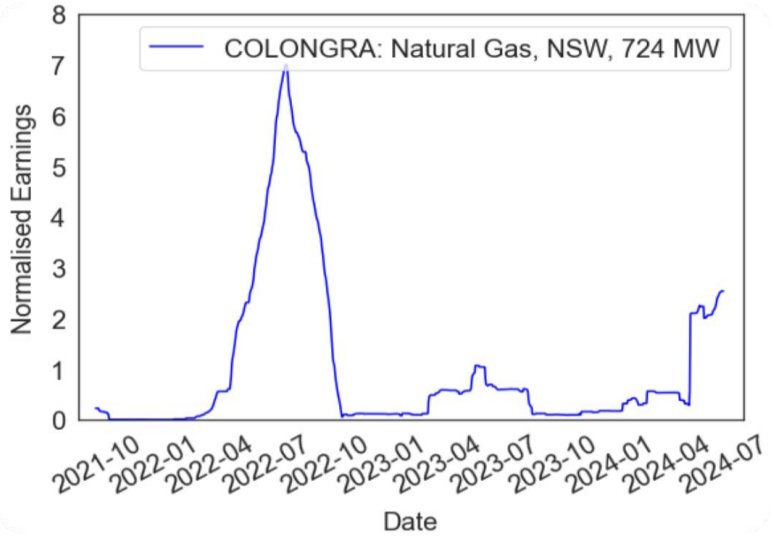


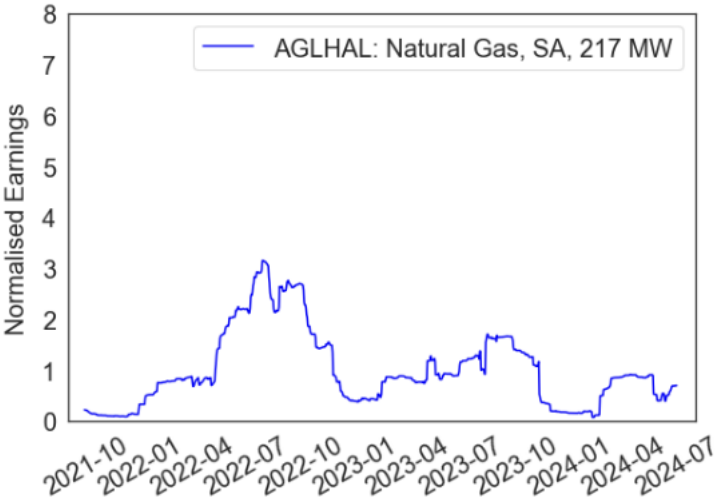
Empirical results (cont.): Actual DWPs for stations in SA

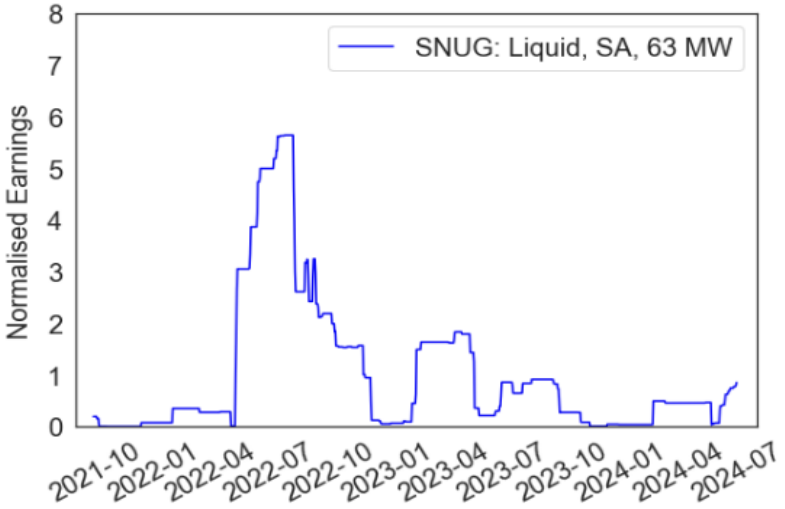


Empirical results (cont.): Earnings of single stations (3-month rolling)

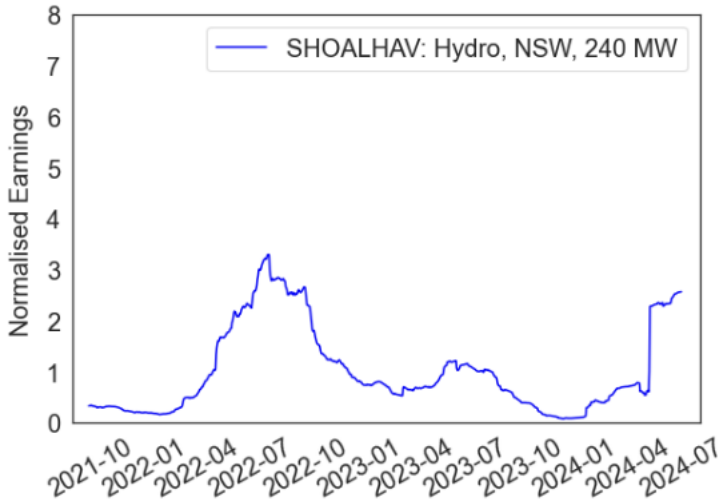


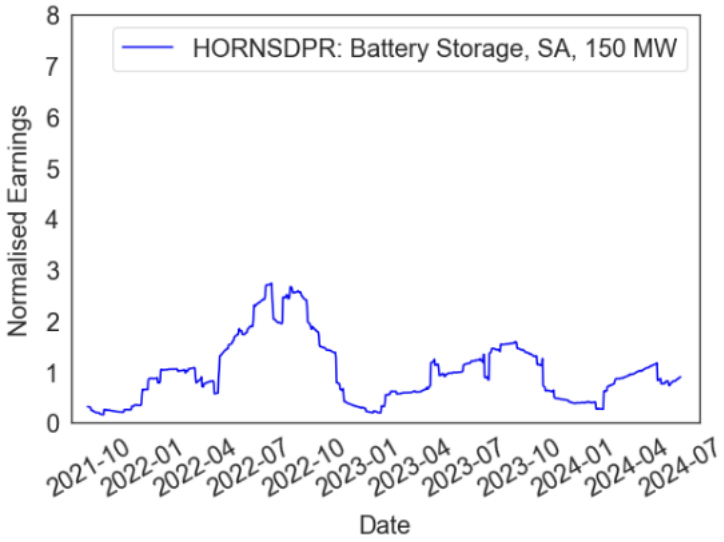


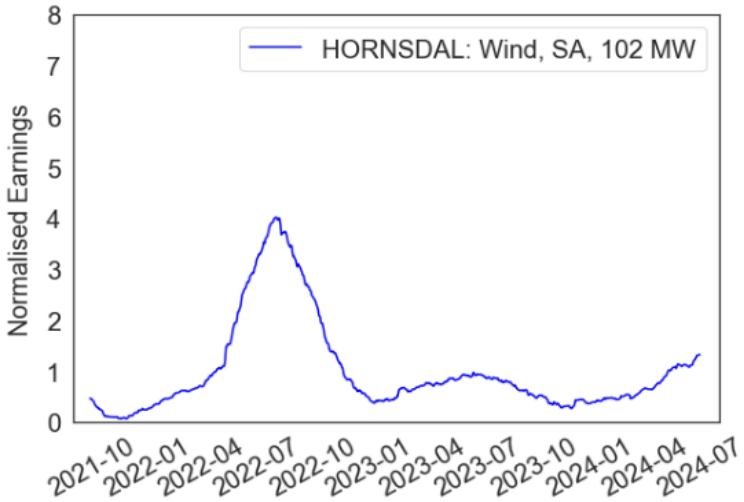


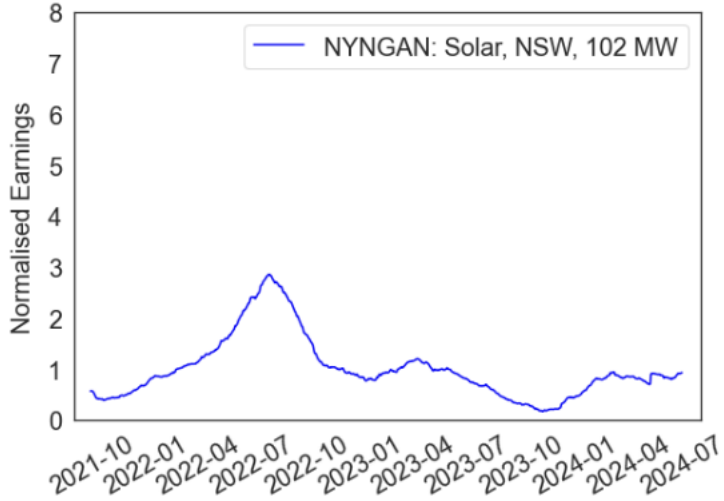


Empirical results (cont.): Earnings of single stations (3-month rolling)

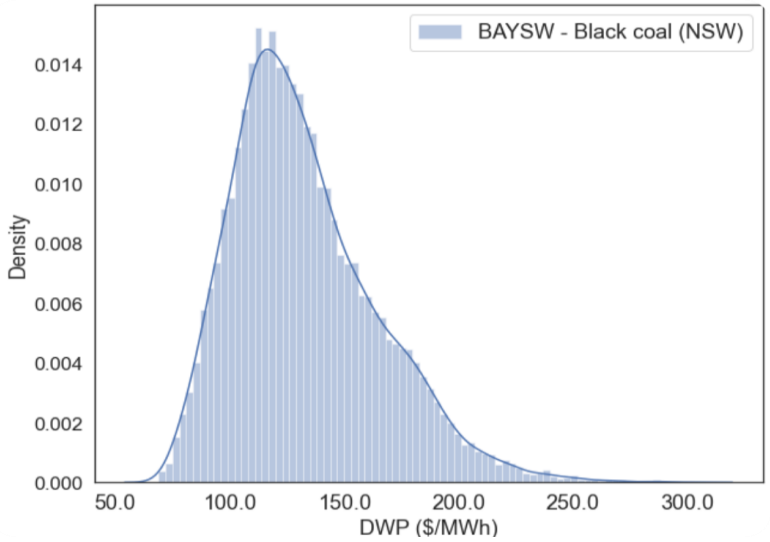


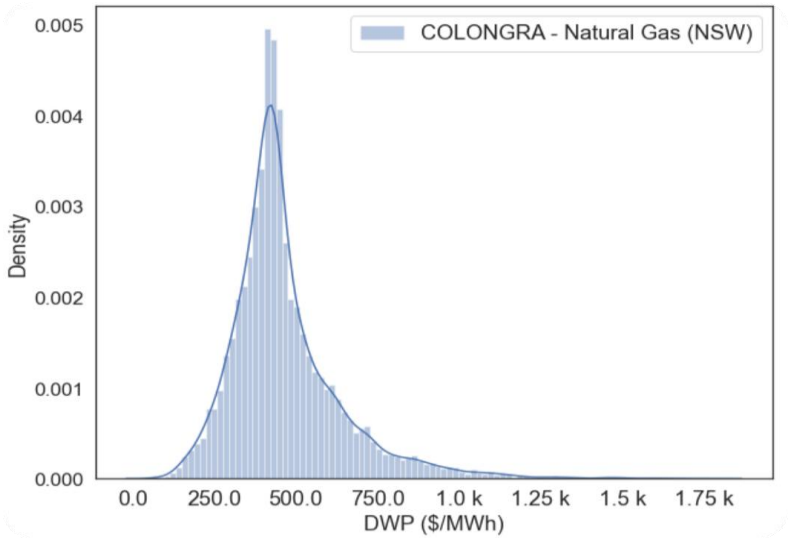


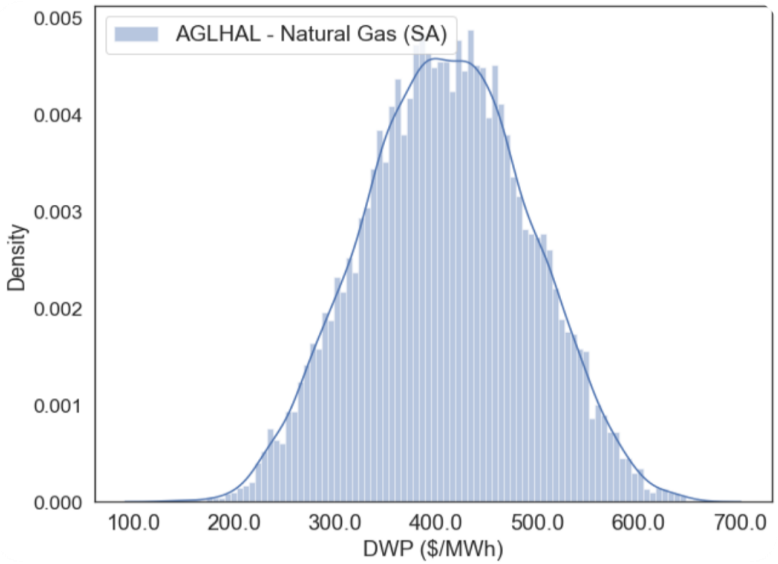


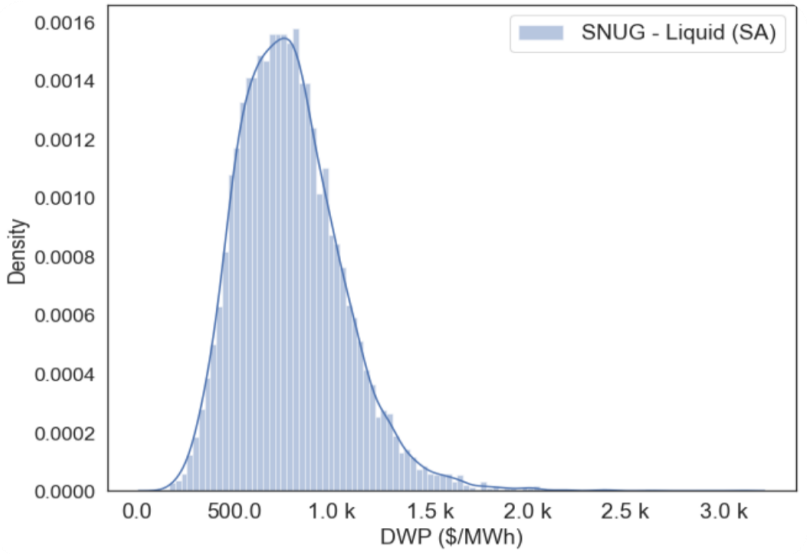


Empirical results (cont.): Simulated 1-year DWPs for stations

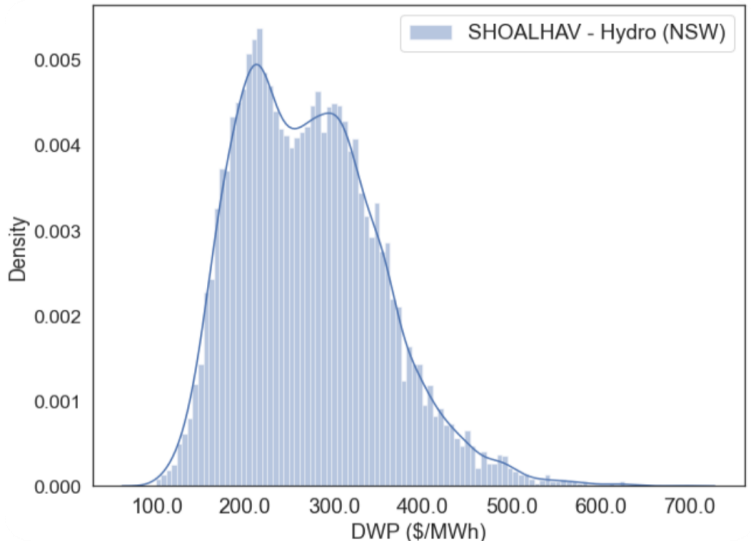


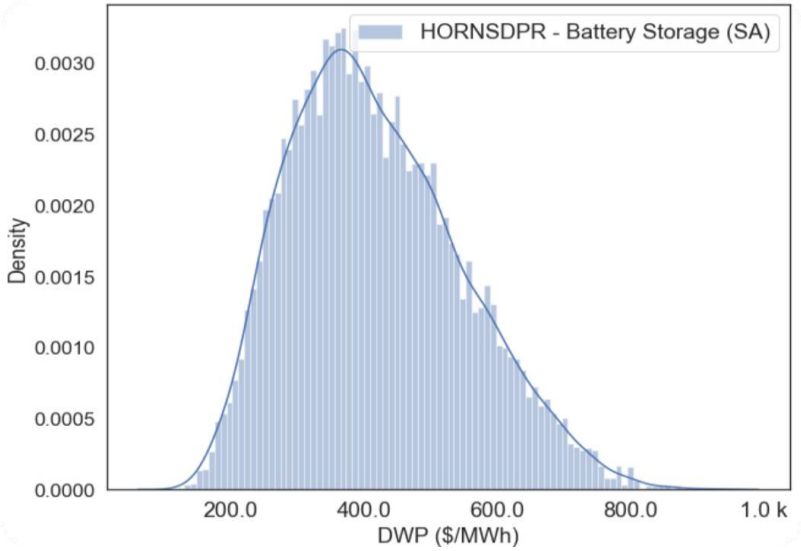


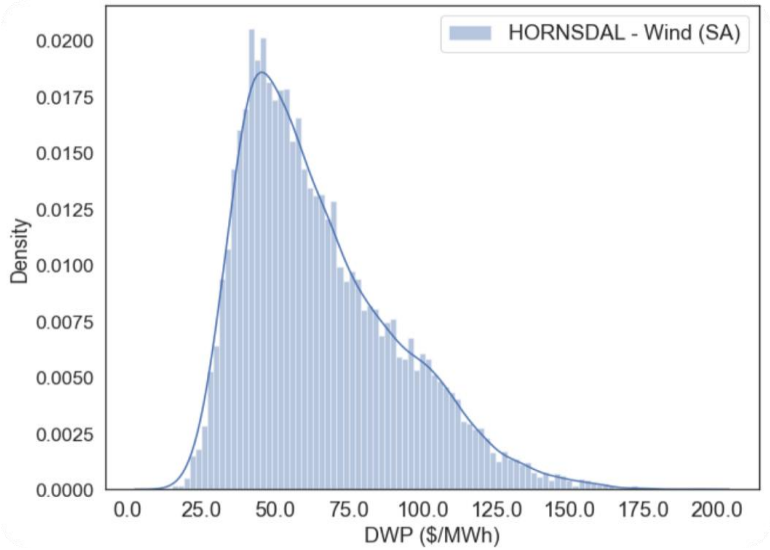


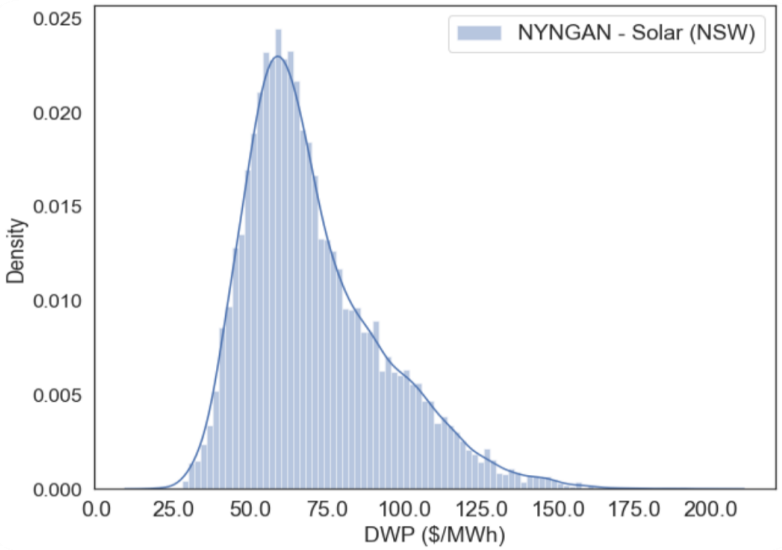


Empirical results (cont.): Simulated 1-year DWPs for stations









Empirical results (cont.): Distributional properties of simulated DWPs - NSW

Technology	Mean	Std.	Skew.	Kurt.	Coefficient of variation	Quartile Coefficient of Dispersion
Solar	**73.12**	18.09	0.865	1.174	0.244	0.1559
Wind	**121.03**	36.53	0.8854	0.3526	0.3025	0.2134
Black coal	**141.91**	36.82	0.8529	0.4563	0.2590	0.1777
Hydro	**205.15**	65.08	0.8161	0.4807	0.3203	0.2315
Battery	**332.71**	71.75	0.4348	0.0032	0.2123	0.1600
Natural Gas	**360.33**	112.69	0.9511	1.9415	0.3023	0.1949

1: Coefficient of variation (CV) (Everitt and Skrondal, 2002) is a measure of relative standard deviation which is defined as the ratio of standard deviation to the mean. It reflects the variability of data in relation to the mean value.
2: Quartile Coefficient of Dispersion (Bonett, 2006) measures the dispersion of a distribution using quartiles. It provides similar information to CV and is calculated as $\frac{Q_3-Q_1}{Q3+Q1}$, where Q_1, Q_3 are the first and third quartiles.

Empirical results (cont.): Distributional properties of simulated DWPs - SA

Technology	Mean	Std.	Skew.	Kurt.	Coefficient of variation	Quartile Coefficient of Dispersion
Solar	**48.85**	20.12	0.9071	1.1803	0.4168	0.2749
Wind	**73.08**	22.56	0.8013	0.3013	0.3136	0.2230
Natural Gas	**278.6**	67.03	0.3444	-0.2436	0.2508	0.1802
Battery Storage	**349.22**	118.08	1.5522	13.3377	0.3173	0.1903
Liquid	**804.6**	339.28	1.0116	1.4919	0.4156	0.2897

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Empirical results (cont.):
Simulated earnings, EaRs and upside potentials - NSW

Technology	Skew	Kurt	Coefficient of variation	Quartile Coefficient of Dispersion	99%EaR	95%EaR	95% upside potential	99% upside potential
Solar	0.2116	0.3517	0.0134	0.1455	42.09%	31.82%	37.40%	53.23%
Wind	0.3416	0.9498	0.6792	0.2353	49.88%	41.44%	64.57%	99.53%
Black coal	0.2869	0.8097	0.4553	0.1982	46.04%	37.50%	53.81%	81.58%
Hydro	0.372	0.9281	0.7688	0.2602	55.83%	46.31%	70.59%	107.19%
Battery	0.2558	0.7828	0.8179	0.1816	40.46%	33.74%	47.51%	74.06%
Natural Gas	0.4893	0.9927	0.9826	0.353	70.09%	59.86%	92.33%	144.90%

Empirical results (cont.):
Simulated earnings, EaRs and upside potentials - SA

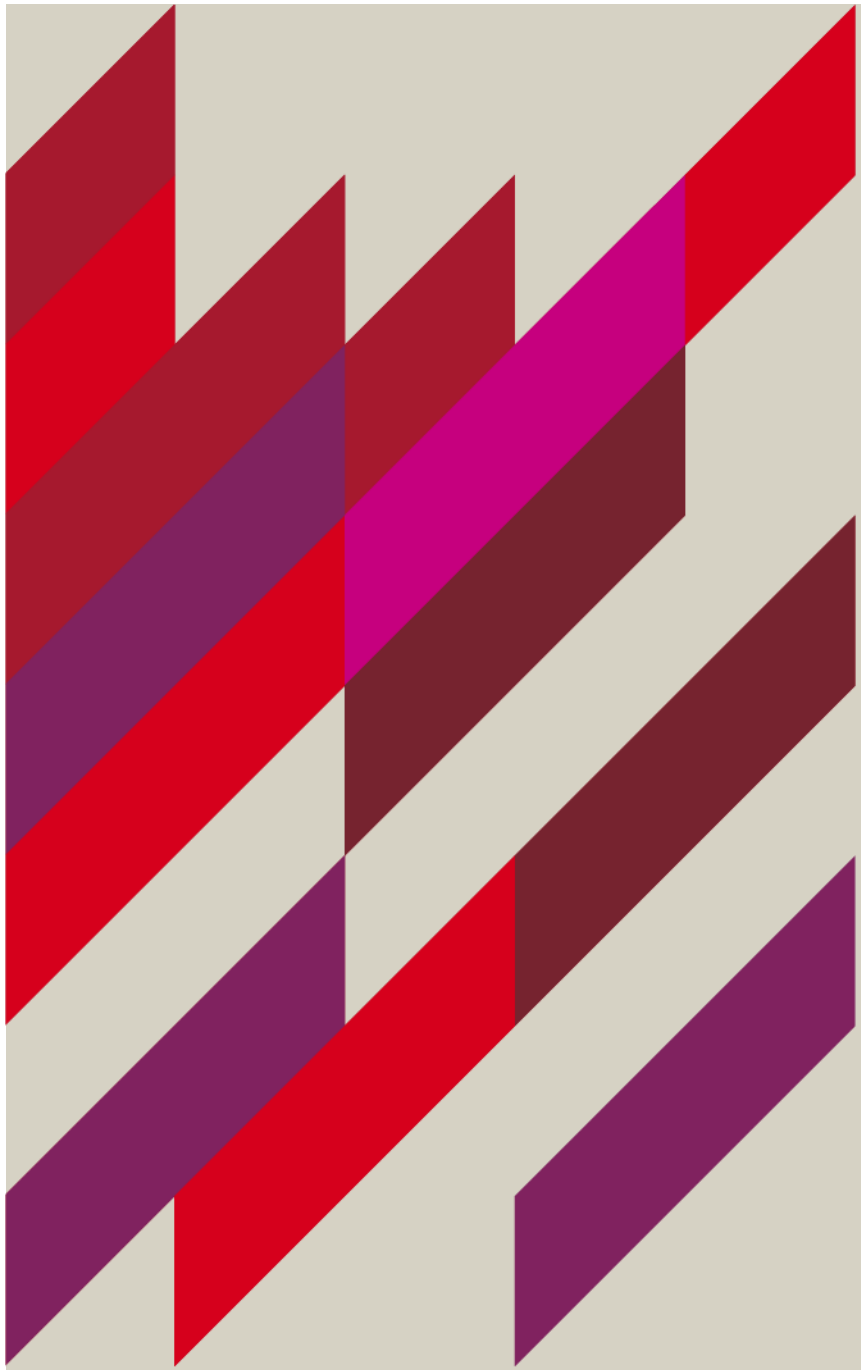
Technology	Skew	Kurt	Coefficient of variation	Quartile Coefficient of Dispersion	99%EaR	95%EaR	95% upside potential	99% upside potential
Solar	0.3830	0.4825	0.0583	0.2694	71.68%	56.12%	69.00%	100.33%
Wind	0.3364	0.8976	0.5891	0.236	48.69%	40.62%	63.92%	96.90%
Natural Gas	0.3969	0.7578	0.457	0.2781	64.43%	53.18%	74.09%	110.99%
Battery	0.2467	0.5029	0.3087	0.1703	47.15%	36.67%	43.95%	65.29%
Liquid	0.5894	0.9781	0.9334	0.4277	76.68%	66.60%	111.13%	178.16%

Conclusions

- Flexible generators such as hydro, natural gas, and liquid stations
  - stronger correlation with spot prices
  - higher DWPs
  - higher upside potential of earnings but also high EaRs

Conclusions (cont.)

- VRE generations based on wind and solar
  - low DWPs and upside potential of earnings, low EaRs
  - increasing cannibalization effects: higher penetration reduces the value of their own generation
  - opportunity for the combination of VRE generations and other dispatchable renewable energy/storage facility to achieve overall higher market value
- Coal generation
  - low DWPs and upside potential of earnings, low EaRs
  - Additional cheaper renewable generators entering the market could further reduce their profitability



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Thank you!