

Electricity Advisory | November 2020

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

Modelling for Greenpeace Australia Pacific

A large, white, stylized number '1' is centered on a solid blue rectangular background. The number has a thick stroke and a slight curve at the top.The word 'BACKGROUND' is written in white, uppercase, sans-serif font, centered on a solid blue rectangular background. The background of the entire image is a grayscale photograph of a power line tower and its associated infrastructure.

BACKGROUND

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

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BACKGROUND

In August 2019, AGL announced a delayed closure schedule for its Liddell coal-fired power station in New South Wales (NSW), with the first unit to close in April 2022 (500 MW), followed by the remaining three units in April 2023 (1,500 MW), supporting system reliability throughout the summer of 2022-23.

AGL has outlined plans to repurpose the existing infrastructure at the Liddell site to support the construction of new energy storage capacity, beginning with a 150 MW battery installation before the summer of 2023-24 (with planning approval up to 500 MW). By June 2024, AGL is targeting the addition of 850 MW of new large-scale storage capacity, as well as 350 MW of coordinated distributed energy resources, such as residential battery storage and demand response capacity, and up to four 50 MW batteries in the NSW Riverina.

In mid-September 2020, the Federal Government warned of higher electricity prices and reliability risks unless new dispatchable capacity is built to replace Liddell, providing the market with an ultimatum to reach a final investment decision on 1,000 MW of generation by April 2021, available for the summer after Liddell closes (2023-24).

If by the end of the first quarter (Q1) of 2021 the private sector has not committed to meet the 1,000 MW target, the government has proposed to develop a 1,000 MW gas power plant at Kurri Kurri in the Hunter Valley via the government-owned Snowy Hydro.

More recently, the government has suggested that Snowy Hydro could instead develop a 250 MW gas generator in the Hunter Valley, supported by AGL's proposed 250 MW Newcastle Gas Peaker at Tomago, and EnergyAustralia's proposed 300-450 MW upgrade to its Tallawarra gas facility, helping to fill the government's 1,000 MW target.

In November, the NSW government announced its Electricity Infrastructure Roadmap, providing a centralised planning pathway to replace the state's aging energy infrastructure via contracts for private sector investment in renewable energy and large-scale storage capacity.

The plan, which reinforces NSW's path towards its net-zero emissions goal by 2050, provides policy certainty and market signals for investment in Renewable Energy Zones (REZs), both for renewable generation and transmission networks. This has cast doubt on the need for additional investment in gas-fired generation, with the Roadmap proposing the development of 12 GW of new transmission capacity through the Central-West Orana (CWO), New England and South West REZs, and 2-3 GW of firm capacity by 2030 ahead of future coal-fired facility closures.

Supported by the Emerging Energy Program, the NSW government therefore aims to ensure sufficient capacity is available to fill the gap left by the closure of Liddell, while supporting the longer-term decarbonisation of the NSW electricity system.

ABOUT THIS REPORT

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

ABOUT THIS REPORT

RepuTex has been engaged by Greenpeace Australia Pacific (Greenpeace) to analyse the impact of scenarios to replace the Liddell power station on wholesale electricity prices, energy reliability and greenhouse gas (GHG) emissions through the financial year ending (FY) 2026.

Specifically, analysis considers the relative impact of the addition of 1,000 MW of gas-fired capacity on the NSW electricity market (prior to the summer of 2023-24) versus the addition of 1,000 MW of zero-emissions dispatchable capacity, such as large-scale battery storage and aggregated distributed energy resources (virtual power plants and demand response capacity).

Analysis considers the following cases:

1. **Reference Case:** Analysis of NSW market shape and wholesale electricity prices assuming only committed investments are made under current state and federal policy, including the Emerging Energy Program.
2. **Market scenario:** The addition of 1 GW of battery and demand side participation by the summer of 2023-24 leading into the NSW Electricity Infrastructure Roadmap.
3. **Gas scenario:** The addition of 1GW of gas-fired generation by the summer of 2023-24.

Outcomes model the impact of each scenario on cumulative capacity changes, energy generation mix, GHG emissions, energy reliability and annual average wholesale electricity prices through FY26.

MODELLING APPROACH

In delivering this project, we utilise our proprietary National Electricity Market Renewable Energy Simulator (NEMRES), which calculates annual generation and capacity expansion decisions in each region of the NEM based on intra-hourly dispatch modelling, imitating the Australian Energy Market Operator's (AEMO's) dispatch engine. For more information, refer to Appendix A.

A common set of assumptions is applied in each case, with different investment settings overlaid in each scenario to provide a materially different outcome. Common assumptions include:

- » **Fossil fuel prices:** Coal prices escalate at an average rate of 1.5% annually. 2020-21 gas prices are assumed to average \$5.73 in Sydney escalating an average 4% per annum over the modelling period to \$7.06 in 2025-26.
- » **Snowy 2.0:** The government's proposed 2GW Snowy 2.0 pumped hydro project is assumed to be fully commissioned in 2025.
- » **Announced closures and capacity additions:** Announced retirements are assumed to occur (e.g. last 3 units of Liddell in April 2023), as is new capacity financially committed as of July 2020, and capital projects awarded by the Emerging Energy Program.
- » **Energy Security Target:** A NSW Energy Security Target (EST) is set equivalent to peak demand surpassed one in every ten years (10 per cent probability of exceedance) plus a reserve margin to cover the unavailability of

the two of the largest NSW generating units. AEMO forecasts 1-in-10-year peak demand for the summer of 2020-21 to be 13,786 MW, rising to 14,406 MW by 2025-26. The firm supply rating for each of the two largest generating units in the state is currently 680 MW (Eraring). Accordingly, the EST for 2020-21 is anticipated to be 15,146 MW. As the market recovers from pandemic impacts this year, maximum demand is estimated to increase next year, and then resume a slight upward trend for the remainder of the decade, proportionally increasing the EST.

- » To meet the EST, NSW is required to have a minimum level of firm capacity available to continuously achieve the real-time balancing of supply and demand. Firm capacity can be shared across interconnected regions based on interconnector capabilities and coincident available capacity in neighbouring regions.
- » **Network assumptions:** Network developments are assumed to be undertaken to address network strength as new capacity comes online. This occurs in a staggered way, with actions implemented in stages to match AEMO's Integrated System Plan (ISP), e.g. the Central-West Orana REZ Transmission link, HumeLink and Project EnergyConnect.

Please refer to the following slide for comparative settings and assumptions for each scenario.

COMPARISON OF SCENARIOS

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

Figure A: Key assumptions for each modelled scenario

	REFERENCE CASE	MARKET SCENARIO	GAS SCENARIO
Average fuel prices	Coal prices escalate at an average rate of 1.5 per cent annually. 2020-21 gas prices are assumed to average \$5.73 in Sydney, escalating an average 4% per annum over the modelling period to \$7.06 in 2025-26.		
Snowy 2.0	Assumed to be committed and fully commissioned in 2025.		
Renewable energy targets	All existing state and federal renewable policy settings are assumed to be fulfilled, including the V-RET (40% by 2025; 50% by 2030), T-RET (100% by 2022), Q-RET (50% by 2030), CWO REZ transmission link, current DER and EE policies, and 26% reduction in emissions by 2030 (NEM).		
Announced closure and committed capacity additions	The first unit of Liddell to close by April 2022 (450 MW), remaining three units by April 2023 (1,350 MW). New capacity committed as of July 2020.		
NSW Electricity Infrastructure Roadmap	No – only announced capital projects under the NSW Emerging Energy Program	Yes - development of 12 GW of new transmission capacity through the Central-West Orana, New England and South West REZs, and 2-3 GW of new firm capacity by 2030.	No – only announced capital projects under the NSW Emerging Energy Program
Additional dispatchable capacity additions	-	1 GW of battery and demand side participation (such as large-scale battery storage, coordinated distributed energy resources and demand response capacity).	1 GW of gas-fired capacity
Energy Security Target	NSW is required to have a minimum level of firm capacity available to continuously achieve the real-time balancing of supply and demand to meet its EST. Firm capacity can be shared across interconnected regions based on interconnector capabilities and coincident available capacity in neighbouring regions.		
Network assumptions	Network developments are assumed to be undertaken to address network strength as new capacity comes online. This occurs in a staggered way, with actions implemented in stages, e.g. the Central-West Orana REZ Transmission link, HumeLink and Project EnergyConnect.	Further network developments from the Reference case are anticipated to be undertaken to integrate more Variable Renewable Energy (VRE), e.g. New England REZ Network Expansion; QNI Medium; Reinforcement of Sydney, Newcastle and Wollongong Supply; and VNI West.	Network developments are assumed to be undertaken to address network strength as new capacity comes online. This occurs in a staggered way, with actions implemented in stages, e.g. the Central-West Orana REZ Transmission link, HumeLink and Project EnergyConnect.



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SUMMARY OF KEY FINDINGS

KEY FINDINGS

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

CLOSURE OF LIDDELL WITHOUT REPLACEMENT COULD CAUSE WHOLESALe PRICES TO RISE

- » Liddell's closure without replacement is anticipated to tighten the NSW supply-demand balance during peak periods, with the reduced number of available coal-fired units forecast to result in a 36% increase in wholesale electricity prices between FY21-24.
- » As Snowy 2.0 and HumeLink are commissioned, additional capacity from southern NSW could alleviate the tight supply-demand balance, causing wholesale prices to decrease from FY24 to FY25-26.
- » The tightest years for NSW energy security are therefore estimated to be the two years after the closure of Liddell in April 2023, yet prior to the commissioning of HumeLink and Snowy 2.0 in 2025.
- » How the market, or the government, replaces the Liddell power station is expected to have considerable implications for energy reliability and wholesale electricity prices in NSW.

GAS GENERATION NOT REQUIRED TO SUPPORT ENERGY RELIABILITY IN NEW SOUTH WALES

- » While the supply-demand balance is forecast to tighten in FY24 and FY25, the NSW EST is not modelled to be breached in the Reference Case. The tight supply-demand balance during peak periods, however, is the largest driver of the wholesale price increasing in this Case.
- » Should 1,000 MW of zero-emissions capacity be added to the NSW system under the "Market Scenario", the addition of very fast charging and generation capacity is forecast to improve reliability in the two year period between the closure of Liddell and the commissioning of the Snowy 2.0 and HumeLink projects. The wider supply-demand balance is also projected to translate into lower wholesale prices relative to the Reference Case.
- » A similar effect is evident under the "Gas Scenario", where fast, long-duration generation capacity is also able to provide increased reliability in the two year period between the closure of Liddell and the commissioning of the Snowy 2.0 and HumeLink projects. This would also support lower wholesale electricity prices.

INVESTMENT IN ZERO EMISSIONS FIRM CAPACITY WILL LOWER WHOLESALe ELECTRICITY PRICES

- » The addition of 1,000 MW of dispatchable storage, such as large-scale battery storage, coordinated distributed energy resources (Virtual Power Plants) and demand response, is anticipated to reduce FY24 wholesale electricity prices by 12% below the Reference Case, with new dispatchable storage reducing peak pricing by shifting daytime energy generation beyond sunset, to compete for dispatch during the evening peak.
- » Under this scenario, NSW wholesale electricity prices are forecast to average \$54/MWh over 2021-26, declining to \$35/MWh in 2026.
- » The addition of 1,000 MW of new gas generation is also estimated to reduce wholesale electricity prices, yet not as far as zero emissions dispatchable capacity. Under this scenario, NSW wholesale electricity prices are expected to average \$57/MWh over 2021-26, declining to \$42/MWh in 2026.
- » While 1 GW of peaking gas is forecast to be beneficial to the system in terms of extended-duration reliability and lower maximum pricing, the long-term return on investment for new gas plants may ultimately be dependent on the closure of further coal-fired plants before replacement capacity is available. Comparably, battery capacity is modelled to be faster, more flexible and precise in responding to peak pricing and volatility events.



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RESULTS
REFERENCE CASE

RESULTS – REFERENCE CASE

LIDDELL RETIREMENT AND CURRENT POLICY

CHANGE IN CAPACITY AND FUEL MIX

Analysis under the Reference Case models announced closures and committed capacity additions as of November 2020.

This translates to 2 GW of generation exiting the market, with the first unit of Liddell to close in April 2022 (0.5 GW), and the remaining three units in April 2023 (1.5 GW). This is balanced by 2.6 GW of new large and small-scale renewable energy capacity being added to the NSW system by FY24, along with 278 MW of new dispatchable capacity. Under this scenario, new additions are driven by developers seeking to access limited transmission infrastructure; along with NSW policy, including the Emerging Energy Program.

The CWO REZ is assumed to add network capacity of 3 GW, with construction proposed to begin in 2022. This is anticipated to result in 1GW of large-scale renewable energy capacity by FY25. Project commissioning in all other NSW REZs is, however, expected to be constrained for the remainder of the decade as transmission access blocks further large-scale VRE development. In cumulative terms, the Reference Case estimates 10 GW of large and small-scale renewable capacity commissioned by 2026.

Black-coal capacity is modelled to benefit from growing VRE capacity in neighbouring regions, as large coal-fired facilities close in other states. As a result, while coal's share of the NSW energy mix is forecast to decline as Liddell is closed, black coal is forecast to remain the dominant player in

the market, contributing around 60% of NSW generation in FY26. Comparably, renewable energy is forecast to grow to approximately 33% of electricity in NSW by FY26.

IMPACT ON ENERGY RELIABILITY

The primary risk to NSW electricity reliability is a capacity shortfall attributed to a generator exiting the market without having been sufficiently replaced, or due to an unplanned outage. As noted, NSW is implementing an EST, calculated at the capacity level needed to meet customer demand during a summer heat wave, while maintaining a reserve margin to account for the unexpected loss of two of the state's largest available generating units.

Under the Reference Case, the EST's tightest years are modelled to be the two-year period after Liddell closes at the end of FY23, yet prior to the commissioning of HumeLink in 2025, which enables access to additional dispatchable capacity from southern NSW. In FY26, the completion of Snowy 2.0 and the HumeLink upgrade is likely to be enough to meet the EST until the next coal-fired facility closes.

IMPACT ON WHOLESALE PRICES

Under the Reference Case, NSW wholesale electricity prices are modelled to decline from \$89/MWh in 2018-19 to around \$50/MWh in 2026, underpinned by lower fossil fuel prices and the continued commissioning of large-scale renewable energy projects.

After the closure of Liddell in 2023, prices are projected to increase by 37%, to \$74/MWh in FY24, before declining until the closure of a second black coal-fired plant.

The Reference Case assumes a relatively static situation in NSW - in contrast to neighbouring states with renewable energy targets - with minimal supply additions beyond current commitments. NSW instead benefits from its central position in the NEM, with access to a variety of cheaper coal and VRE resources from neighbouring regions, while having a relatively large amount of flexible capacity to call upon in all but the most extreme hours of maximum demand. Together, these factors result in relatively low wholesale electricity prices in NSW, yet could also suppress signals for private sector investment.

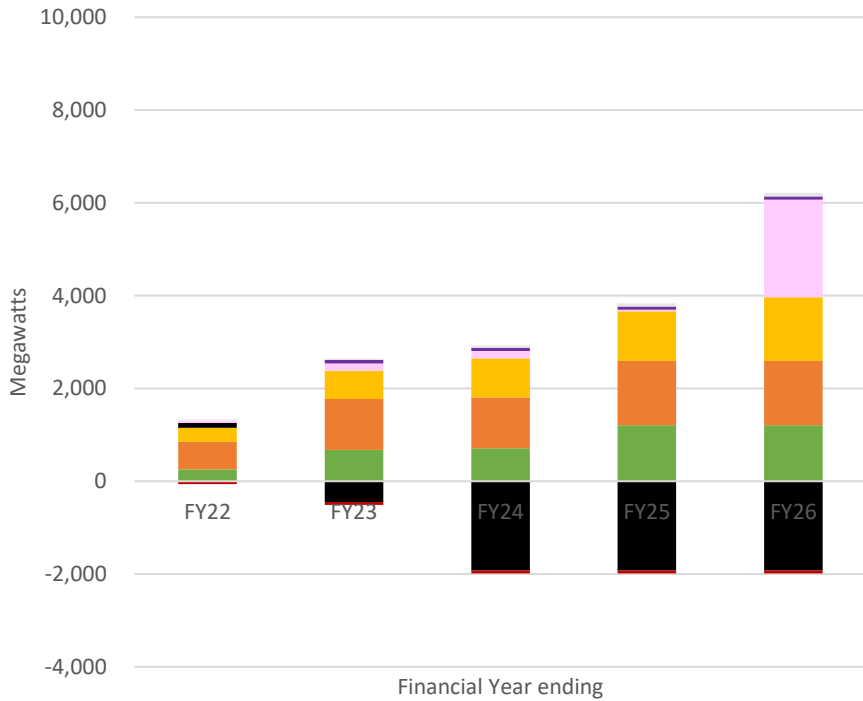
IMPACT ON ELECTRICITY SECTOR GREENHOUSE GAS EMISSIONS

As shown in Figure 4, under the Reference Case, NSW electricity emissions are forecast to decline to around 38 Million tonnes (Mt) in 2026, underpinned by the closure of Liddell. This is equivalent to 34% below 2005 levels.

RESULTS – REFERENCE CASE

LIDDELL RETIREMENT AND CURRENT POLICY

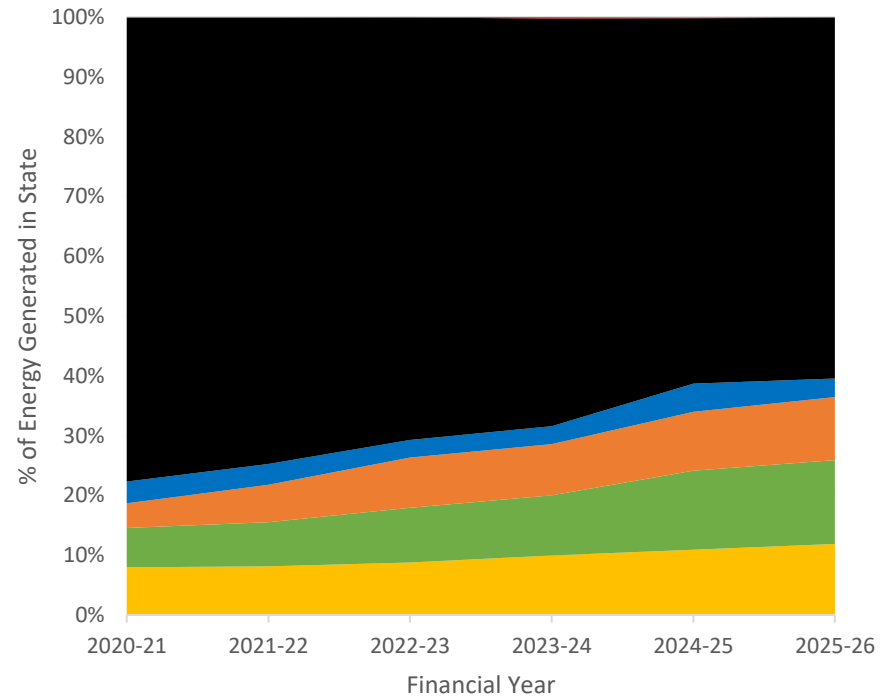
Figure 1: Reference Case – NSW change in capacity by technology (2020-26)



- Wind
- Solar
- Distributed PV
- Black Coal
- CCGT
- Dispatchable Storage
- Peaking Gas+Liquids
- DSP

Source: RepuTex Energy, 2020

Figure 2: Reference Case – NSW fuel mix (2020-26)



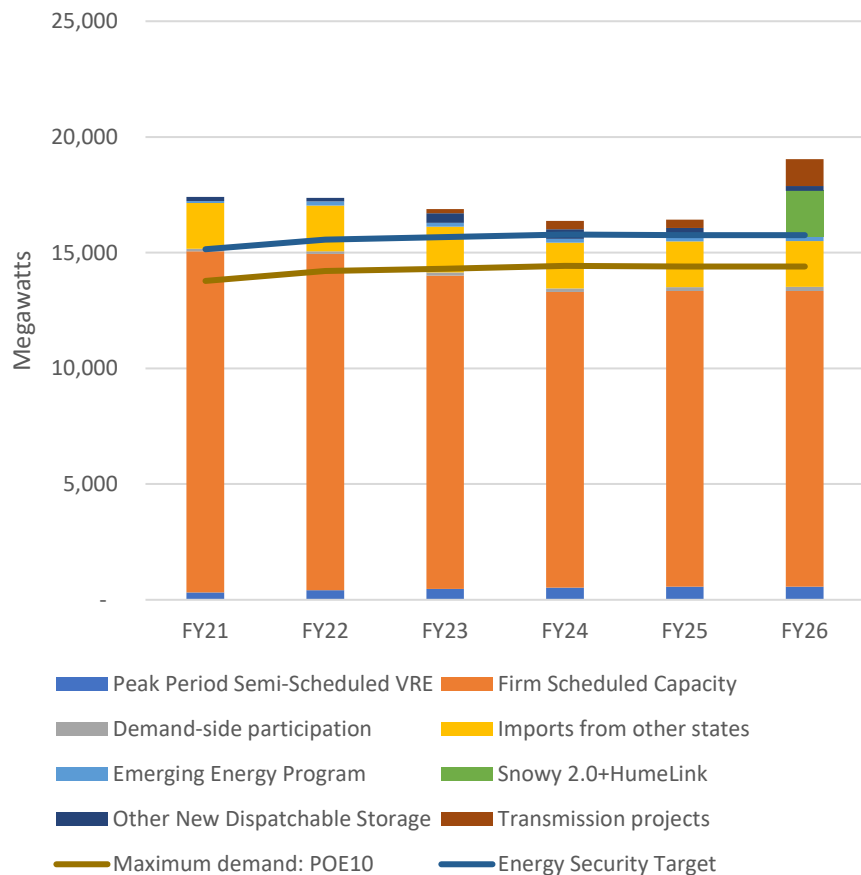
- Distributed PV
- Wind
- Solar
- Hydro
- Black Coal
- CCGT
- Peaking Gas+Liquids
- DSP

Source: RepuTex Energy, 2020

RESULTS – REFERENCE CASE

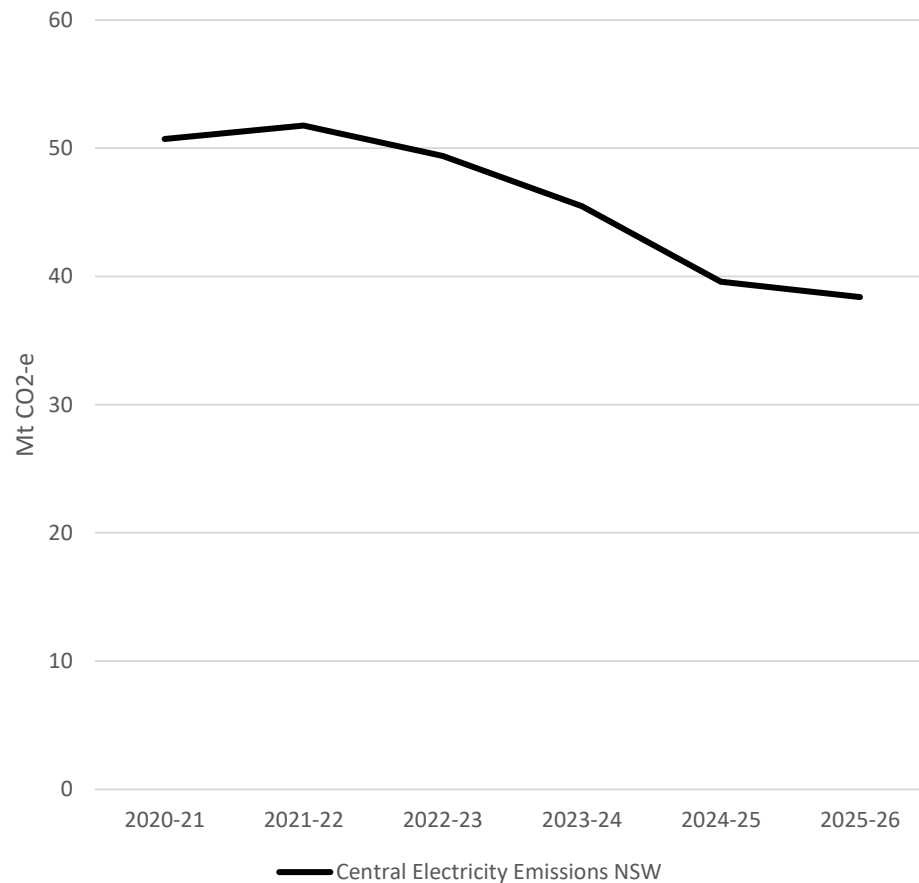
LIDDELL RETIREMENT AND CURRENT POLICY

Figure 3: Reference Case – NSW Energy Security Target outlook (2020-26)



Source: Reputex Energy, 2020

Figure 4: Reference Case – NSW annual electricity emissions (2020-26)

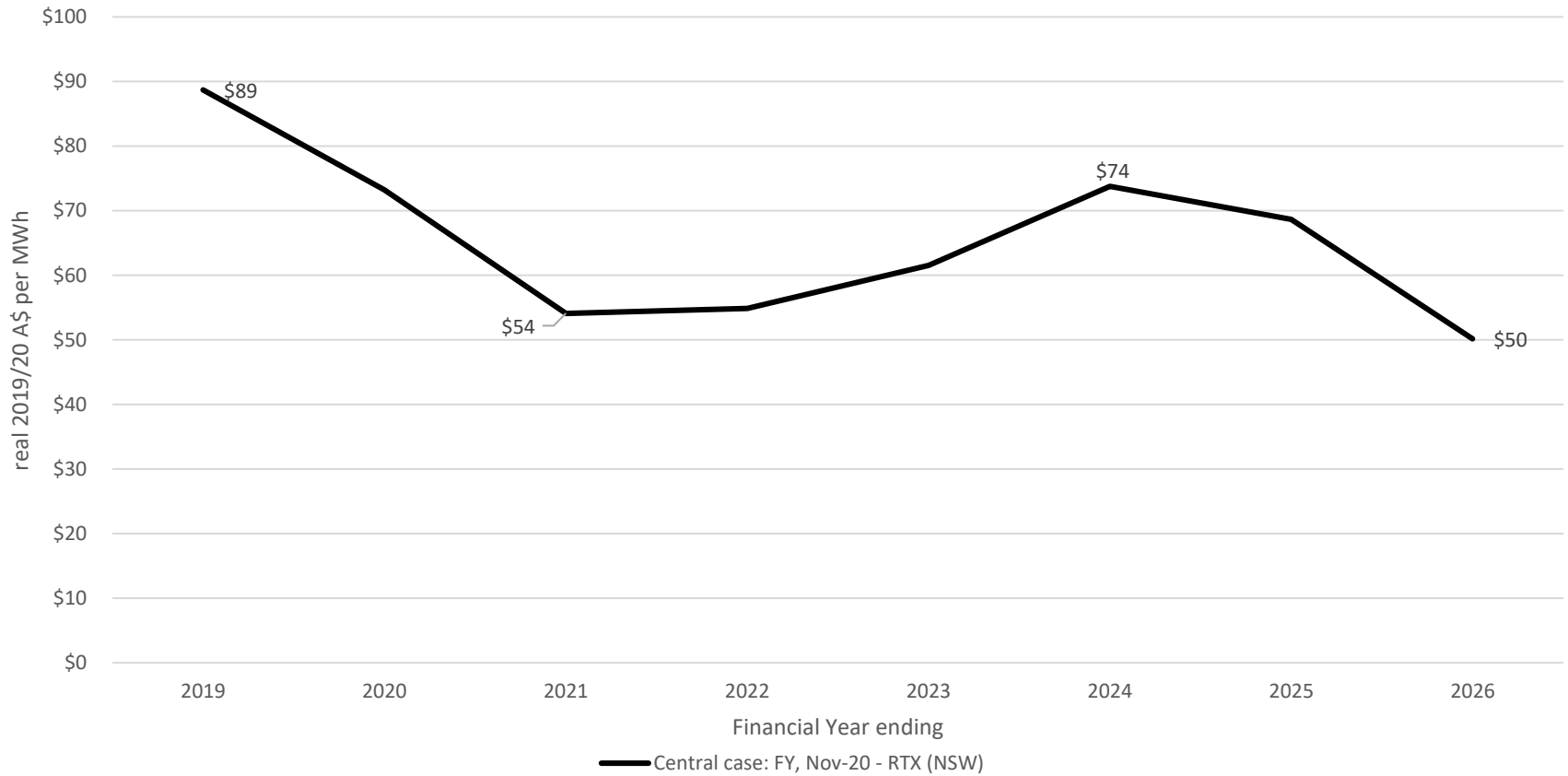


Source: Reputex Energy, 2020

RESULTS – REFERENCE CASE

LIDDELL RETIREMENT AND CURRENT POLICY

Figure 5: Reference Case – NSW wholesale electricity price (2020-26)



Source: Reputex Energy, 2020



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RESULTS
MARKET SCENARIO

RESULTS – MARKET SCENARIO

MARKET BUILDS AN ADDITIONAL 1,000 MW OF DISPATCHABLE CAPACITY

CHANGE IN CAPACITY AND FUEL MIX

Analysis under the Market Scenario assumes the addition of 1GW of zero-emissions dispatchable capacity by 2024 under the NSW government's Electricity Infrastructure Roadmap.

This is anticipated to be made up of 858 MW battery energy storage, along with 142 MW additional demand side participation (DSP). This is in addition to 278 MW of new dispatchable capacity under the Reference Case, resulting in a total of 1.3 GW of new dispatchable capacity.

Under this scenario, 5.9 GW of additional VRE is calculated to come online by FY26, 3.6 GW more than the Reference Case. The CWO REZ is estimated to add network capacity of 3 GW by FY25, resulting in 1.9 GW of large-scale solar and wind capacity being commissioned in FY25.

Project commissioning in all other NSW REZs, however, is forecast to be constrained to less than 0.8 GW until FY26, at which point New England may commission 1.3 GW. Although the full Roadmap of 13 GW of new large-scale VRE is not modelled to be commissioned until the end of the decade, it bears noting that - including distributed PV - the Market Scenario's total VRE capacity is predicted to be 13 GW by FY26.

Unlike the reference case, 1 GW of batteries and DSP is projected to be commissioned by 2024, considerably enhancing available capacity during peak periods, capturing meaningful revenue, and also lowering annual average prices.

In particular, gas and hydro's daily peak period dispatch is eroded by additional battery storage capacity, which shifts more low-cost daytime energy into the post-solar energy ramp-up. As a result, daily peak pricing and annual average prices are calculated to be lowered.

IMPACT ON ENERGY RELIABILITY

In line with the Reference Case, the primary risk to NSW electricity reliability is a capacity shortfall attributed to a generator exiting the market without having been sufficiently replaced, or due to an unplanned outage. As noted, NSW is implementing an EST to ensure customer demand is met while maintaining a reserve margin.

Under the Market Scenario, the EST's tightest period continue to be the two years after Liddell closes at the end of FY23, yet prior to the commissioning of HumeLink in FY26, which is expected to enable access to additional dispatchable capacity from southern NSW.

The addition of 1 GW of dispatchable energy storage and DSP under this scenario, however, is forecast to provide significantly more competition during maximum demand events, and may increase reliability in contingencies where more than two coal-fired units are unavailable.

In FY26, the completion of Snowy 2.0 and the HumeLink upgrade, along with a QNI or VNI interconnector project, is modelled to be enough to meet the EST for the remainder of the decade - even after the closure of a further coal-fired power plant in NSW.

IMPACT ON WHOLESALE PRICES

Under the Market Scenario, NSW wholesale electricity prices decline from around \$89/MWh in 2018-19 to \$54/MWh in 2021. After the closure of Liddell in 2022 and 2023, prices are calculated to increase 22% to approximately \$65/MWh, before declining to \$35/MWh in 2026.

The major difference in this scenario is the 1 GW of dispatchable capacity added prior to 2024 and the introduction of the NSW Electricity Infrastructure Roadmap. 1 GW of dispatchable capacity could take the form of large batteries, small batteries aggregated into a VPP, and Demand Side Participation (DSP). Beyond the NSW Emerging Energy Program, several battery projects have already been announced in NSW that are estimated to make up between 700 and 800 MW of capacity. By 2024 this is forecast to amount to an additional 860 MW of large- and small-scale batteries and 142 MW of DSP.

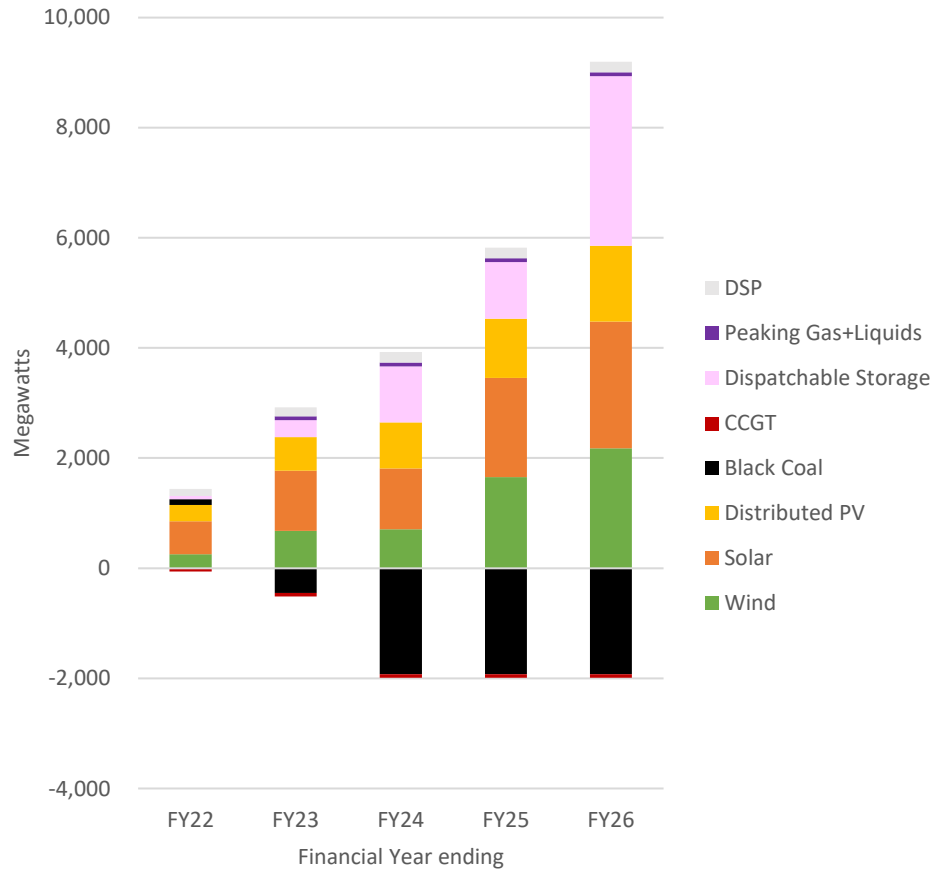
IMPACT ON ELECTRICITY SECTOR GREENHOUSE GAS EMISSIONS

As shown in Figure 9, under the Market Scenario, NSW electricity emissions are forecast to decline to 37 Mt in 2026, equivalent to 36% below 2005 levels. This is underpinned by the closure of Liddell, with output modelled to be partially replaced by other black coal plants, while emissions free renewables displace the remainder.

RESULTS – MARKET SCENARIO

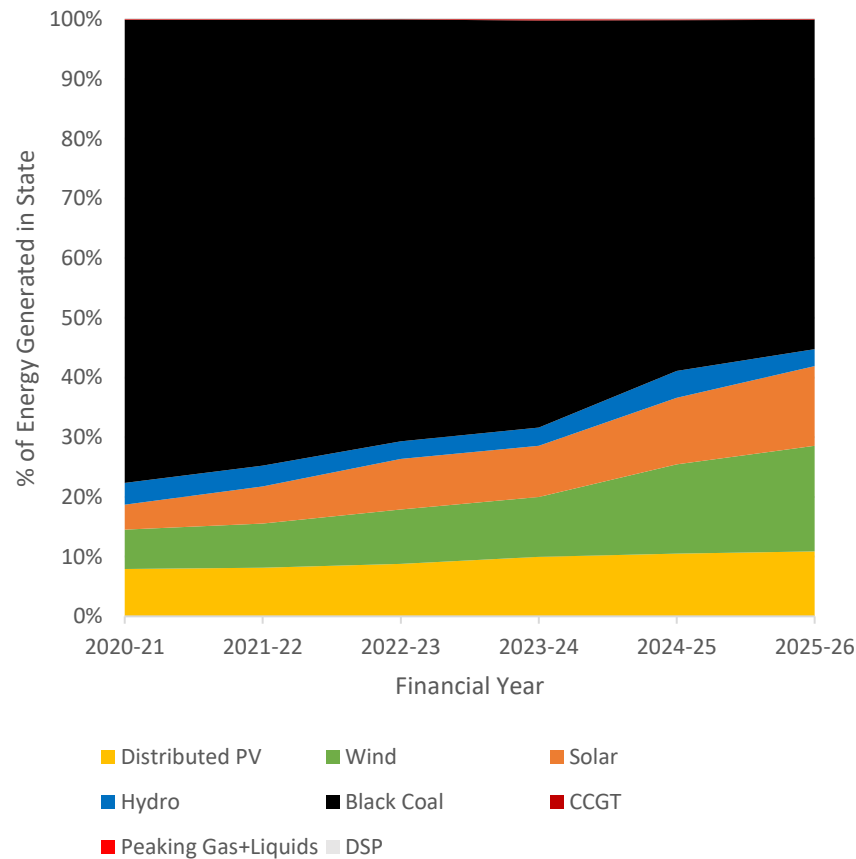
MARKET BUILDS AN ADDITIONAL 1,000 MW OF DISPATCHABLE CAPACITY

Figure 6: Market Scenario – NSW change in capacity by technology (2020-26)



Source: Reputex Energy, 2020

Figure 7: Market Scenario – NSW fuel mix (2020-26)

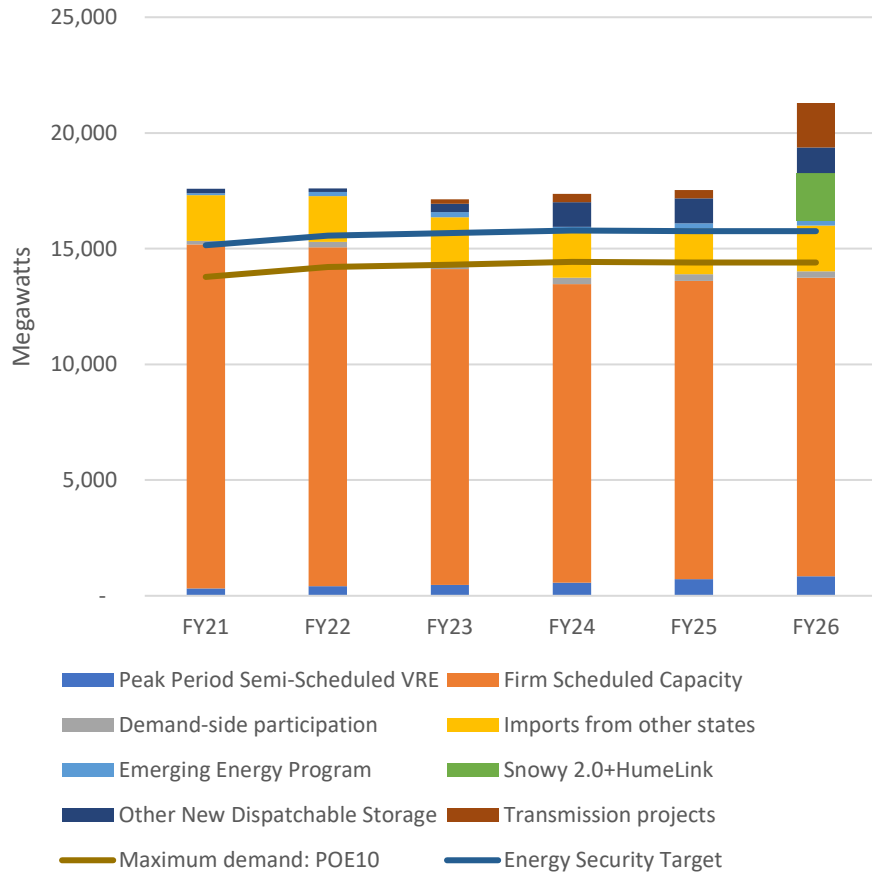


Source: Reputex Energy, 2020

RESULTS – MARKET SCENARIO

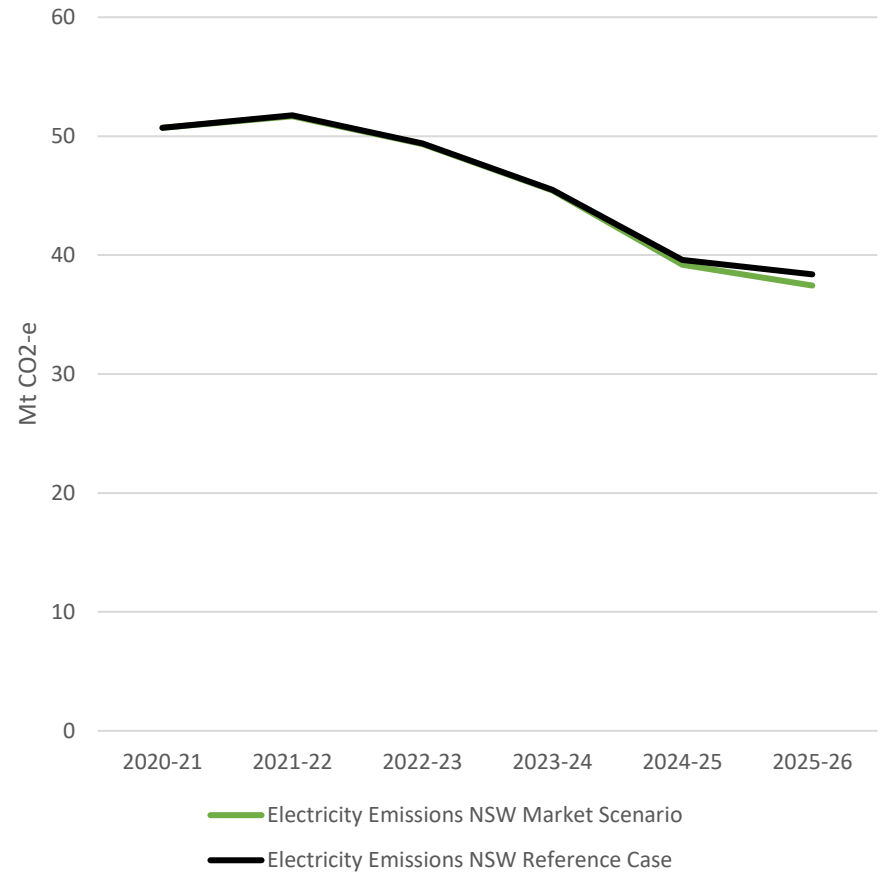
MARKET BUILDS AN ADDITIONAL 1,000 MW OF DISPATCHABLE CAPACITY

Figure 8: Market Scenario – NSW Energy Security Target outlook (2020-26)



Source: Reputex Energy, 2020

Figure 9: Market Scenario – NSW annual electricity emissions (2020-26)

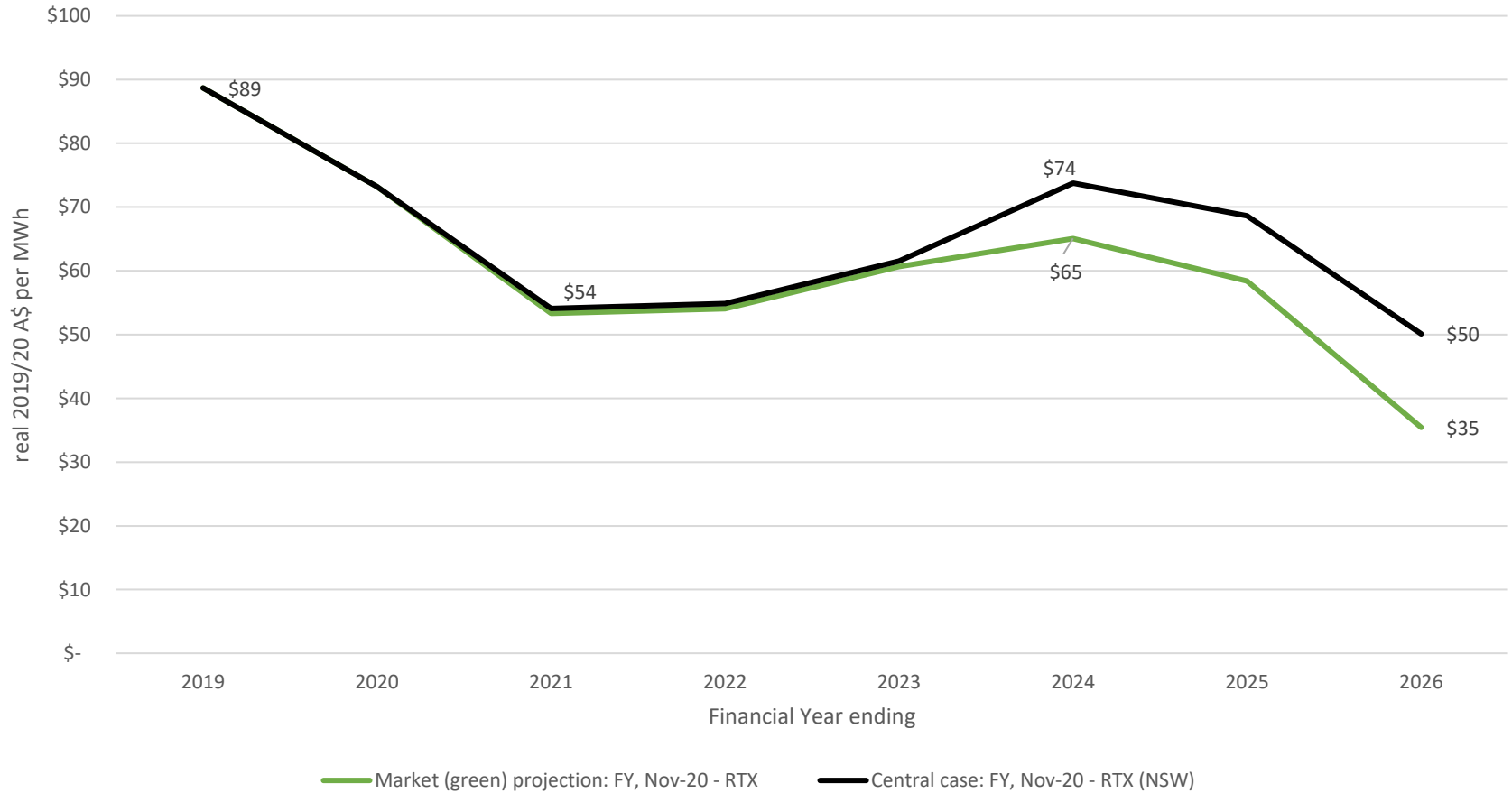


Source: Reputex Energy, 2020

RESULTS – MARKET SCENARIO

MARKET BUILDS AN ADDITIONAL 1,000 MW OF DISPATCHABLE CAPACITY

Figure 10: Market Scenario – NSW wholesale electricity price (2020-26)



Source: Reputex Energy, 2020



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RESULTS
GAS SCENARIO

RESULTS – GAS SCENARIO

ADDITION OF 1,000 MW OF GAS CAPACITY

CHANGE IN CAPACITY AND FUEL MIX

This scenario models the addition of 1GW of gas-fired generation by 2024 as an alternative to the addition of 1GW of zero-emissions dispatchable capacity by 2024 under the Market Scenario.

After 2024, the CWO REZ is assumed to add network capacity of 3,000 MW, with construction proposed to begin in 2022. 4 GW of additional renewables is forecast to come online by FY26 in total, including 2.6 GW of new large-scale solar and wind capacity. Large-scale capacity already committed amounts to 1.6 GW, with a further 1 GW calculated to be commissioned by FY25.

Project commissioning in all other NSW REZs, except Tumut and Wagga Wagga, is expected to be constrained for the remainder of the decade as transmission access blocks further large-scale VRE development. Annual average additions could largely be limited to distributed PV. In cumulative terms, the Gas Scenario estimates 4.0 GW of large and small-scale renewable capacity being commissioned by 2026.

Unlike neighbouring regions, opportunities for new dispatchable capacity in NSW are likely to be limited by black coal generation capacity, 1 GW of new gas capacity, and the addition of 2 GW of new capacity from Snowy 2.0 in 2025.

Similar to the Reference Case, black-coal capacity is modelled to benefit from growing VRE capacity in neighbouring regions, and the closure of large coal-fired facilities in other states.

As a result, while coal's share of the energy mix is forecast to decline as Liddell is closed, black coal again remains the dominant player in the NSW market, contributing 61% of NSW generation in FY26, versus 39% for renewable energy.

This is modelled to leave little room for gas-fired capacity to be dispatched - at between 35,000 and 130,000 MWh per year - or just 0.1 to 0.2 per cent of generation in NSW. This is anticipated to consume between 0.3 to 1 Petajoules (PJ) of gas per year, amounting to 429,000 MWh and 3.4 PJ cumulatively over the six years.

IMPACT ON ENERGY RELIABILITY

Under the Gas Scenario, the addition of 1 GW of new gas capacity may maintain the same supply-demand balance as Liddell's 1,660 MW power station. The commissioning of HumeLink in 2025 reinforces the southern network and provides access to renewable and peaking generation in southern NSW and Victoria, meeting demand in major load centres. By FY26, the completion of Snowy 2.0 and HumeLink is likely to be enough to meet the EST until the next black-coal closure.

IMPACT ON WHOLESALE PRICES

Similar to the Reference Case, the Gas Scenario assumes a relatively static situation in NSW. 1 GW of dispatchable gas capacity is anticipated to be developed from announced projects (250 MW by Snowy Hydro, 250MW at Tomago, the 450MW upgrade to Tallawarra, and 50 MW of highly flexible gas reciprocating engines integrated with

hybrid renewable energy projects). Beyond the NSW Emerging Energy Program and Snowy 2.0, NSW therefore adds a negligible amount of dispatchable storage.

Under this scenario, NSW wholesale electricity prices are anticipated to decline from around \$89/MWh in 2018-19 to \$53/MWh in 2021. After the closure of Liddell in 2022 and 2023, annual average prices are forecast to increase by 24% to approximately \$68/MWh - around our estimated long-run cost of new energy - signalling new investment, yet not high enough to generate enough return on capital that would normally trigger our model to add any of the announced gas peaking capacity.

As a hypothetical, however, the addition of 1GW of new gas-fired capacity is forecast to provide considerable competitive pressure during maximum demand events, and headroom to maintain reliability. The average offer price of gas-fired facilities, however, is modelled to be approximately \$17/MWh higher than Liddell, providing minimal price relief during peak periods.

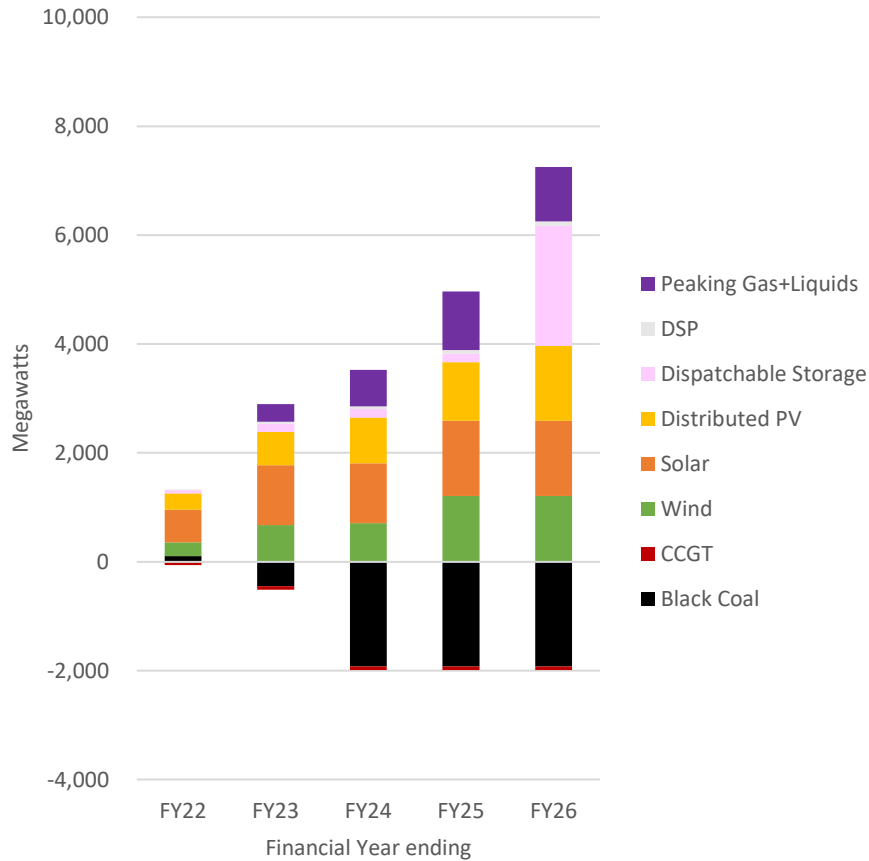
IMPACT ON ELECTRICITY SECTOR GREENHOUSE GAS EMISSIONS

As shown in Figure 14, under the Gas Scenario, NSW electricity emissions are forecast to decline to about 39 Mt in 2026, underpinned by the closure of the Liddell power station. This is equivalent to 34% below 2005 levels.

RESULTS – GAS SCENARIO

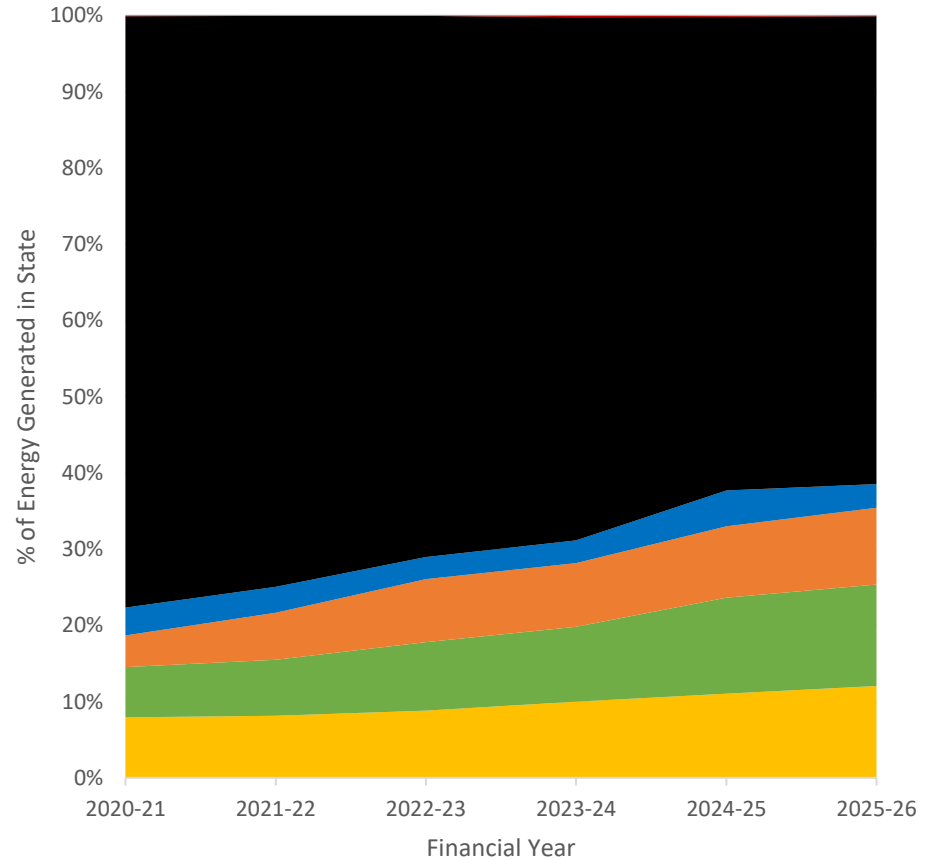
ADDITION OF 1,000 MW OF GAS CAPACITY

Figure 11: Gas Scenario – NSW change in capacity by technology (2020-26)



Source: Reputex Energy, 2020

Figure 12: Gas Scenario – NSW fuel mix (2020-26)

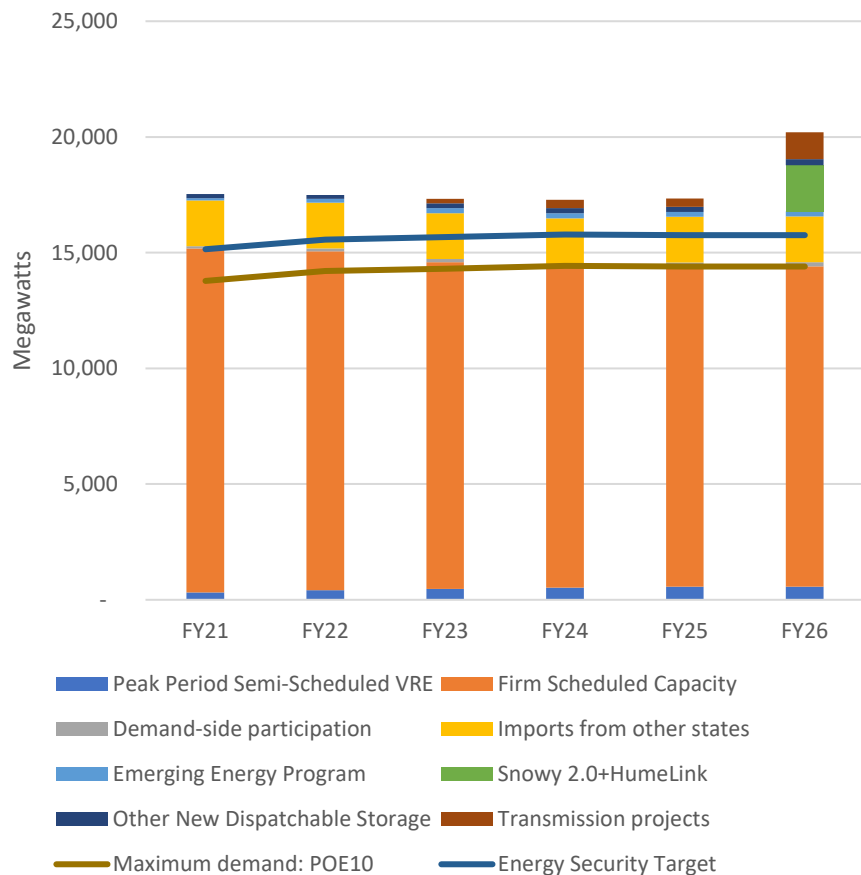


Source: Reputex Energy, 2020

RESULTS – GAS SCENARIO

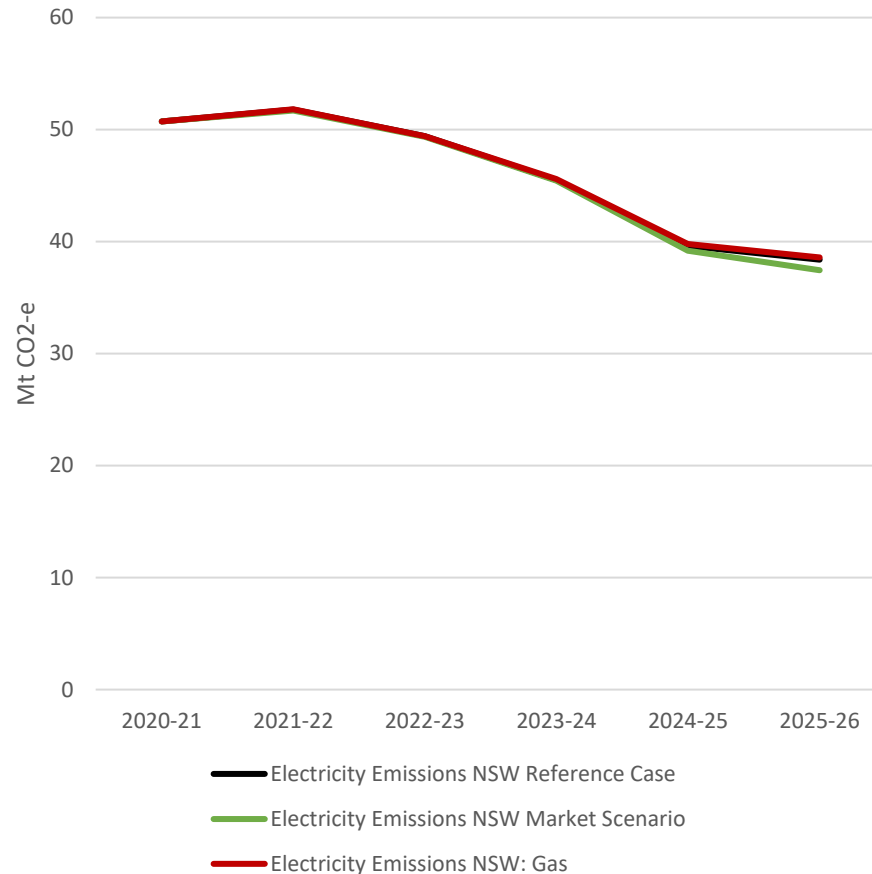
ADDITION OF 1,000 MW OF GAS CAPACITY

Figure 13: Gas Scenario – NSW Energy Security Target outlook (2020-26)



Source: Reputex Energy, 2020

Figure 14: Gas Scenario – NSW annual electricity emissions (2020-26)

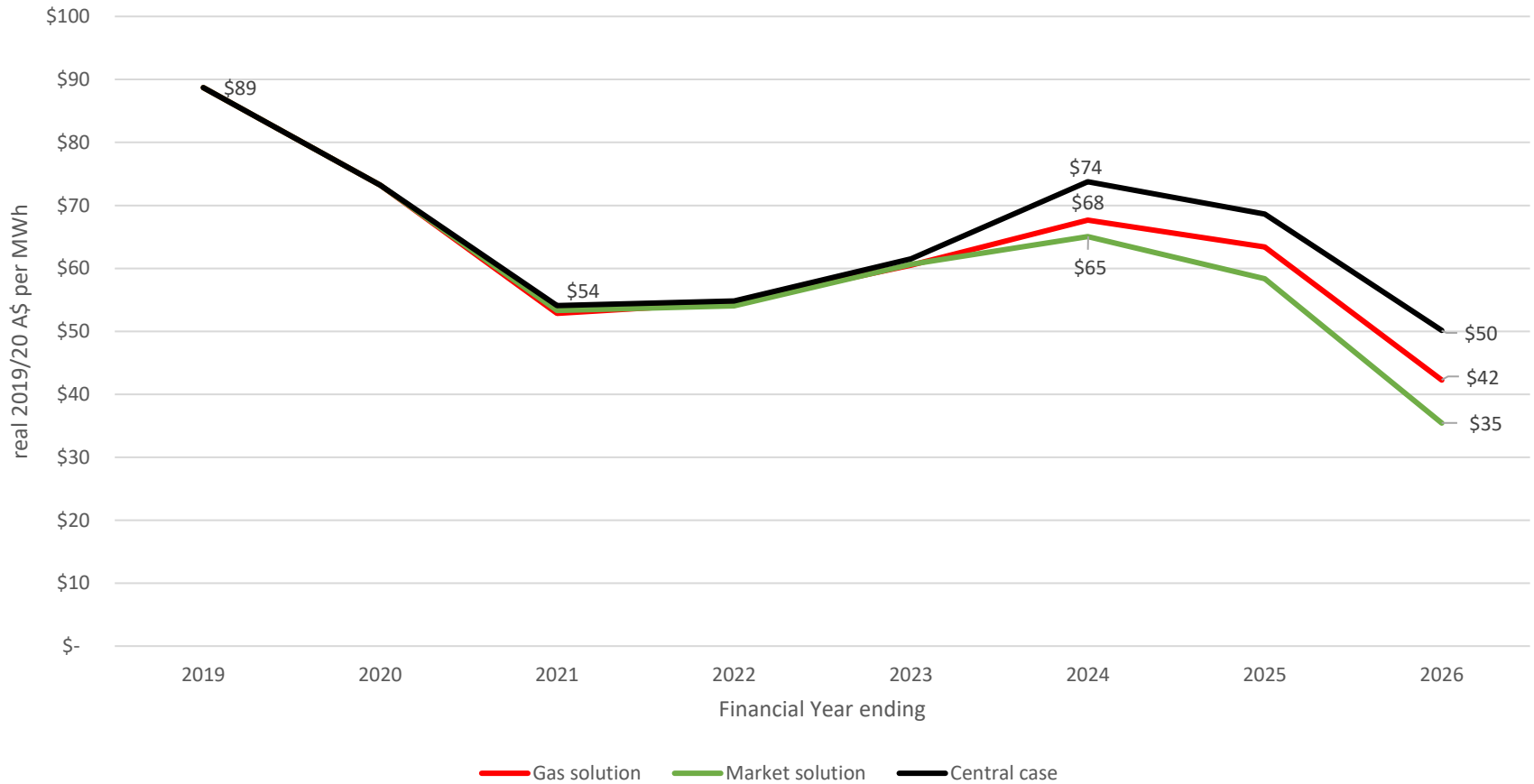


Source: Reputex Energy, 2020

RESULTS – GAS SCENARIO

ADDITION OF 1,000 MW OF GAS CAPACITY

Figure 15: Gas Scenario – NSW wholesale electricity price (2020-26)



Source: RepuTex Energy, 2020

A large, stylized white number '6' is centered on a solid blue rectangular background. The number is composed of two parallel lines, giving it a thick, graphic appearance. The background of the entire slide is a grayscale photograph of a power transmission tower and its associated power lines, which are partially obscured by the blue overlays.

SUMMARY OF
RESULTS AND
DISCUSSION

KEY CONCLUSIONS

SCENARIOS FOR THE REPLACEMENT OF THE LIDDELL POWER STATION

KEY CONCLUSIONS AND DISCUSSION

Liddell's closure without replacement is anticipated to cause NSW annual average wholesale prices to increase due to the reduced availability of dispatchable resources during both maximum demand and peak periods. These high prices are calculated to persist until HumeLink is developed, reinforcing the southern NSW network and providing access to renewable and peaking generation in southern NSW and Victoria, in order to meet demand in the major load centres of Sydney, Newcastle and Wollongong.

An additional 1 GW of dispatchable capacity is shown to alleviate price spikes, and increase the reliability of the power system. Batteries and/or gas-fired technologies are flexible enough to be traded in a peaking capacity and are therefore the most likely candidates to be built to provide additional dispatchable capacity.

In particular, batteries are an enormously flexible resource. Like solar panels they are modular, and therefore highly scalable, with potential for deployment in homes and businesses, on the network, in vehicles, or aggregated into large utility-scale installations. They are also able to respond very quickly, ramping up to hundreds of MW capacity in a minute or two. This speed of response is very useful in filling the gap when other power plants suddenly go offline, creating volatility events which often result in high (and low) prices. These events are occurring more frequently, creating a higher value for faster response batteries and 'spinning' gas-turbines.

1 GW of peaking gas is expected to be most beneficial for the system when batteries are unlikely to provide power over a sustained period (several hours) and during lower maximum price events. These maximum price events are uncertain, however, and may ultimately be dependent on large coal-fired units being unavailable, such as closing before other replacement capacity is brought online.

The addition of dispatchable capacity from either battery or gas-fired technologies is estimated to reduce peak pricing that occurs around sunset, which marks a period of fast supply ramping as solar generation rapidly reduces output. This generation must not only be replaced, but often increased to match rising demand. By 2024-25, batteries are anticipated to provide this power ramping more cost effectively by shifting excess, very low priced daytime electricity production into the evening, without high fuel and start-up costs associated with additional electricity generation.

The market could build hundreds of MW of dispatchable large- and small-scale batteries (as well as demand side participation), while still reaping a good return on these investments, both now and throughout the NSW Electricity Infrastructure Roadmap.

For example, AGL has committed to develop 850 MW of battery storage across the NEM, as evidenced by the announcement of a large battery to be installed at the company's Torrens Island site in Adelaide. South Australia serves as a real-world example of an environment with a range of

gas-fired power plants competing against continued investment in large batteries, in a high penetration renewable energy market. In this region, batteries have shown their advantage, including unappreciated declines battery costs, decreasing trends in charging costs, fast and modular construction, operational flexibility and opportunities to access multiple revenue streams.

Being able to derive revenue from many markets - rather than primarily protecting against price spikes - could prove to be the tipping point. NSW has announced that it intends to ensure that required new capacity is not delayed by investment uncertainty. While it remains to be seen how this will work in practice, it is possible that the state - through a new consumer trustee rather than private energy companies - will take on more of the risk when renewable projects operate outside a range of wholesale prices.

The NSW policy framework has delayed final investment decisions in gas peaking, with both AGL and Energy Australia again deferring a final investment decision beyond Q1 2021 (AFR: AGL hits pause on NSW gas power after energy road map, 17 Nov 2020), as the relative economics of gas-fired facilities become less favourable.



APPENDIX A

MODELLING APPROACH

OUR WHOLESALE ELECTRICITY MARKET SIMULATION MODEL

OUR NEMRES ELECTRICITY MODEL

In undertaking this analysis, we utilise our proprietary National Electricity Market Renewable Energy Simulator (NEMRES), which calculates annual capacity changes, energy generation, and transmission expansion decisions at 30-minute intervals, imitating AEMO's dispatch engine

Various rules, laws and policies govern the operation of the NEM, with the key elements being power supply always matching power demand, adjusted for constraints in the electricity transmission and distribution network. The supply side is comprised of fossil fuel and renewable generators that offer capacity based on calibration with current offers and dispatched by AEMO from the least to more costly offers, subject to system conditions, to meet demand.

Demand is affected by several factors such as weather, economic activity and population. Although demand for power has patterns, it is generally unplanned and highly inelastic. System operators rely on demand forecasting for the daily market operation and long-term planning. As such AEMO publishes forecast demand over different time frames, which we apply based on our forecast horizon and the precision of time-steps being used.

NEMRES simulates the NEM least cost dispatch processes and supply and demand conditions in the forecast periods, modelling the resulting generation and emissions from each scheduled and semi-scheduled plant. Contracts impact the

percentage of electricity subject to bidding behaviours and spot price revenue. NEMRES explicitly models all scheduled and semi-scheduled power plants, also allowing for non-market plant traces.

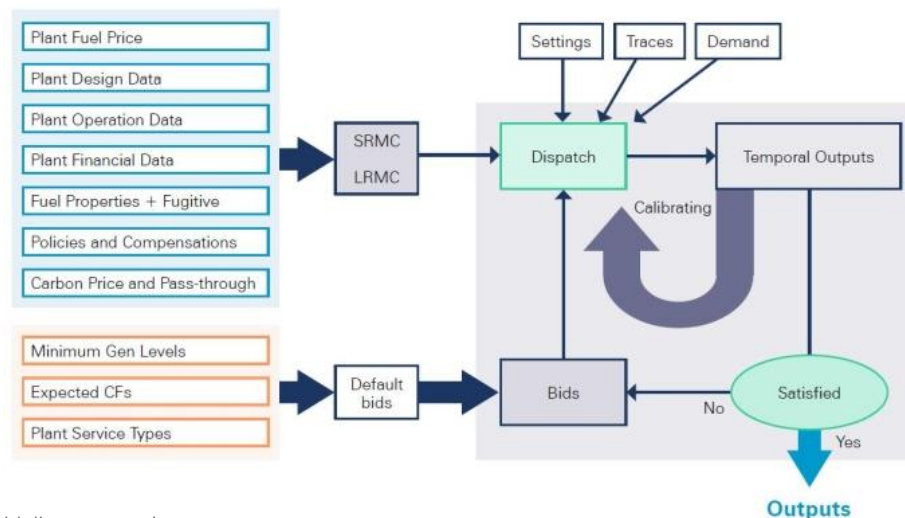
The figure below outlines the main model components and model process flows. The central component of NEMRES is the least cost dispatch model, which dispatches the generation of plants based on default bids calibrated to each generator's most recently observed patterns.

Hydro generation is allocated by model based on historical inflows and the proportion of run-of-river generation and storable hydro energy. As shown, input data preparation and model calibration are important blocks, supported by a number of

criteria in checking the validity of model optimisations, including analyst checks against the feasibility of entry and exit of facilities.

Each new entrant in a given sub-region is based on announced projects generating a specified return on capital subject to asset-specific costs, generation volume and shape, captured wholesale prices, and various grid constraints. NEMRES modelling projects the new and replacement generation and storage capacity required to meet renewable policy settings. Generators are flagged for exit when their forecast revenues are no longer predicted to exceed projected costs, or an emissions constraint is imposed, via an assumed emissions intensity restriction or the market choosing to close the least profitable facility.

Figure 1 – Reputex NEMRES modelling process



MODELLING APPROACH

OUR WHOLESALE ELECTRICITY MARKET SIMULATION MODEL

MERIT ORDER MODEL

A merit order is constructed via the bids offered by all scheduled and semi-scheduled plants. Our algorithm orders the price bands offered by plants from the least to highest and accumulates the quantities of corresponding power offers accordingly. For each dispatch interval, bids are optimised for individual facility profitability. Hydro generation is allocated by the model based on historical inflows and the associated proportion of run-of-river generation and storable hydro energy. As shown, the input data preparation and model calibration are important blocks, supported by several criteria in checking the validity of model outputs, including analyst checks against closing facilities projected to be the least profitable, and the feasibility of new entrants in each region that have been publicly announced.

BIDDING MODEL

The bidding model constructs four price and quantity pairs. All the price and quantity pairs are in percentage of the cost and available capacity of each plant. The first price band of a bid characteristic applies to generation that does not want to be dispatched. The second band relates to the short-run marginal cost (SRMC) or variable operating cost that is calculated based on assumptions for existing and committed facilities. For example, renewable facilities normally have a SRMC less than \$10 per Megawatt-hour (MWh), while coal-fired generators fall between \$10 and \$50 per MWh and gas-fired plants greater than \$50 per MWh.

The third offer relates to a Levelised Cost of Energy or long-run marginal cost (LRMC) target. The last band is affected by the facility's market power to push the market clearing price higher.

The quantity pair is the percentage that a plant is willing to offer to the market at the four offers outlined above. The quantity is incremental, in that the sum of the four quantity components must be 100 per cent. The quantity at the SRMC cost is related to the generator's contracted level, while the quantity at the LRMC is allocated to the normal design level less the amount that has already been allocated in the previous price bands. The last band can be considered quantity held back to maximise profit.

There are three bidding formats. Long-term forecasting calculates dispatch on an annual demand duration curve and is used for inter-annual forecasting. Medium precision dispatch is performed at the daily level to adjust for fuel switching. Half-hour, high precision modelling is performed on critical days to resolve which facilities are dispatched in atypical situations.

COST MODEL

The cost of a generator depends on several factors: plant characteristics such as plant efficiency/heat rate, plant auxiliary usage, fuel cost, fuel combustion emission factor, variable operating & maintenance (VOM), fixed operating & maintenance cost (FOM), etc. Of these variables, fuel costs are updated quarterly, with other variables are adjusted annually.

The SRMC and LRMC are calculated by summing each of the fixed and variable cost components.

Offer strategies may be adjusted based on plant profitability. Annual and/or quarterly profit is calculated as total revenue from the sent-out energy + any fixed subsidies less the variable cost associated with per MWh generation and less the annual fixed cost.

DEMAND MODEL

Annual forecast demand comes with three forecasts for the NEM. One is for annual energy consumption and the other two are for maximum and minimum demand loads. Reputex fits historical demand profiles to AEMO's various forecasts and aims to mimic the modelling intervals between 365 to 17,520 periods per year, equivalent to averaging demand over 1 to 0.02 days. Weekends and public holidays load profiles are checked and matched as required.

ABOUT REPUTEX

AUSTRALIAN ENERGY AND CARBON MARKET ADVISORY

COMPANY OVERVIEW

Established in 1999, Reputex is a leading provider of modelling services for the Australian electricity, renewable energy and emissions markets.

Our forecasts and analysis have been at the forefront of energy and climate thinking for over two decades, with a strong history of providing trusted, data-driven analysis for public and private sector customers in Australia and Asia.

We have worked with over 150 customers across Australia and Asia-Pacific – including policymakers, regulators, high emitting companies and large energy users, project developers, investors and capital markets – working across the Electricity, Renewable Energy and Climate Change service streams.

Reputex has offices in Melbourne and Hong Kong, with a team of analysts with backgrounds in energy commodities, policy and regulation, meteorology, mathematics and engineering.

The company is a winner of the China Light and Power-Australia China Business Award for energy and climate research across Asia-Pacific.

To learn more, please visit www.reputex.com

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