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Fast Erosion of Coal Plant Profits in the National Electricity Market

Analysis of Likely 2025 Generation Mix Shows Coal Plant Revenue Reductions of 44% - 67%

Executive Summary

Coal-fired power stations in Australia's National Electricity Market (NEM) will confront grave financial difficulties within the next 5 years due to extra competition from a large influx of renewable energy supply. The analysis detailed in this report suggests that the financial viability of several coal generators in the NEM will become severely compromised by 2025 such that closure becomes an attractive or even unavoidable choice for at least one power plant owner.

An additional 28 gigawatts (GW), or 70,000GWh (annualised) of renewables is expected to be installed by 2025, compared to our 2018 baseline year. By 2025, it is forecast that the installed renewables capacity will be 8GW of utility scale solar, 12GW of wind, and 22GW of rooftop solar. Renewables is forecast to provide 40-50% of NEM 2025 demand.[1]

Coal and gas generators will be displaced in the NEM by 2025.

The additional renewable energy generation coming online from 2018 to 2025 will be enough to supply 99.9% of the Australian Energy Market Operator's (AEMO) expected demand growth and 98% of the gap expected to be left from the Liddell power station retirement. Even after filling the demand growth and Liddell gap there will be surplus renewable generation of approximately 57,000GWh.

As a result, coal and gas generators will be displaced in the wholesale market, due to the merit order effect. Renewable generators have extremely low operating costs (economically defined as short run marginal cost or SRMC) largely due to having no fuel costs (as wind and solar resources are free). Renewable generators can therefore bid into the market at prices close to zero, undercutting other generators

[1] Renewables in 2025 predicted to total 93,161GWh. Spillage of 16,966GWh is observed. Total NEM generation in 2025 is 189,283GWh. Renewables will be 49% of total generation however if spillage is applied to renewables only, renewable penetration will be to 40%. See appendix for further details.

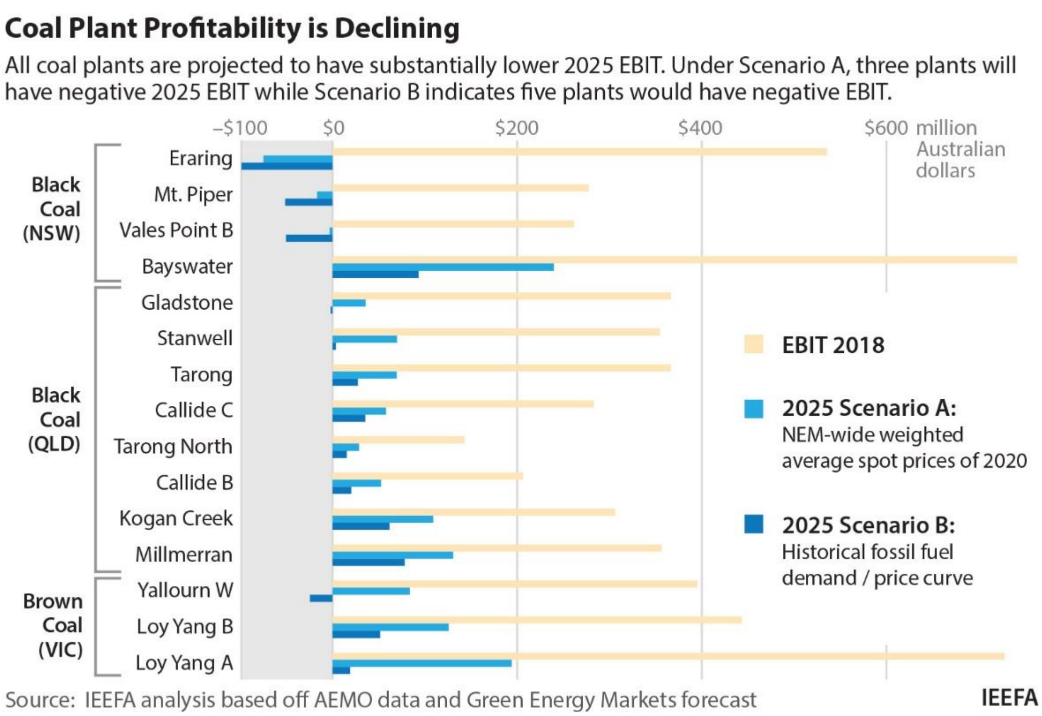
on price. Increasing amounts of renewable installations therefore reduce the output of other generators with higher operating costs. We expect around three-quarters of gas generation and one-quarter of coal-generation to be replaced by renewable energy generation in the seven year period.

The incoming renewables will also have a deflationary impact on wholesale electricity prices, further decreasing the profitability of existing plants.

Coal plants will see a double hit to their electricity sales: both volume and price is forecast to decrease out to 2025. The considerable reduction in coal generation and wholesale electricity prices is expected to drive reduction in coal plant wholesale spot market earnings (Earnings Before Interest and Taxes or EBIT). Coal plants could suffer an estimated EBIT reduction of up to 119% comparing 2018 to 2025.

In a scenario where prices in 2025 are the same as NEM-wide 2020 prices (Scenario A in our study), Eraring, Mt Piper and Vales Point B would be expected to be losing money. In a scenario where price reduces down below 2015 prices (Scenario B), Eraring, Mt Piper, Vales Point B, Gladstone and Yallourn W be making a loss. This is based on EBIT estimations in the case that the generators are, theoretically, fully spot market exposed (i.e. does not include contracts) and excludes revenue from other services such as FCAS.

Figure 1: Earnings Before Interest and Taxes of Coal Plants 2018 vs 2025 ($AUDm)



With this magnitude of reduction in EBIT, coal generator exits are likely to occur far sooner than AEMO has planned for in its Integrated System Plan (ISP). Once a coal generator exits the market, the dynamics outlined in this study will change: prices are likely to then increase near term and other coal generators that remain online may benefit from increased revenue.

Electricity sector investors are recognising that the plunging cost of solar, its rapid speed to deploy, and its vast popularity with investors and Australian householders has led to an irrevocable change in the shape of the electricity supply-demand curve and market that leaves inflexible and high fixed cost baseload coal plants ill-suited to the future grid.

Unfortunately for investors in coal plants, while there remains plenty of evening demand after the sun sets, the amount of daytime demand is becoming so small that coal plants are left in a battle amongst each other to remain online. This is a serious problem for aging coal plants because once they switch off, it typically takes several hours to start back up again and then several more hours to be capable of reaching full output, and by then the evening peak demand window of opportunity has passed. In addition, such modes of operation place considerable stress on the components of a coal plant, increasing maintenance costs and reducing their life.

Other dispatchable power plant technologies are much better suited to this new future, dominated by solar and wind, because they can ramp their output up and down more quickly and with less stress on their components.

Given this context, the New South Wales Government's Electricity Infrastructure Roadmap (2020) provides an essential and timely response to ensure coal plant capacity is replaced in advance of their exit.

Supporting the findings in our report are that several energy market corporations have already substantially written-down the value of their generation assets or cancelled upgrade plans, as announced over February 2021:

- Origin Energy has downgraded its energy market full year EBITDA by 8.6% (earnings before interest, taxes, depreciation, and amortization), blaming low wholesale prices and the drop in demand due to the pandemic[2]

- AGL has written down over $2.7 billion of value, due to reduced wholesale power prices, a failure to account for coal closure site rehabilitation and government plans to underwrite plants[3]

- More than $1 billion has been wiped off the value of Queensland government-owned fossil fuel generators as falling wholesale electricity prices slash generator profits.[4] Profits generated by Queensland government-owned generators, including those controlled by Stanwell

[2] The Australian. Origin downgrades guidance, AGL takes giant writedown. 4 February 2021.
[3] Australian Financial Review. AGL Energy hit by $2.69b of write-downs. 4 February 2021.
[4] The Australian Business Review. Queensland coal and gas power plants slashed in value. 4 February 2021.

Corporation, CS Energy and CleanCo, fell by 88% in the 2019-20 financial year.[5]

- Delta Electricity, the owner of Vales Point coal plant, dropped its bid for an $8.7m publicly funded upgrade.[6]

This report has chosen to focus its analysis on coal plant profitability, as exit of coal plants has substantial implications for energy security, price and emissions outcomes but gas power plants will also suffer substantial deterioration in profits (exacerbated by recent dramatic hikes in gas prices). Yet this is partly mitigated by the fact that gas power plants tend to have lower fixed costs and much greater ability to ramp output up and down quickly. Peaking gas will thus play a role into the future, however the high short run marginal cost compared to renewables and batteries is likely to drive significant reduction in gas generation. Energy storage technologies such as batteries or pumped hydro have a feature that gas does not possess; they can take advantage of periods of plentiful sun or wind to replenish their storages at very low cost. This is in addition to having significantly faster ramping capabilities than gas plants, let alone coal power plants. Furthermore, for short peaks in demand batteries are already the lowest cost option for providing dispatchable capacity.[7] It is expected batteries will play a growing role into the future due to ongoing technology improvements that have been characterised by double-digit percentage annual cost reductions.

These physical and economic realities mean that efforts to keep inflexible coal plants afloat, let alone build new plants, are likely to be counter-productive in terms of both energy affordability and reliability as well as being contrary to both Federal and State Government's commitments to address climate risk. Rather than seeking to delay or even deny the inevitable exit of coal, governments, as well as investors, need to be planning to replace them.

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[5] RenewEconomy. More than $1 billion wiped off value of Queensland coal and gas power stations. 4 February 2021.
[6] The Guardian. Vales Point coal plant drops controversial bid for government funding. 11 February 2020.
[7] AEMO. 2019 Input and Assumptions workbook. 5 July 2020.

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Introduction

This report was prompted by the growing realisation that Australia's National Electricity Market (NEM) is in the process of being swamped by a tidal wave of new power supply and storage. This new supply will push aside much of the existing gas generation, will easily account for the exit of the Liddell power station in 2023, and is likely to bring about the closure of a further major coal power station sooner than is being planned for.

Our analysis suggests the closure of at least one coal power plant (in addition to Liddell) as soon as 2025 is now quite likely. While coal power plant closures are necessary to meet climate change goals, any closure has the potential to be economically disruptive if it occurs without replacement capacity built in advance.

Policy makers need to rapidly adjust their thinking about how the NEM might look in a few years' time and urgently develop and implement strategies to ensure Australia can smoothly adjust as coal power plants exit ahead of predicted end-of-life.

The Coming Tidal Wave of New Solar and Wind Supply

By 2025, it is forecast that the NEM cumulative installed capacity of utility-scale solar will be 8GW, 12GW of wind, and 22GW of rooftop solar. It is expected that by 2025 wind and solar will account for 40-50% of NEM generation.[8] Of this total capacity 28GW will have been added after 2018 (excluding any new capacity supported through the NSW Government's Infrastructure Roadmap). This new generation coming online over a 7-year period will be capable of generating almost 70,000GWh (annualised). To provide some perspective that is equivalent to -

- 8 ½ times larger than the generation from the coal-fired Liddell Power Station;
- 6 times larger than generation from the Hazelwood Power Station shut in 2017;
- 4 ½ times larger than generation provided by all the gas-fuelled generators across the NEM;
- More than a third of current NEM-wide power consumption.

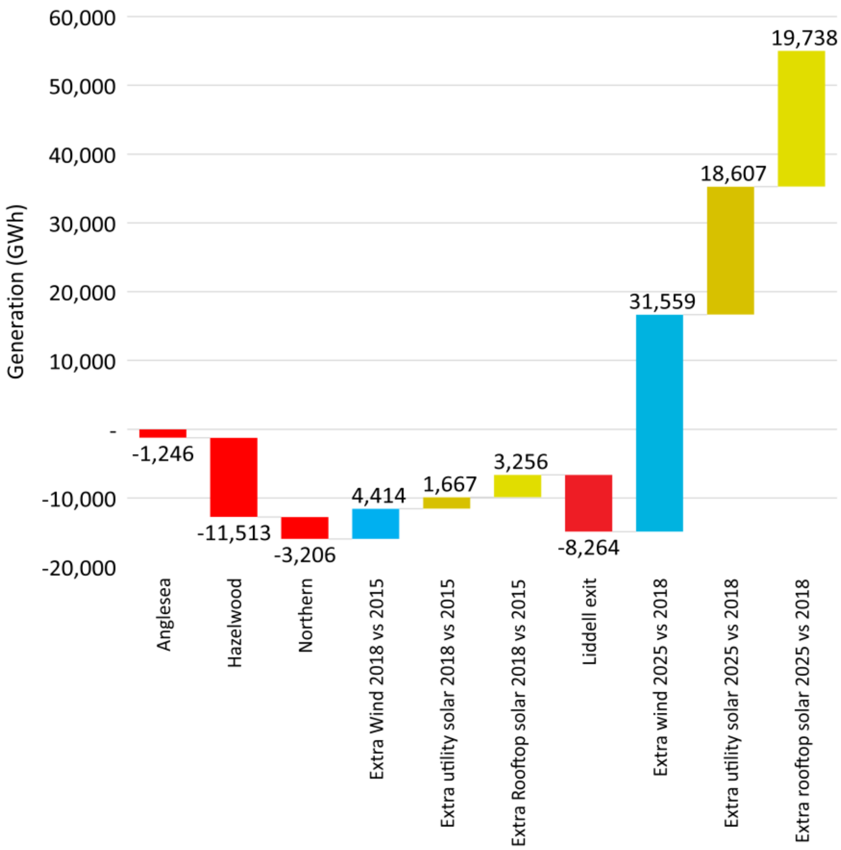
The reality is that the level of new supply coming forward is vastly greater than anything energy market institutions, government authorities, electricity businesses or independent market analysts (including the co-authors of this report) forecast or

[8] Wind and solar generation in 2025 predicted to total 93,161GWh. Spillage of 16,966GWh is modelled assuming coal plant can't be reduced below minimum stable levels of capacity for all operating generators. Total NEM generation in 2025 is 189,283GWh. Wind and solar will be 49% of total generation however if spillage is applied to wind and solar only, then its penetration will be to 40%. See appendix for further details.

even contemplated just two years ago. It is also independent of accelerating uptake of batteries or EVs.

The idea that we might soon be awash with power supply is likely to come as a surprise to many. Since 2015, three coal-fired power stations have exited the market with only a few months' notice - Anglesea giving 4 months,[9] Hazelwood 6 months,[10] Northern less than 1 year.[11] The community was greeted after these closures with news stories of spiking power prices and impending shortages and black-outs. However, Figure 2 illustrates these announced exits of coal power stations since 2015 are being dwarfed by new renewable supply, with the vast majority of new renewable supply coming online after 2018 – when NEM wholesale power prices peaked.

Figure 2: Losses and Gains in Annual Generation Since 2015 – Comparing Coal to New Renewable Supply (GWh Lost/Gained 2015-2025)



Source: IEEFA analysis, based on AEMO generation data post auxiliary and transmission losses. See appendix for further details.
Note: Only renewable generation and coal generation losses and gains included. Other generation losses and gains excluded from chart (battery, bioenergy, hydro, gas etc.)

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[9] Alcoa. Alcoa to Close the Anglesea Power Station. 12 May 2015.
[10] RenewEconomy. Beginning of the end of coal as Hazelwood smokestacks demolished. 25 May 2020.
[11] The Guardian. Port Augusta's coal-fired power station closes in South Australia. 9 May 2016.

The Good News: Greater Competition Sees Lower Prices

For consumers of electricity, more power supply is mostly good news.

Our analysis suggests average wholesale power prices are likely to fall lower than 2015 levels. Because wind and solar plants tend to bid their output into the market at prices close to or even below zero, the more expensive gas and then coal generators will be pushed aside, suffering significant losses in sales volumes. As generators find themselves under greater competitive pressure to get dispatched, it will also lead to reduced prices for all generators.

It should be noted that the cost of actually generating energy makes up around 39% of the average residential consumer's bill – the remainder coming from transmission, distribution, retail and other fees.[12] Therefore while reduced wholesale prices will drive reduction in consumer bills, it is not the full picture.

The Challenge We Need To Prepare for: Coal Exits

Impending coal power station exits and ever greater new renewable supply points to a number of issues that need to be addressed:

- **Unanticipated coal plant closures can lead to price spikes and heightened risk of outages.**

While gas power plants with their higher fuel costs should be the first to give way, the extra renewable supply is so large that it must also erode demand for coal generators as well.

While the exit of coal power stations is absolutely necessary in order to reduce the risks of dangerous climate change, if not managed well it could lead to substantial economic disruption. Understanding how this surge in renewable energy supply might affect the financial viability of coal generators is of special significance to both government policy makers and market participants because each individual coal power station tends to represent a large proportion of supply in its respective state.

As shown by the sudden unplanned exit of Northern and Hazelwood Coal Power Stations, if a major coal generator shuts with little forewarning it has the potential to lead to significant spikes in prices. The NEM-wide weighted average spot price 2 years prior to closure of Hazelwood was $59/MWh. After closure the price increased dramatically, with a 2 years post closure average spot price of $89/MWh (evidenced by Figure 33 in the appendix). Sudden closure of coal plants may also increase the risk of blackouts in times of extreme demand (such as a multi-day heatwave). It can take several years to develop, finance and then construct new power plants and even longer for new transmission lines. So, to avoid significant disruption from the exit of coal requires several years of preparation.

[12] Clean Energy Council. How much does electricity cost. 2018.

Aurora Energy Research[13] and Frontier Economics[14] have previously examined potential future coal profitability, finding coal power stations shouldn't need to close in advance of planned retirement dates. However, since these pieces of analysis were undertaken, it has become apparent that the amount of new supply from renewable energy will be far greater than either analyst envisaged, and wholesale prices have reduced dramatically from average $88/MWh in 2019 to $50/MWh in 2020.[15] This has made it necessary to re-evaluate coal plant's viability.

This has been publicly acknowledged by Dr Kerry Schott, chair of the ESB, who stated that additions of renewable supply are moving at rates far higher than had previously been anticipated. According to Schott this would likely mean coal plants "will go broke" and close 4-5 years earlier than expected such that by the mid-2030s Mt Piper will be the sole coal power plant operating in NSW. Interestingly, Schott indicated this was under the conditions of AEMO's Step Change Scenario (intended to be a rapid decarbonisation scenario)[16] –which saw wind and solar at around 35%[17] of the generation mix by 2024-25. Yet our analysis suggests wind and solar will be closer to 40-50% penetration in 2025. Therefore, closures could unfold faster than even this rapid decarbonisation scenario envisaged.

- **Investors are likely to apply short time horizons to investment in coal making them vulnerable to closure.**

There are good reasons to suspect that some coal plants could be vulnerable to closure if their profitability were substantially eroded. Many coal generators are already several decades old and are likely to require significant ongoing maintenance expenditure to remain reliable and safe. Yet given the fact that coal plants must close before theoretical end-of-life, if Australian state and federal governments are to achieve their emissions-reductions pledges, rational and prudent investors will only make investments that they can expect to recoup within a short period of time.

This is the issue that confronted the owners of Hazelwood. In the months preceding the decision to close, WorkSafe Victoria inspectors identified a series of safety issues with the power plant which required at least $400m in repair works to resolve.[18] The owner Engie ultimately decided that these repairs weren't worth the cost and closed the plant as part of a global strategy to exit coal and reposition itself for a low carbon future,[19] consistent with growing global investor pressure.

[13] Aurora Energy Research. Aurora Energy Research analysis of AEMO's ISP Part 2: Economics of coal closures. May 2019.
[14] Frontier Economics. Modelling of Liddell Power Station Closure. 6 December 2019.
[15] NEM-wide weighted average spot price. Further details in appendix.
[16] AFR. Coal power stations going broke: Schott. 16 February 2021.
[17] AEMO. AEMO ISP 2020 – Step Change (DP1). Tab: Summary_2. 5 July 2020. Note that the scenario and modelling Schott was referring to is unclear: Schott referred to "step change" therefore it is assumed this means the AEMO ISP 2020 step change scenario under DP1.
[18] ABC. Worksafe notices detail extent of repairs needed at Hazelwood power station. 1 December 2016.
[19] Engie. Hazelwood power station in Australia to close at the end of March 2017. 3 November 2016.

The poor output flexibility of coal power plants also threatens their long-term viability. With solar and wind growing as a proportion of supply, there is increasing value in other generators being able to rapidly flex their output either up or down in a counter direction to balance supply and demand. While newer black coal power plants have proven themselves to be surprisingly flexible when required, as a general rule, the ability of coal plants to ramp output up and down is slower than gas turbines and engines, far slower than hydro, and downright snail-like compared to batteries. Importantly, while they are physically capable of flexing output, they aren't as well suited economically to doing so.

Coal plants were designed with the intention of operating as base-load plants with only moderate variation in their output. This means their components can suffer serious physical stress from ramping output by a large proportion of their capacity, shortening their lifespan and increasing maintenance costs. They also need to maintain some minimum level of output if they are to remain capable of ramping up output later in the day. If they trip and fall 'cold' then the process of restarting them and ramping back up to full output can take over 24 hours.[20] In addition, they have relatively high fixed operations and maintenance costs (costs that are constant irrespective of output), so their economics are best suited to maximising output rather than playing a balancing role.

- **Regulations do not protect against sudden closure with inadequate notice.**

Following the Finkel Review, the electricity market rules were changed to require coal plant owners to give three years advance notice of closure. Frontier Economics[21] and the Grattan Institute[22] have each identified a series of flaws with this regulation. Effectively, this is only an information requirement, so there is no regulatory protection against a sudden coal plant withdrawal. Further exacerbating the public policy issue is that in the one circumstance where a company gave several years of advance notice to the market that it would close a coal power station (AGL in relation to Liddell), it was subject to aggressive criticism by Federal Government ministers and backbench members of Parliament for doing so.

The reality is that the owners of coal power plants face a degree of uncertainty about the opportune timing for closing their plants. The large remediation costs that come with closure (e.g. Liddell's remediation cost is estimated to exceed $500m)[23] can mean a plant may be run at a loss for several years in order to forestall those costs, sometimes in the hope that another coal plant will close first, leading to a spike in wholesale prices and therefore recovery in profitability.

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[20] Parliament of Australia. Options for the retirement of coal fired power stations. 1 February 2017.
[21] Frontier Economics. Analysis of the Victorian power market prepared on behalf of the Victorian Liberal Party. 2018.
[22] Wood, Dundas and Percival. Power play: how governments can better direct Australia's electricity market. 7 October 2019.
[23] The Guardian. Liddell power station: five extra years could give government $1bn rehab bill. 8 September 2017.

Coal plant closures have the potential to be highly disruptive. Therefore, understanding their likelihood, the consequences, and how they might best be managed is important.

Method for Estimating Coal Plants' Profitability

The coming tidal wave of new, low-cost renewable energy supply when evaluated on an annual basis provides a strong indication that both gas and coal power plants will suffer significant declines in revenue going forward. However, to properly evaluate the impact on profitability requires analysis down to the 30-minute price settlement intervals of the NEM.

While there are good reasons to believe that further coal plants beyond Liddell are vulnerable to closure, they have quite low fuel costs (when compared to gas) and so are capable of withstanding some noticeable falls in wholesale prices (relative to historical levels over the past few years) while maintaining a short-term cash profit (positive EBIT). Furthermore, prices in the wholesale electricity market are highly sensitive to changes in the supply-demand balance that can lead to very large changes across 30-minute intervals. Given that the extra supply from wind and solar will vary with weather conditions rather than in response to demand, it is important to evaluate the time patterns of this supply and its relationship with the time patterns of electricity demand. This has been analysed on a 30-minute basis throughout this report.

Our analysis has deliberately sought to avoid many of the complexities that tend to characterise market modelling exercises in order to make it as transparent and easily understood as possible.

The conclusions we make seem unlikely to change significantly.

Key simplifications in our model include: not taking into account interconnector constraints, not taking into account constraints that limit the speed that generators can ramp their output up or down, assuming other generation (battery, bioenergy, hydro and pumped hydro) remains stable from 2018 to 2025, excluding revenue from any other NEM services apart from wholesale electricity spot market revenue, modelling coal plants as completely spot market exposed (in order to estimate EBIT figures), and analysing EBIT of coal plants ignoring depreciation and amortization (in order to utilise AEMO Input and Assumptions generator costs[24]). In some cases, these

[24] AEMO. 2019 Input and Assumptions workbook. 5 July 2020.

considerations might help to shield some generators from negative impacts but at the expense of increasing the negative impact on profitability for other generators.

Furthermore, some coal power plant owners are investigating installation of batteries onsite at the coal plants in order to gain new revenue streams (e.g. Origin's 700MW battery at Eraring,[25] AGL's 200MW battery at Loy Yang A[26]) and possibly lessen the degree of ramping the coal plants need to do. The impacts of these are not included in this study.

Given these and other simplifications in our model, the findings should be treated as indicative rather than definitive. Nonetheless, we would point out that the erosion of coal power plant spot market revenues and profitability is of such a magnitude that our conclusions would be unlikely to change significantly with a more complicated modelling approach.

Estimating Generators' Displaced Output

To assess the potential impact of the current surge in new supply on the electricity market, and the profitability of coal generators, we used 2018 power plant generation patterns as our reference point after deducting transmission and auxiliary losses. This year was chosen because it was the first entire year without any output from Hazelwood Power Station and therefore it provides a reasonable picture of the role played by the remaining coal generators in meeting NEM power demand. 2018 also precedes much of the impact from the investment supercycle in wind and solar plants. Lastly, it represents a period after the start-up of LNG plants which have now linked domestic gas prices to Asian markets. The year 2018 effectively represents the point that black coal power plants reached the peak of their importance to the NEM's power supply.

Green Energy Markets forecasts were used to determine expected growth in renewable energy generation to 2025. 2025 was chosen because by then all the renewable energy projects currently under contract or active tender should have been built and it was the final year of solar capacity forecasts GEM has prepared for the Clean Energy Regulator (in work prepared in September 2020). It is in effect the limit of the forecasting horizon where we have reasonably good confidence about likely future renewables generation (at least on the lower end).[27] On the other hand, if another coal closure were to occur by or before 2025 it poses a serious challenge because it would be in advance of the Snowy 2.0 expansion coming online (due in 2026) and also several years ahead of the next scheduled coal closure – 2029 for Vales Point B.

- For **utility-scale wind and solar farms**, Green Energy Markets maintains a database of all projects in operation, under construction, contracted under

[25] Origin Energy. Origin progresses plans for nation's largest battery at Eraring Power Station. 12 January 2021.
[26] AGL. AGL firms up capacity with grid-scale battery in Victoria. 23 November 2020.
[27] The forecasts of utility scale wind and solar generation only includes projects for which there is high likelihood of proceeding. If additional projects proceed, the amount of 2025 generation would go up. See appendix "2025 Renewables Generation" for further details.

long-term power purchase agreements but not yet committed, and also a series of tenders by major corporations and government entities to contract for renewable energy under long-term supply agreements. These formed the basis for our forecasted 2025 generation from these power sources.

- For **rooftop solar**, Green Energy Markets' forecasts of solar capacity prepared for the Clean Energy Regulator in September 2020[28] were used to determine expected annual generation in 2025.

The expected 2025 annual wind and solar output was then distributed across 30-minute intervals in accordance with the distribution of output from solar and wind plants that were fully operational at the beginning of 2018 as well as 2018 rooftop solar generation patterns estimated by AEMO.

To evaluate how this generation would act to displace fossil fuel generators we undertook the following steps:

1. The extra renewables first went towards meeting the small growth in electricity consumption predicted between 2018 and 2025, as forecast by AEMO in its 2020 Statement of Opportunities.[29] The extra renewables covered 99.9% of the demand growth. In the small number of intervals where renewables were insufficient, gas output was assumed to increase to fill the remaining demand growth.

2. After this, the growth in renewables then had to cover the loss of generation during each 30-minute interval from the exit of Liddell (based on its 2018 generation levels); this was the case for 98% of 30-minute intervals. In the small number of intervals where renewable generation was insufficient, gas output was assumed to increase to fill the difference.

3. In the vast majority of cases where the extra renewable generation exceeded Liddell's generation, it was then assumed to displace gas generation, as gas generation has the highest short run marginal cost (SRMC) of all the key energy generation technologies in the NEM (as shown in) and therefore usually bids into the wholesale spot market at high prices (see appendix for further details).

4. In the event that the extra renewables generation exceeded the above three items, it would then act to displace output from coal generators, as coal has the next highest SRMC after gas as shown in . To examine how each coal generator is affected, displacement by the extra renewable generation would first be allocated to the coal plant with the highest SRMC and would then proceed to the next highest SRMC coal generator. Generation from each coal plant would be displaced until it reached the total minimum stable generation load of all its generating units, as specified by AEMO. At this

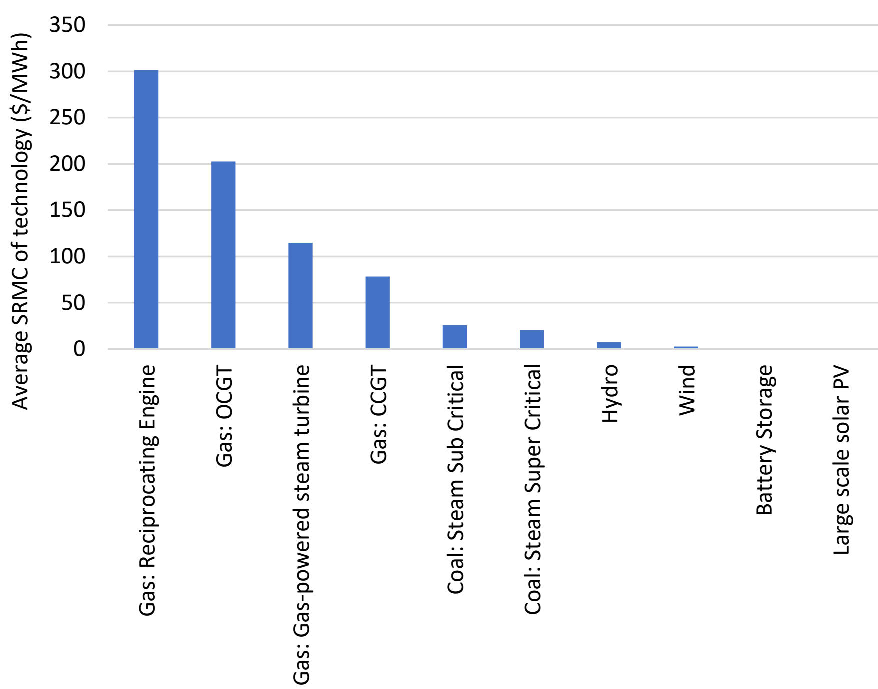
[28] Green Energy Markets (2020) Updated STC Forecast prepared for the Clean Energy Regulator, September 2020
[29] AEMO. 2020 Electricity Statement of Opportunities (ESOO) – electricity consumption and demand forecasts used. 27 August 2020.

point, the coal power plant's generation would no longer be displaced and any remaining renewable energy generation would be used to displace the next highest cost coal generator.

5. In cases where all coal generators' output was displaced down to their minimum stable generation level (as shown in Table 1) we assumed any remaining generation was curtailed and spilled (lost). The amount of generation spilled under this simplified assumption was actually quite large at almost 17,000GWh. In practice, we suspect the spillage would be far smaller because during months of low electricity demand a number of coal generators would elect to take some of their generating units out of service to minimise wear and tear from ramping stress and to reduce operating costs. Batteries, which are not included in this analysis, are also likely to soak up some of this spillage.

Our analysis did not consider the degree to which the growth in wind and solar output might displace hydro output. This is because hydro generation is ultimately dictated by water inflows and requirements to release water for agricultural and environmental purposes. Any displacement of hydro in one period will ultimately return as increased output at another period in time.

Figure 3: Average Short Run Marginal Cost of Each Technology in the NEM ($/MWh)



Source: AEMO.[30]

[30] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator Summary - Existing, Committed and Anticipated Generators.

Table 1: Coal Plant Minimum Generation Levels

Plant	Min Stable Level (MW)
Bayswater	1000
Callide B	280
Callide C	242
Eraring	720
Gladstone	440
Kogan Creek	300
Liddell	440
Loy Yang A Power Station	1080
Loy Yang B	400
Millmerran	360
Mt Piper	480
Stanwell	540
Tarong	420
Tarong North	117
Vales Point B	500
Yallourn	780

Source: From AEMO Input and Assumptions Workbook, Tab: Generator operating limits and behaviours used in AEMO's Detailed Long Term (DLT) Model.[31]

Estimating Prices

In addition to evaluating lost output, our analysis also considered two different pricing scenarios as shown in Table 2:

- **Scenario A** conservatively assumes that 2020 spot prices continue – therefore the 2020 NEM-wide (weighted average by region) spot price is applied to all generators in 2025. This gives an average annual price of $50/MWh.

- In **Scenario B**, prices are determined based on the extent of fossil fuel capacity required to satisfy demand. This gives an average annual price of $34/MWh.

A strong relationship exists between historical demand for fossil fuel capacity and price: the higher the fossil fuel demand, the higher the price, as shown in Figure 4. Historically, typical price setters are fossil fuel plants, and price takers are wind and solar. Wind and solar, as noted in Box 1, typically bid into the market at prices close to or below zero. Therefore, it can be assumed that fossil fuel demand is

The higher the fossil fuel demand, the higher the price.

[31] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator operating limits and behaviours used in AEMO's Detailed Long Term (DLT) Model.

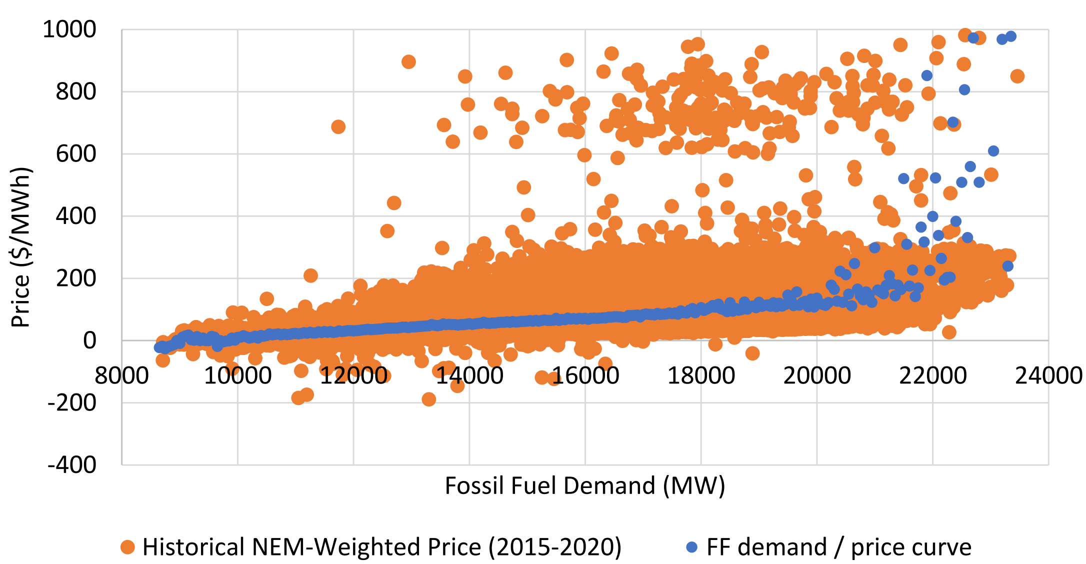
an indicator of historical price. Prices for 2025 can therefore be estimated by using a fossil fuel demand/price curve, shown in Figure 5. Shut coal plants were removed from the historical fossil fuel demand (Liddell, Northern, Anglesea, Hazelwood) in order to simulate the tight supply and therefore provide an indicative price after the closure of these plants.

Table 2: 2025 Price Forecast Scenarios

Scenario		Description	Average Price ($/MWh)
A	**2020 spot prices NEM**	2020 spot prices weighted average across all NEM regions.	50
B	**Matching up to historical demand average intervals, removing shut coal, price at extremities is average of 2000MW range**	Fossil fuel demand/price curve created and future fossil fuel demand matched up to corresponding price on the curve. For future fossil fuel demand that fell below historical fossil fuel demand minimums, average spot price for lowest 2000MW of fossil fuel demand used. For fossil fuel demand above maximum historical fossil fuel demand, average spot price for highest 2000MW of demand used.	34

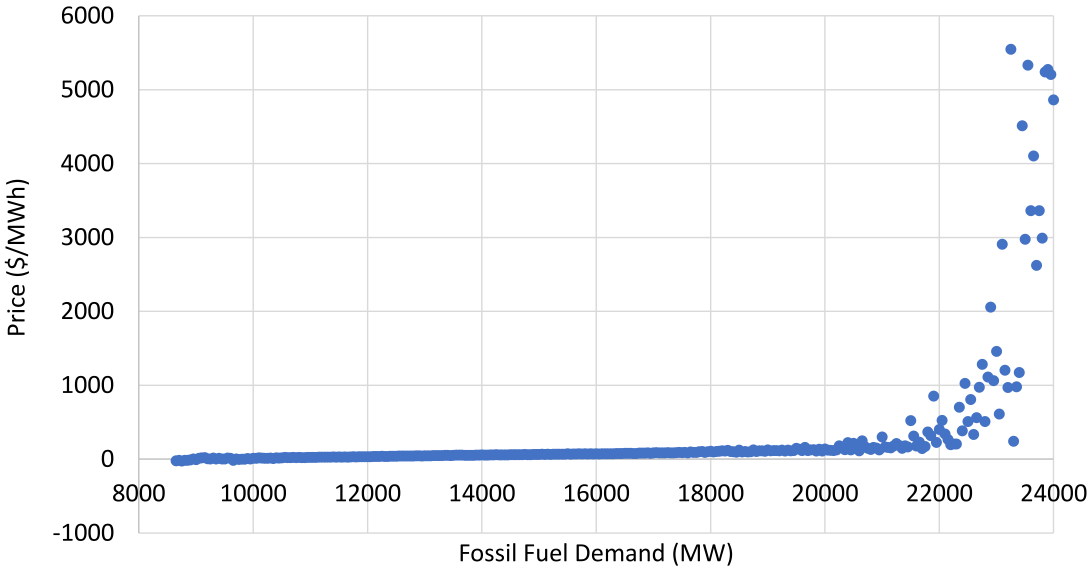
Source: IEEFA analysis.

Figure 4: Historical NEM Price vs Demand (2015-2020) Overlaid With Fossil Fuel Demand vs Price Curve



Source: IEEFA analysis. Based on AEMO historical price and generation data.
Note: Price axis has been truncated at $1000/MWh. Orange - 30 minute spot prices of 2015-2020 period plotted against historical fossil fuel demand, removing shut coal (Liddell, Northern, Anglesea, Hazelwood). Blue - Fossil fuel demand vs price curve.

Figure 5: Fossil Fuel Demand vs Price Curve Created Using Historical Data (Including Tail-end)



Source: IEEFA analysis.

Notably, in 2025 it is predicted that fossil fuel supply will dive lower than historical minimums as gas and coal plants are pushed out of the market. This typically happens in the middle of the day when solar output is at its highest. At these times, the price of electricity has been assumed as the average price for the lowest 2000MW of historical fossil fuel demand ($12/MWh). This assumption is generous to generators' top line, as in reality prices are likely to regularly fall to negative values.

Price Is Forecast To Continue Falling

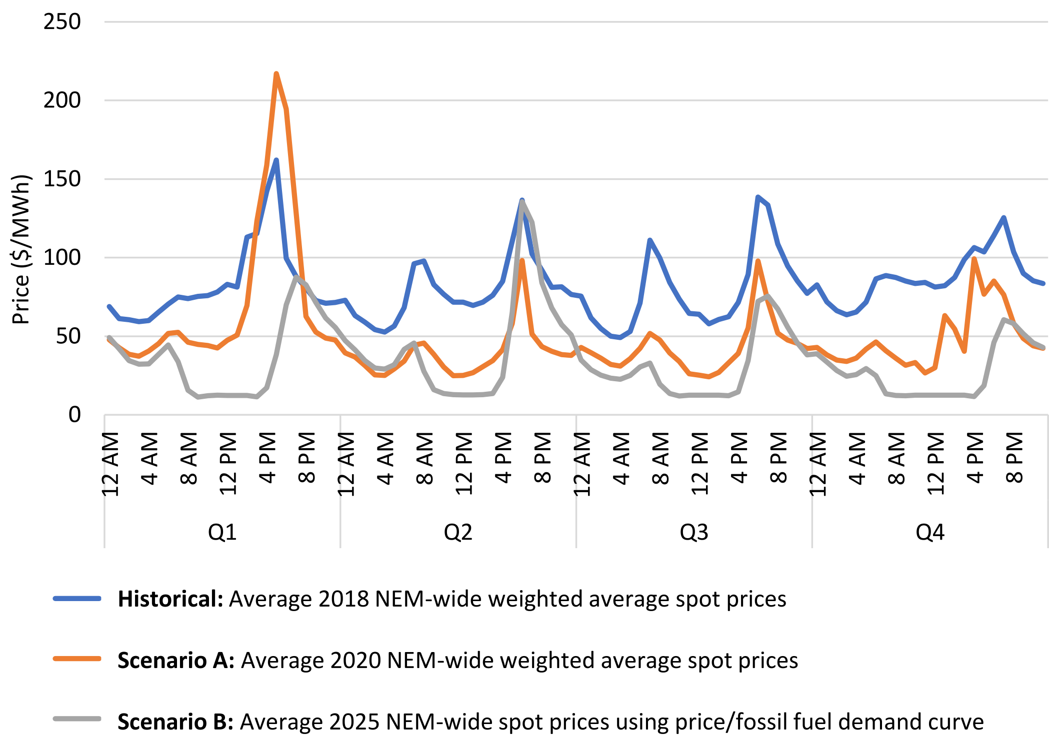
Through this method we see the 2025 price moving downwards to below 2015 levels, as shown in Table 3. Prices in the middle of the day reduce dramatically due to large amounts of solar available at those times. Price peaks in the evening are still experienced, however, the additional wind generation installed displaces coal plants, leading to lower fossil fuel generation levels and therefore lower prices in the evenings. This is demonstrated in the daily price profile shown in Figure 6.

Table 3: Historical and Future NEM-wide Average Prices

Year	Average Wholesale Price NEM-wide	% Reduction
2015	43	
2016	62	44%
2017	98	59%
2018	82	-16%
2019	88	7%
2020	50	-43%
2025 Scenario A (2020 prices continue)	50	0% (v2020)
2025 Scenario B (price/fossil fuel demand curve)	34	-32% (v2020)

Source: IEEFA analysis. Based on historical AEMO generation and price data. See appendix for further details.

Figure 6: Average Quarterly Prices in Each Scenario



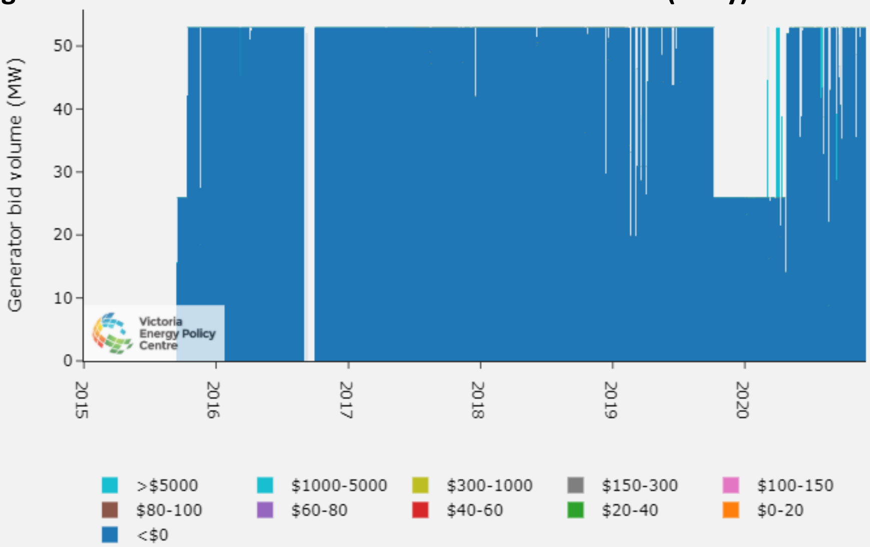
Source: IEEFA analysis. Based on historical AEMO generation and price data.

The uncertain timing of entry and exits into the NEM impacts the accuracy of energy price forecasts, therefore we have included multiple scenarios that we expect may span possible future outcomes. 5-minute settlement will change the market dynamics and may impact on price, however this has not been incorporated into the analysis.

Box 1: Price Bidding Behaviour of Renewables

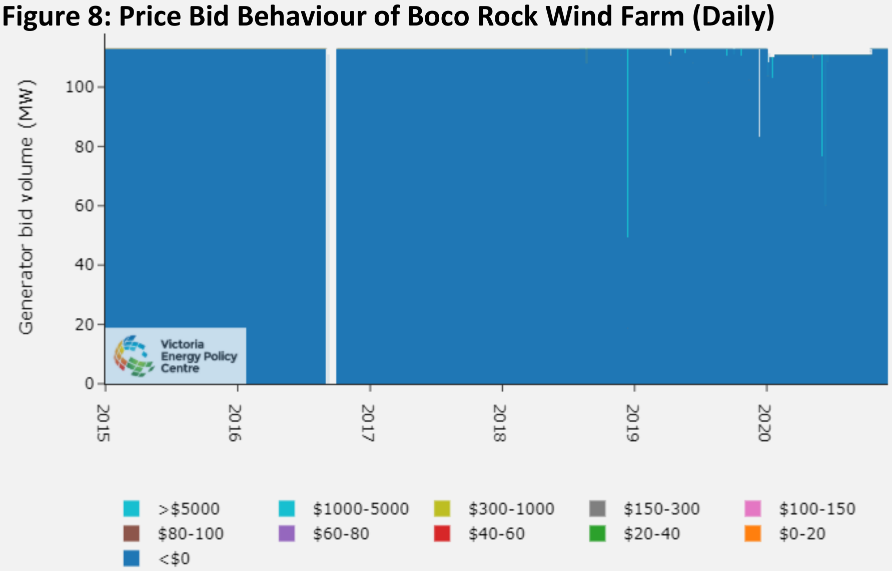
Renewables usually bid into the market at zero or negative prices, as visualised in the historical energy market bids of Broken Hill Solar Plant (Figure 7) and Boco Rock Wind Farm (Figure 8). Additionally, seven renewable generators were selected to examine the bidding behaviour of renewable energy plants, and the amount of time they bid at zero or below was 99% as shown in Table 3. Therefore, for the purpose of this analysis it is assumed that renewable generators are dispatched first in line with the merit order.

Figure 7: Price Bid Behaviour of Broken Hill Solar Plan (Daily)



Source: *VEPC NEM Data Dashboard*.

Figure 8: Price Bid Behaviour of Boco Rock Wind Farm (Daily)



Source: *VEPC NEM Data Dashboard*.

Table 4: Bidding Behaviour of Sample of Wind and Solar Plants

Plant Name	Technology	<$0	$0-5000	>$5000	% Time Less Than Zero
Bannerton Solar Park	Solar	853	0	10	99%
Beryl Solar Farms, Units 1-60	Solar	591	1	5	99%
Broken Hill Solar Plant	Solar	1875	0	26	99%
Ararat Wind Farm	Wind	1557	0	42	97%
Bald Hills Wind Farm	Wind	2077	2	18	99%
Boco Rock Wind Farm	Wind	2132	2	23	99%
Bodangora Wind Farm	Wind	848	0	13	98%
Average					**99%**

Source: VEPC NEM Data Dashboard.

Generator Costs

In order to determine the financials of coal plants, costs have been taken from AEMO's Integrated System Plan (ISP) Input and Assumptions Workbook, as shown in Table 5.

Table 5: Coal Plant Generator Information

Coal Plants	State	FOM ($/kW/annum)	Maximum Capacity (MW)	VOM ($/MWh sent-out)	Heat Rate (GJ/MWh HHV s.o.)	Fuel Cost ($/GJ)	SRMC ($/MWh)
Liddell	NSW	54.05	2000	4.28	10.14	1.61	21
Eraring	NSW	54.05	2880	4.28	9.55	3.99	42
Mt Piper	NSW	54.05	1320	4.28	9.25	3.99	41
Vales Point B	NSW	54.05	1320	4.28	9.68	3.57	39
Gladstone	QLD	54.05	1680	4.28	9.47	2.65	29
Stanwell	QLD	54.05	1460	4.28	9.07	2.51	27
Tarong	QLD	54.05	1400	4.28	9.21	2.36	26
Callide C	QLD	54.05	840	4.28	9.3	2.22	25
Tarong North	QLD	54.05	450	4.28	8.65	2.36	25
Callide B	QLD	54.05	700	4.28	9.16	2.22	25
Bayswater	NSW	54.05	2640	4.28	9.45	1.61	19
Kogan Creek	QLD	54.05	744	4.28	8.8	1.37	16
Millmerran	QLD	54.05	852	4.28	9.21	1.18	15
Yallourn W	VIC	153.64	1450	4.28	13.9	0.64	13
Loy Yang B	VIC	116.9	1115	4.28	12.54	0.64	12
Loy Yang A	VIC	147.9	2210	4.28	12.16	0.64	12

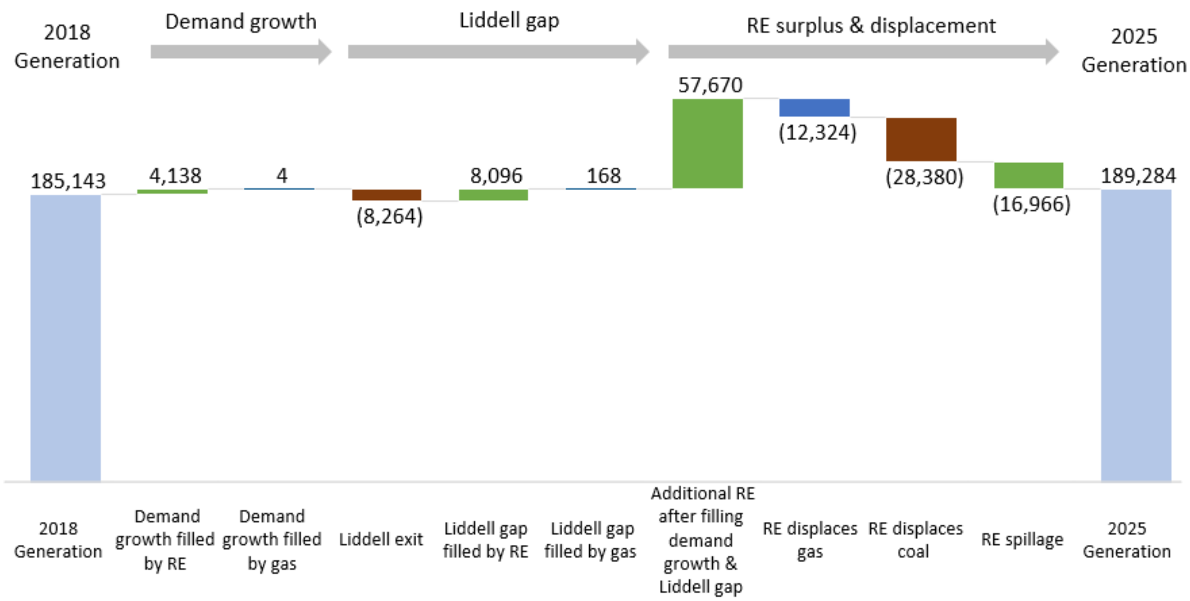
Source: AEMO.[32]

[32] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator Summary - Existing, Committed and Anticipated Generators.

Results Show Overall Displacement of Fossil Fuels

Figure 9 below illustrates how the growth in renewable energy is modelled to first cover demand growth (covering 99.9% of intervals), then the lost generation from Liddell (covering 98% of intervals). Gas is assumed to fill any remaining gaps in demand growth or Liddell exit. After that, the growth in renewable energy displaces gas in line with the merit order effect, as gas has the highest SRMC of all the key generating technologies in the NEM. Then coal is displaced, as it has the next highest SRMC. The remaining surplus renewable generation is assumed to spill.

Figure 9: Annual Generation Changes From 2018 to 2025 (GWh)

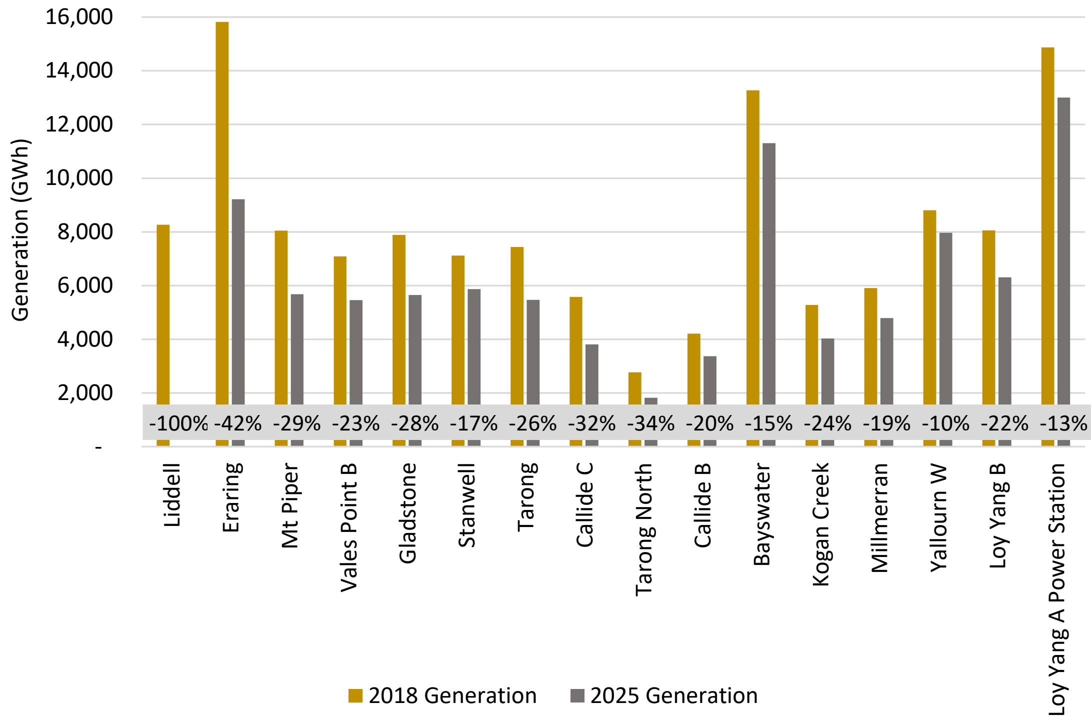


Source: IEEFA analysis. See appendix for further details.

Revenue Reductions of Between 44% to 67% for Coal Plants

Figure 10 shows how the displacement flows to lost sales volumes (generation) for each coal generator. Note that these are listed in order of AEMO's estimate of the SRMC, with the highest cost generator on the left, and costs progressively declining as generators move further to the right. Lost sales volumes are partly a function of their cost position but also the degree to which the generator's output can reduce down to minimum stable generation levels. This means some generators with lower costs (but lower minimum generation level) can experience greater falls in output than those generators that are higher cost (but with higher minimum generation level).

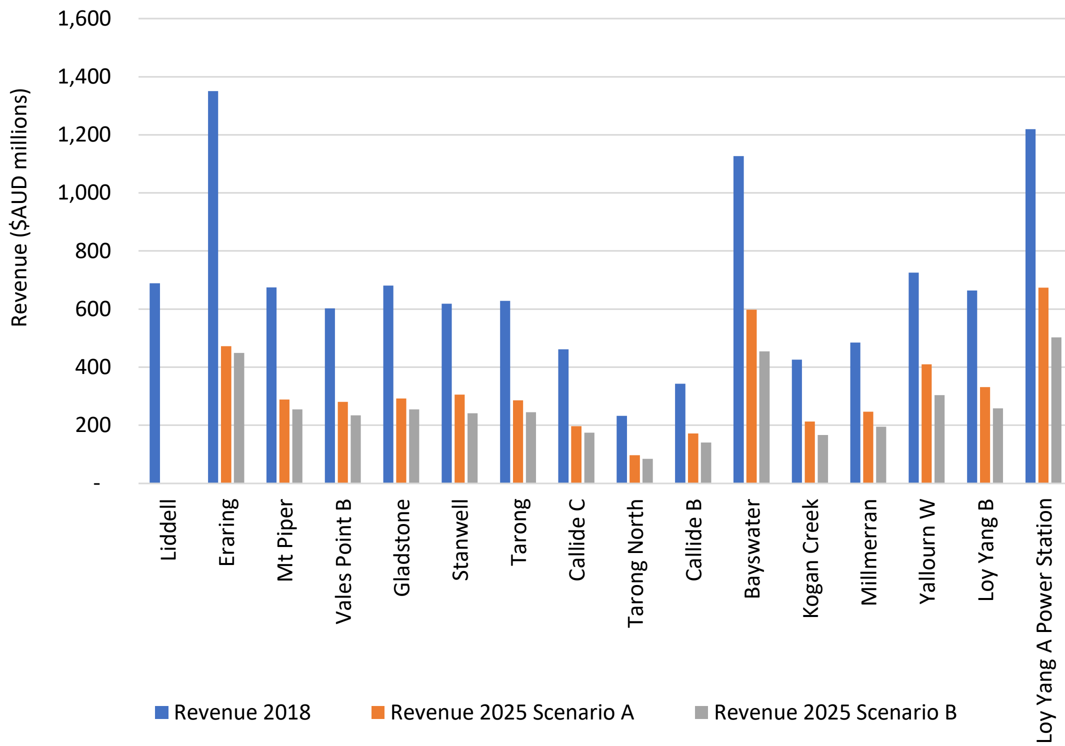
Figure 10: Coal Plant Generation 2018 to 2025 Forecast (GWh)



Source: IEEFA analysis. See appendix for further details.

Figure 11 details how the lost sales volumes in conjunction with reduced prices flow through to revenue reduction for each coal generator relative to 2018 levels. The revenue of most coal plants is expected to reduce by 44% to 67%. The most impacted is Eraring as the model acts to curtail its output first because it has the highest short-run marginal cost (SRMC) of all the coal plants based on AEMO's data. Eraring's revenue will reduce by 65% in scenario A (if NEM-wide 2020 prices are at play in 2025) and by 67% in scenario B (using fossil fuel demand/price curve).

Figure 11: Revenue in 2018 vs 2025 ($AUDm)



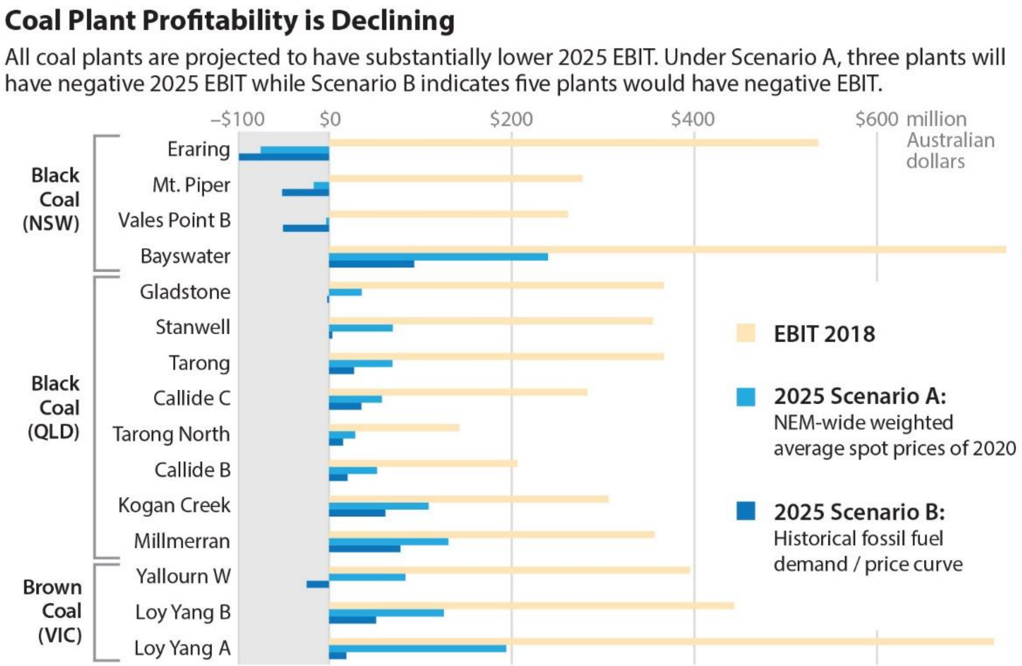
Source: IEEFA analysis. See appendix for further details.

Several Coal Plants Likely to Become Unprofitable or Barely Profitable

Based on our analysis, EBIT for coal plants will also reduce in line with reducing revenue. The EBIT for coal plants has been taken as the wholesale spot market revenue (modelling 100% of the plant to be exposed to the spot market) and subtracting the fixed operations and maintenance costs (FOM) and short run marginal cost (which consists of variable operations and maintenance costs (VOM) and fuel costs). The cost assumptions are outlined previously in Table 5. Figure 12 details our estimates of EBIT for each coal plant in 2025 compared to 2018.

In scenario A, Eraring, Mt Piper and Vales Point B have negative EBIT in 2025. In scenario B, Eraring, Mt Piper, Vales Point B, Gladstone and Yallourn have negative EBIT in 2025. Additionally, in scenario B the spot price is predicted to fall below the SRMC of various coals plants between 7% to 67% of the time, indicating that they will not be recovering their variable costs in those time periods.

Figure 12: EBIT of Coal Plants 2018 vs 2025 ($AUDm)



Source: IEEFA analysis based off AEMO data and Green Energy Markets forecast. See appendix for further details.

As Figure 12 clearly illustrates, EBIT for several coal generators in the NEM is eroded down to thin levels, especially under scenario B price assumptions.

The important point to take away from these results is not so much about which individual power plants are, or are not, generating a cash profit. Rather, it is that many of them end up with very thin levels of profitability which suggests closure is reasonably likely (and this is without taking into account several non-operating costs such as financing). A closure would in turn reduce the supply available and likely drive an increase in wholesale electricity prices, making other coal plants more profitable.

As an example, it is probable that Eraring may not be as severely affected as modelled because our assumption that it is fully curtailed down to minimum stable output before other generators curtail is a simplification of reality. But, while this might lift EBIT for Eraring somewhat, it means several other coal generators will have even thinner levels of cash profit than modelled, or greater losses.[33]

The fact that our results show several coal power plants barely generate a cash profit suggests at least one of them is vulnerable to closure, but exactly which one is extremely difficult to judge. Scenario A shows 3 plants to have negative EBIT, and

[33] Non-electricity spot market revenue is excluded (e.g. revenue from FCAS (Frequency Control Ancillary Services)) and therefore plants may have higher EBIT than shown above if able to generate revenue from other markets or via contractual arrangements.

Scenario B 5 plants, however once one coal plant exits the dynamics of this study would change (explored further below with Eraring example).

The businesses that own coal generators face an array of complex commercial factors that feed into their decisions about whether to continue operating a plant. These can include the extent and cost of maintenance the plant requires, the contracts they have in place with coal suppliers and customers, site clean-up/remediation costs, the possible impact of plant closure on the profitability of other generators/assets they own, the financial strength of the parent company, broader strategic goals around decarbonisation, or the impact the owner thinks closure will have on their competitors.

Our results show several coal power plants barely generate a cash profit.

As just one example, it is reported that the NSW Government, in selling Vales Point for $1m, agreed that the Vales Point owner would take on only $10m of the environmental clean-up costs for the plant, leaving the NSW Government on the hook for the remaining amount, which could be more to the order of $300m or more (Hazelwood rehabilitation cost was above $300m, Liddell rehabilitation is expected to cost above $500m).[34] This might mean that the owners of Vales Point could be more willing to close Vales Point plant ahead of Eraring being closed, even if Eraring was losing more money than Vales Point.

Implications for the NEM

The analysis detailed in this report suggests that the financial viability of several coal generators in the NEM will become severely compromised by 2025, such that closure becomes an attractive or even unavoidable choice for an owner. However, whether or not this is a problem for the Australian community and economy is dependent on whether replacement capacity is actually needed and whether it is built in advance of closure to ensure both reliability and affordability is maintained.

The Answer To Less Coal Is Unlikely To Be Subsidies for More Coal

A number of policy makers have approached this issue with a flawed and simplistic chain of logic: the closure of coal plants has led to problems in the past so therefore we need to prevent coal plants from closing or build new coal plants to replace them.

[34] RenewEconomy. NSW exposed to 'unquantifiable liabilities' for Vales Point decommissioning, documents show. 12 July 2019.

This kind of flawed thinking was personified when AGL announced many years in advance that it would close the Liddell Power Station in 2022 (since deferred to 2023). Responses included suggestions that AGL be forced to sell the plant to another operator immediately, and well in advance of the planned closure. Former Prime Minister Tony Abbott even argued that the government should nationalise the power station including sending in the military to seize possession.[35]

To help explain why this logic is flawed, it is useful to delve into the detail of our modelling of the time distribution for the extra wind and solar generation coming online.

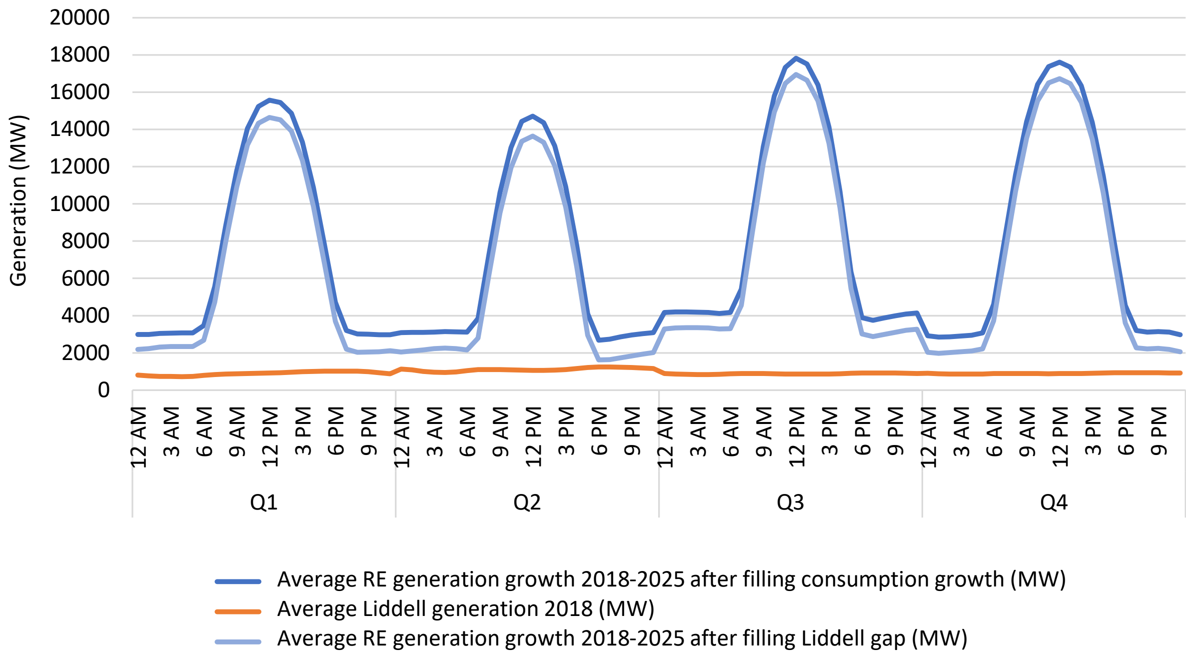
As explained earlier, we distributed expected 2025 annual wind and solar output across each 30-minute interval in accordance with distribution of output from solar and wind plants that were fully operational at the beginning of 2018. Before getting to the point of displacing the output from coal power stations, the extra renewables first went towards meeting the small growth in electricity consumption forecast by AEMO in their 2020 Statement of Opportunities.[36] After this, it then had to cover the loss of generation from the exit of Liddell.

At this point our analysis got very interesting.

In the dark blue line in Figure 13, we illustrated the average time-of-day profile for renewable energy in 2025 by quarter, using 2018 patterns after it had covered off on expected electricity demand growth. The orange line meanwhile depicts Liddell's average time-of-day generation pattern for each quarter over 2018. As you can see, the extra wind and solar output dwarfs the output from Liddell. This is particularly noticeable during daytime as a result of solar generation. But even in the evenings, renewables output tends to be much larger than the output from Liddell. The light blue line illustrates the amount of extra renewable generation remaining to displace other fossil fuel generations after covering the lost generation from Liddell's closure.

[35] Phil Coorey. Ministers rally behind Malcolm Turnbull, Tony Abbott agitates, Australian Financial Review. 9 April 2018.
[36] AEMO. 2020 Electricity Statement of Opportunities (ESOO) – electricity consumption and demand forecasts used. 27 August 2020.

Figure 13: Renewables Will Mostly Fill the Gap Left by Liddell Exit



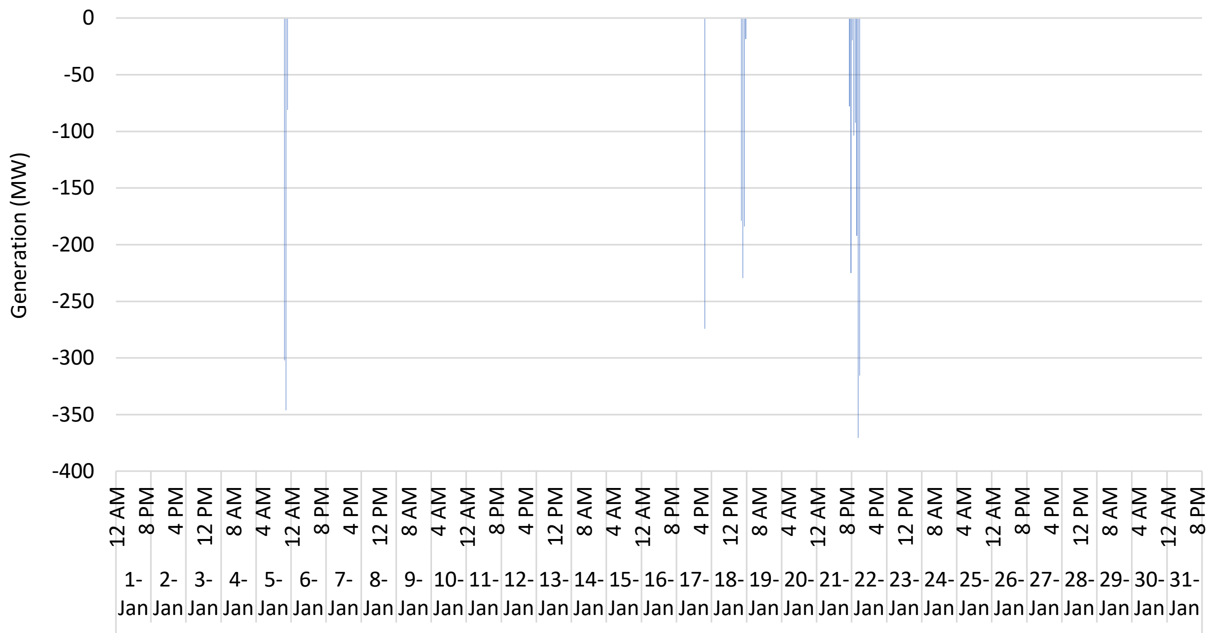
Source: IEEFA analysis. See appendix for further details.

What this serves to show is that even if AGL had sought to keep Liddell open, it would have struggled to survive against this huge amount of extra renewable supply.

It should be noted that the averages illustrated above do obscure some short points in time where the extra renewables output would not entirely cover the generation provided by Liddell. Yet the problem for an inflexible coal generator, particularly one as old as Liddell, is that the window of time when it might be needed in 2025 would be incredibly brief. To use January as an illustration of how brief the gaps are that are left by the exit of Liddell (January was the month when demand for power peaked in 2018), Figure 14 shows an hourly break-down of points in time when the extra renewables output fell short of the amount of output provided by Liddell. From the 744 hours in January, there were just 16 hours or about 2% of the time when Liddell's output was not entirely covered by the expected growth in wind and solar output.

Even if AGL had sought to keep Liddell open, it would have struggled to survive.

Figure 14: Liddell Gap Not Met by Renewables (MW)



Source: IEEFA analysis. See appendix for further details.
Note: The gaps left from Liddell's exit not covered by solar or wind are infrequent and short. These are assumed to be covered by gas in this analysis (although could also be covered by batteries or other generation technology).

If we look across the whole entire year, the total Liddell gap that is not met by renewables is 168GWh[37] which given Liddell's total capacity of 2000MW, equates to a utilisation rate of less than 1% which is simply not practical for such a plant.

The point of this analysis is *not* to suggest that we need not worry about coal power plants closing. Rather, it serves to illustrate that our requirements for power from dispatchable power plants (which includes several technology options) are changing and they will be needed far less frequently than in the past. They will also need to have greater capacity to quickly ramp their output up and down if they wish to continue to effectively participate in wholesale markets.

Our requirements for power from dispatchable power plants are changing.

[37] The Liddell gap not filled by renewables in 2025 is assumed to be filled by gas in this analysis, however could also potentially be covered by committed battery projects (or other types of generation), which have not been taken into account in this study.

In 2025 coal plants are likely to be ramping down to their minimum generation levels more frequently. There are risks that the ramping of coal plants may place physical stress on plants, increase the risk of failure, or increase maintenance costs. These risks will need to be considered and managed. The need to ramp down may lead to coal plants turning off one or more units, as typically there are 2-4 generating units in an Australian coal plant.[38] It could also lead to coal plants looking to further reduce their minimum generation levels – to explore how they can ramp down even further, particularly during periods of time when electricity prices are below their operating costs. This may require investment in ramping capability – however the question will be whether that will be worthwhile given the financial outlook of the plant.

Origin's head of supply in its energy markets business, Greg Jarvis, said several options were being considered in response to lower wholesale prices and other market contexts, including closing one or two of Eraring's four units in the "shoulder" seasons of Spring and Autumn, and dialling down generation further during the day.[39] Origin Energy plans to install a 700MW battery energy storage system onsite at Eraring Power Station.[40]

Coal power plants are in some way like a big, heavy, blunt instrument, such as a sledgehammer. They are good if you want to hit a large target that doesn't move around much. They work best satisfying very large blocks of relatively stable electricity demand. Yet the demand that renewables are unable to satisfy requires something that can be more nimbly and finely targeted. Suggestions that the solution to our future reliability needs lies in building more coal or in subsidising existing coal power plants are a bit like suggesting a surgeon should use a sledgehammer instead of a scalpel to conduct a delicate operation.

To help explain this principle of applying the right tool for the job, it is helpful to compare coal with batteries. A number of policy planners have mocked the suggestion that batteries could be useful to our electricity system by pointing out the short duration over which they are typically built to supply their maximum capacity. It is certainly true that batteries are an expensive way at present to meet demand over long durations of time. Yet, if you want a burst of power over a short period of time, batteries are one of the cheapest ways you can get it (although the best option is to encourage customers to briefly reduce their demand or shift their load in time).

Figure 15 shows estimated build costs in 2020-2021 for a kilowatt of capacity from different technologies. A battery delivering its capacity for 2 hours is the cheapest option. While 2 hours doesn't sound like much, if we refer back Figure 14, it is apparent that the gaps left by Liddell's exit are short, with lots of time left between them for the battery to recharge. Some of the gaps are longer than 2 hours, but the

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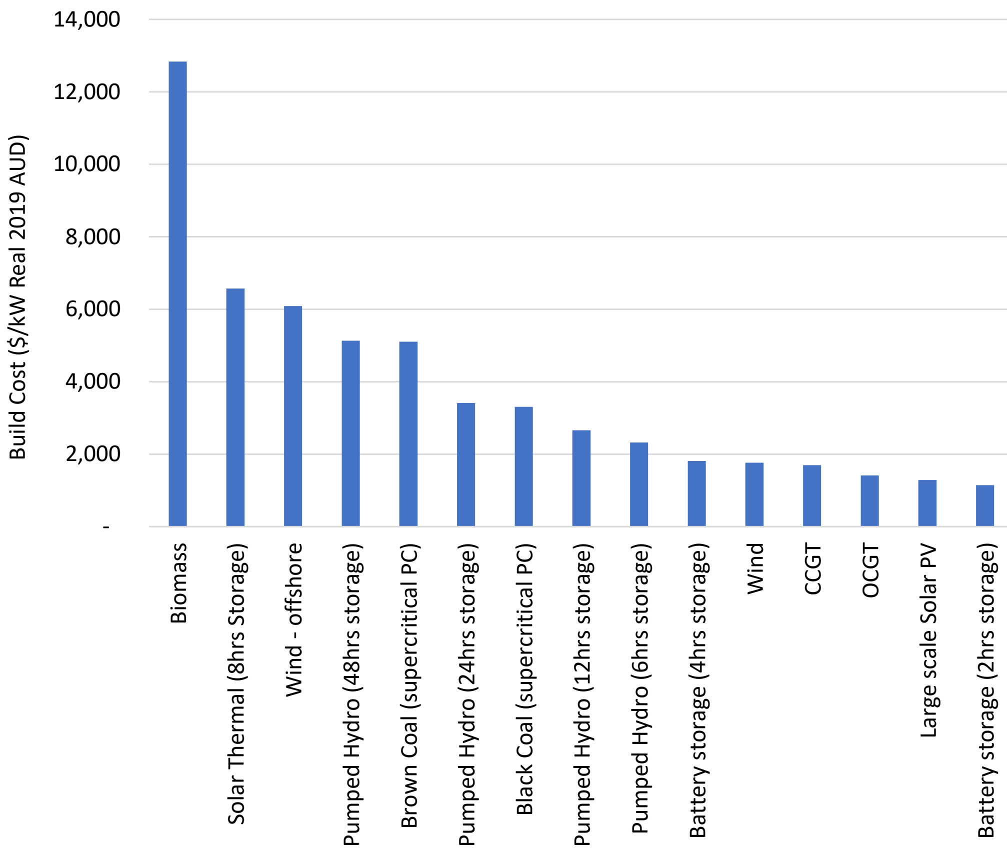
[38] AEMO. 2019 Input and Assumptions workbook. Tab: Generator operating limits and behaviours used in AEMO's Detailed Long Term (DLT) Model.
[39] Financial Review. Origin upgrades APLNG guidance. 26 November 2020.
[40] Origin Energy. Origin progresses plans for nation's largest battery at Eraring Power Station. 12 January 2021.

times when the gap coincides with high demand periods tends to be just 2 hours, with the remaining time capable of being filled by other pre-existing generators.

Figure 15: Build Costs for Generation Technologies 2020-2021



Source: AEMO – Original Source CSIRO GenCost 2020 and Entura 2018.[41]

By comparison, building new coal power stations would incur a cost around three times greater than a battery, and those stations would be physically incapable of switching on and off for the short periods of time needed. Alternatively, it might operate as baseload but that would simply push another coal generator into the same impossible and unviable position Liddell would have faced of desperately trying to swing in and out of the market around low priced wind and solar.

The same zero-sum game comes from pursuing the proposal of "underwriting" or subsidising an existing coal power station to prop it up. This would simply move the displacement onto another already struggling coal generator, increasing its risk of closing in response to the government subsidised plant.

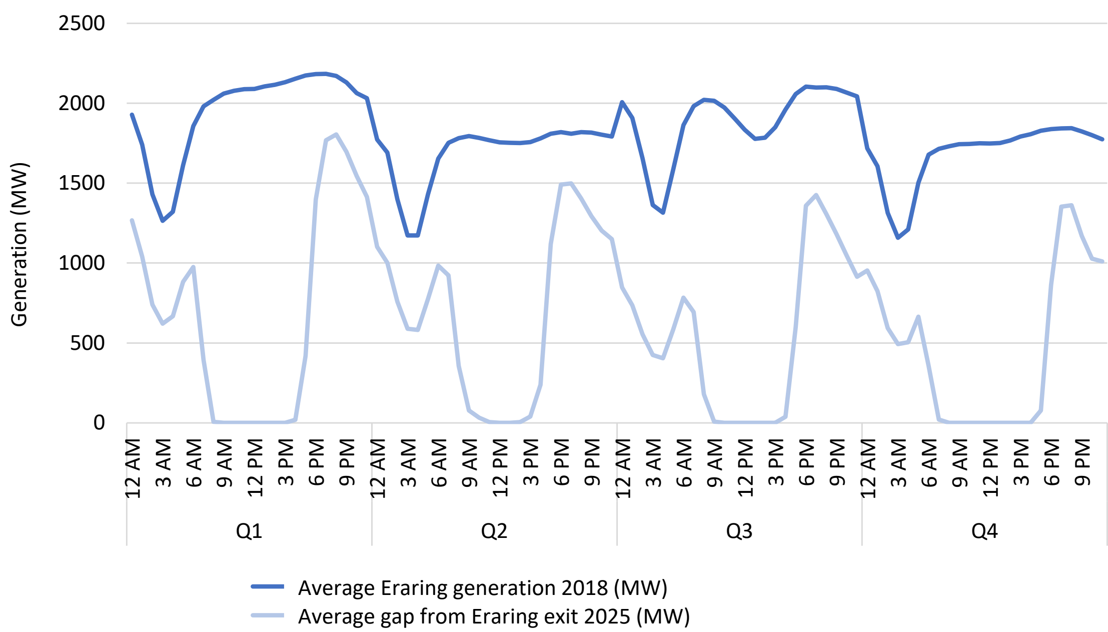
If we move our gaze beyond Liddell to the next possible coal closure, we see the gaps not met by renewables will be larger, but they remain constrained to night time. We have chosen to examine Eraring because our method only considers short-

[41] AEMO. 2019 Input and Assumptions workbook. 5 July 2020.

run marginal cost as the determinant of which plant is most displaced, and Eraring has the highest SRMC (but notably other coal plants may be more vulnerable to closure than Eraring due to other factors e.g. contractual arrangements, investor pressure, rehabilitation cost).

Figure 16 shows the average time profile for generation from Eraring in 2018 (in dark blue) and then the supply gap that would be left in the event of its closure, taking into account the extra supply from wind and solar in 2025. This shows that over almost the entire middle of the day from 8am until 4pm, there is virtually no gap at all (i.e. there is enough new renewable supply to fill the Eraring exit gap). But then any replacement generators would need to rapidly ramp up to meet the evening demand peak before rapidly ramping down after 8pm, with a brief burst in the early morning before falling to zero at 8am. This is clearly not a lucrative job for a new coal generator.

Figure 16: Eraring Generation in 2018 and Supply Gap in 2025 in Event of Closure (MW)



Source: IEEFA analysis.

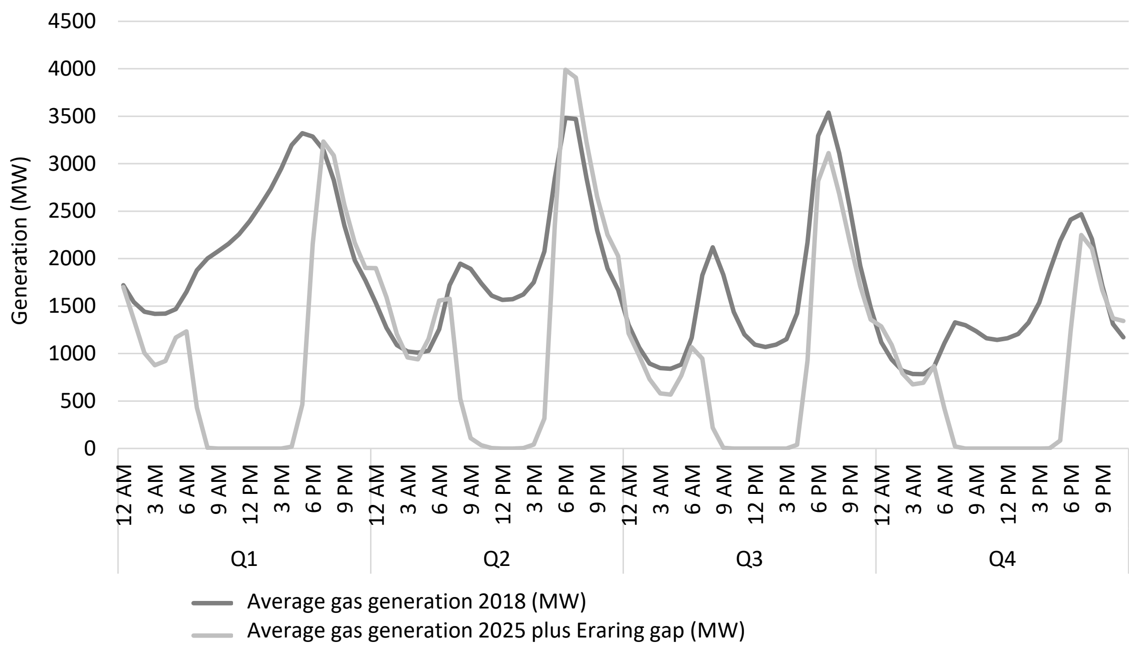
Do We Need More Gas?

Replacing short gaps in supply with gas power plants makes much more sense than coal given their lower build costs and lower fixed costs, as well as their greater flexibility. However, the picture is complicated as to whether gas is the answer when there are other options available.

Figure 17 illustrates (in the dark grey line) the average time-of-day generation profile for gas by quarter for 2018. The light grey line depicts the profile of gas generation after taking into account displacement by the growth in wind and solar plus the supply gap left if Eraring were to close. Overall annual gas generation in 2025, even if it had to completely cover the exit of Eraring, would still be 45% less than what it was in 2018. This is because solar generation is so huge in the middle of the day that it can displace all daytime gas generation while also covering Eraring's lost output. Surprisingly, average generation levels over the evening aren't that much higher for 2025 than they were in 2018. This shows we would not need more supply of gas fuel in the case of an Eraring exit.

We certainly won't need more gas fuel supply.

Figure 17: Gas Profile in 2018 and 2025 if Eraring Exits (MW)



Source: IEEFA analysis.

However, if we examine peak or maximum output requirements rather than just averages, this indicates that we will need to draw on a greater amount of power plant generating capacity than required in 2018 (beyond that provided by growth in wind and solar) to make up for the shortfall from an Eraring exit. This suggests we may well need more power generating plants, even though we will need far less gas to run them.

It is not necessarily a given that the answer to this is more power generators fuelled by gas. The economics around any new build plant to fill potential capacity gaps that are of relatively short duration are complicated. A gas plant could be viable over the short-term, but it involves a large upfront investment that probably needs many years of operation to pay this investment back. It also faces significant fuel costs.

Meanwhile, pumped hydro and batteries will be able to take advantage of plentiful cheap electricity to recharge their energy storages in the middle of the day. They can also potentially earn revenue in the middle of the day by providing frequency control services by moderating their charging levels. Also, battery costs are expected to decline substantially over the coming decade. They are also likely to prove popular with the 2.7m households that have adopted solar systems. These households have a significant and reliable arbitrage opportunity in not exporting solar to the grid at very low midday wholesale rates, and instead using it later via the battery to avoid importing power from the grid at retail rates.

Battery costs are expected to decline substantially over the coming decade.

It is also important to consider that the Snowy 2.0 expansion is due for completion in 2026 and will probably be sufficient to cover any capacity gap left by a possible early exit of Eraring.

While a gas power plant may not need to be used all that frequently, it emits substantial CO2 when it does generate electricity. To ensure Australia meets the Paris Agreement commitment to help limit global warming below 2 degrees, very rapid decarbonisation of electricity supply is needed, and therefore the regulatory lifetime on a new gas plant needs to be short.

Helping the Market to Decide and Invest on a Timely Basis

Trying to decide which is the optimal set of options for meeting Australia's future electricity needs is highly complex and subject to considerable uncertainty.

Ideally, governments should try to delegate such decisions to professional experts and those willing to risk their own money on the wisdom of their decisions. However, in practice, there are some serious uncertainties and co-ordination problems that Federal and State/Territory governments need to resolve in order for the private sector to have reasonable confidence to invest.

The future lifespan of existing coal generators is one of the greatest elements of uncertainty affecting the Australian electricity market, with potentially profound impacts for commercial returns on investments. While AEMO publishes a schedule for expected closures of coal power plants, the reality is that these are not set in stone. Closures could happen sooner or later depending on commercial circumstances, and changes in the regulatory or policy environment. The factor that most clouds the timing around coal plant closures is the lack of an emissions reduction regulatory framework that investors see as likely to hold over the next decade or two.

If there was an unambiguous and legally binding timeframe for emission reductions, it is likely that private sector investors would be willing to invest in new generation capacity aimed at replacing coal capacity in advance of certainty about their closure dates. This is because they would know that even if made an investment in replacement capacity too early, it would not be too long before a coal closure occurred, and the investment paid off. This would also help to better guide regulators and transmission system planners on the need for investment in new transmission capacity to support connection of replacement capacity and energy.

Unfortunately, a legally binding emissions reduction framework does *not* exist and repeated attempts at introducing one have proven politically difficult. While our analysis suggests coal plant closures may be closer than expected, it will take a brave investor to build a plant over the next few years in advance of a firm closure commitment, given the degree of oversupply and depressed prices ahead.[42]

Another alternative would be to legally lock-in the dates that coal plants will close, with incentives for owners to honour these dates by keeping plants operational up until the date of closure or when sufficient replacement capacity is in place. Such an idea has been put forward by Australian National University (ANU) Professor Frank Jotzo who proposed an auction process that would provide a reward to plants that agreed to shut on a certain schedule ahead of other coal power plants.[43] With the dates publicly known and certain, private sector investors could then make investment decisions about building new supply with far greater confidence. Jotzo's proposal is extremely useful for avoiding potential disruption from unanticipated coal exit because it puts in place a legally enforceable and public schedule for coal exit.

Unfortunately, the idea of seeking to lock-in closure dates, which would then leave the private sector free to decide what to invest in to replace it, has also failed to gather much political traction. For example, an auction process has recently been

[42] The amount of extra wind and solar farm capacity estimated in this study is based solely on projects which are already committed to construction or will be supported under a long-term power purchase contract. These are therefore insensitive to future wholesale power prices or they are so far advanced in construction that they can not be withdrawn in spite of the fact they will suffer from very low power prices. Rooftop solar investment is driven to a large degree by retail prices rather than wholesale prices. In addition, retailers commonly provide an above market premium in their feed-in tariff offers as a way to lure new customers. Also, householders tend not to make sophisticated forward-looking financial evaluations in deciding to purchase solar systems. Consequently, rooftop solar installations are expected to remain strong relative to historical levels, although year install is expected to fall from the amount installed in 2020.
[43] Frank Jotzo, ANU. Brown coal exit: a market mechanism for regulated closure of highly emissions intensive power stations. November 2015.

indicated as unfavourable by the ESB.[44]

Blueprint Institute has also suggested various mechanisms to manage a phase down of coal generators including sectoral emissions targets, offering contracts for emissions, implementing a sealed-bid auction system to allocate contracts for emissions, redeploying/ retraining/ remunerating the affected workforce, and allocating government funding towards the phase down.[45]

Another option which has so far proven to be much more commonly practiced has been for Governments to underwrite or directly fund new power generation capacity. To date state governments have focussed on running periodic competitive open tenders but without any explicit consideration or criteria about how the projects contracted could effectively cover for the exit of coal generators over time. The Federal Government has been more focussed on the issue of providing capacity that is dispatchable but their processes for selecting and funding projects are opaque, and appear to be reactionary. There is no clear coherent strategy evident that is tied to overarching numerical objectives to ensure timely replacement of coal plant and/or reduced emissions. This lack of strategic direction and what appears to be a random and disjointed process for selecting and funding projects has meant the government has not fostered and harnessed the benefits of competition. This is perhaps best illustrated by the decision to approve Snowy Hydro to spend $5 billion on its 2000MW pumped hydro expansion without any open competitive process to consider and evaluate potential alternatives.

So far only the NSW Government has stepped forward with a long-term, clear plan and set of formal processes for how it will ensure new capacity is built that can replace exiting coal on a timely basis while also reducing emissions. While the policy may be overly prescriptive about the nature of the replacement plant and where it should be located, it has established a framework built on competitive selection processes that appear to be open to wide number of participants.

The Energy Security Board (ESB) has also proposed to consider mechanisms to ensure the orderly exit of thermal plants as part of the Post 2025 Market Design work. The ESB has noted that expected reduction in electricity prices will "make it difficult for thermal plants to maintain commercial viability. It is therefore likely to lead to exits of thermal plant faster than anticipated." Yet the fact that their reform process is focussed on introduction of changes only after 2025 means it is likely to be too late to address the challenges identified in this report.

Appropriate transmission and distribution infrastructure will also need to be in place to accommodate new generator entries into the market to replace exiting thermal generation. We would note that the Australian Energy Regulator tends to evaluate whether to approve such investments without any regard to state government's commitments to net zero emissions by 2050. Rather it relies heavily on AEMO's Central Scenario which only takes into account current legislative binding and budgeted measures. This convention effectively assumes state governments will not implement new measures necessary to honour their

[44] AFR. Coal power stations going broke: Schott. 16 February 2021.
[45] Blueprint Institute. Phasing Down Gracefully. 21 December 2020.

commitments to net zero emissions by 2050. This acts to significantly inhibit the degree to which we can replace coal on a timely and efficient basis.

Our analysis suggests that coal plant closures may occur sooner than previously expected. Governments need to urgently put in place the regulatory frameworks that will encourage investors to build the mix of capacity to effectively replace them.

Appendix

Detailed Results: Coal Plant Financials

Table 6: 2018 and 2025 Generation, 2018 Financials

Coal plants	State	2018 Generation (GWh)	2025 Generation (GWh)	Generation change from 2018-2025	Revenue 2018 ($m)	FOM ($/kW/ annum)	Maximum Capacity (MW)	VOM ($/MWh sent-out)	Heat Rate (GJ/MWh HHV s.o.)	Fuel Cost ($/GJ)1	SRMC ($/ MWh)	Total Fixed Cost 2018 ($)	VOM 2018 ($m)	Fuel cost 2018 ($m)	Total variable cost 2018 ($m)	Total Fixed + Variable Cost 2018 ($m)	EBIT 2018 ($m)
Liddell	NSW	8,264		-100%	$689	54.05	2000	4.28	10.14	1.61	21	$108	$35	$135	$170	$278	$410.80
Eraring	NSW	15,818	9,211	-42%	$1,350	54.05	2880	4.28	9.55	3.99	42	$156	$68	$603	$670	$826	$524.25
Mt Piper	NSW	8,051	5,678	-29%	$675	54.05	1320	4.28	9.25	3.99	41	$71	$34	$297	$332	$403	$271.62
Vales Point B	NSW	7,090	5,463	-23%	$603	54.05	1320	4.28	9.68	3.57	39	$71	$30	$245	$275	$347	$256.25
Gladstone	QLD	7,889	5,651	-28%	$681	54.05	1680	4.28	9.47	2.65	29	$91	$34	$198	$232	$323	$358.63
Stanwell	QLD	7,115	5,871	-17%	$618	54.05	1460	4.28	9.07	2.51	27	$79	$30	$162	$192	$271	$346.99
Tarong	QLD	7,438	5,472	-26%	$628	54.05	1400	4.28	9.21	2.36	26	$76	$32	$162	$193	$269	$358.82
Callide C	QLD	5,576	3,814	-32%	$461	54.05	840	4.28	9.3	2.22	25	$45	$24	$115	$139	$184	$277.07
Tarong North	QLD	2,769	1,823	-34%	$232	54.05	450	4.28	8.65	2.36	25	$24	$12	$57	$68	$93	$139.37
Callide B	QLD	4,209	3,370	-20%	$343	54.05	700	4.28	9.16	2.22	25	$38	$18	$86	$104	$141	$201.96
Bayswater	NSW	13,269	11,307	-15%	$1,127	54.05	2640	4.28	9.45	1.61	19	$143	$57	$202	$259	$401	$725.82
Kogan Creek	QLD	5,275	4,026	-24%	$426	54.05	744	4.28	8.8	1.37	16	$40	$23	$64	$86	$126	$299.75
Millmerran	QLD	5,909	4,788	-19%	$485	54.05	852	4.28	9.21	1.18	15	$46	$25	$64	$89	$136	$349.17
Yallourn W	VIC	8,806	7,965	-10%	$726	153.64	1450	4.28	13.9	0.64	13	$223	$38	$78	$116	$339	$386.78
Loy Yang B	VIC	8,055	6,310	-22%	$664	116.9	1115	4.28	12.54	0.64	12	$130	$34	$65	$99	$229	$434.30
Loy Yang A	VIC	14,869	13,006	-13%	$1,219	147.9	2210	4.28	12.16	0.64	12	$327	$64	$116	$179	$506	$712.89
Total Coal		**130,401**	**93,757**														

Table 7: 2025 Financials Under Scenario A and Scenario B

		Scenario A									Scenario B								
Coal plants	State	Revenue 2025 ($AUDm)	Revenue change from 2018-2025	Total Fixed Cost 2025 ($m)	VOM 2025 ($m)	Fuel cost 2025 ($m)	Variable cost 2025 ($m)	Total Fixed + Variable Cost 2025 ($m)	EBIT 2025 ($m)	EBIT change 2018 to 2025 (%)	Revenue 2025 ($AUDm)	Revenue change from 2018-2025	Total Fixed Cost 2025 ($AUDm)	VOM 2025 ($AUDm)	Fuel cost 2025 ($AUDm)	Total variable cost 2025 ($AUDm)	Total Fixed + Variable Cost 2025 ($AUDm)	EBIT 2025 ($AUD m)	EBIT change 2018 to 2025 (%)
Liddell	NSW		-100%							-100%		-100%							-100%
Eraring	NSW	$473	-65%	$156	$39	$351	$390	$546	-$73.49	-114%	$449	-67%	$156	$39	$351	$390	$546	-$96.91	-118%
Mt Piper	NSW	$289	-57%	$71	$24	$210	$234	$305	-$16.60	-106%	$255	-62%	$71	$24	$210	$234	$305	-$50.60	-119%
Vales Point B	NSW	$280	-54%	$71	$23	$189	$212	$283	-$3.13	-101%	$234	-61%	$71	$23	$189	$212	$283	-$49.51	-119%
Gladstone	QLD	$292	-57%	$91	$24	$142	$166	$257	$34.97	-90%	$255	-63%	$91	$24	$142	$166	$257	-$2.08	-101%
Stanwell	QLD	$306	-51%	$79	$25	$134	$159	$238	$68.23	-80%	$241	-61%	$79	$25	$134	$159	$238	$3.25	-99%
Tarong	QLD	$286	-54%	$76	$23	$119	$142	$218	$67.97	-81%	$244	-61%	$76	$23	$119	$142	$218	$26.49	-93%
Callide C	QLD	$197	-57%	$45	$16	$79	$95	$140	$56.41	-80%	$175	-62%	$45	$16	$79	$95	$140	$34.43	-88%
Tarong North	QLD	$97	-58%	$24	$8	$37	$45	$69	$27.91	-80%	$84	-64%	$24	$8	$37	$45	$69	$15.09	-89%
Callide B	QLD	$172	-50%	$38	$14	$69	$83	$121	$51.24	-75%	$141	-59%	$38	$14	$69	$83	$121	$19.86	-90%
Bayswater	NSW	$598	-47%	$143	$48	$172	$220	$363	$234.51	-68%	$454	-60%	$143	$48	$172	$220	$363	$91.27	-87%
Kogan Creek	QLD	$212	-50%	$40	$17	$49	$66	$106	$106.43	-64%	$166	-61%	$40	$17	$49	$66	$106	$60.15	-80%
Millmerran	QLD	$246	-49%	$46	$20	$52	$73	$119	$127.72	-63%	$195	-60%	$46	$20	$52	$73	$119	$76.46	-78%
Yallourn W	VIC	$410	-44%	$223	$34	$71	$105	$328	$81.78	-79%	$303	-58%	$223	$34	$71	$105	$328	-$24.23	-106%
Loy Yang B	VIC	$331	-50%	$130	$27	$51	$78	$208	$123.20	-72%	$258	-61%	$130	$27	$51	$78	$208	$50.48	-88%
Loy Yang A	VIC	$674	-45%	$327	$56	$101	$157	$484	$189.85	-73%	$502	-59%	$327	$56	$101	$157	$484	$18.41	-97%

Methodology and Assumptions

To determine the financials associated with each type of technology in a potential future generation mix, two years were chosen for the analysis. 2018 was selected as a base year, and 2025 as the forecast year as discussed in the section "Method for estimating coal plants' profitability".

2018 Generation and Revenue

For the 2018 base year, AEMO 30-minute generation by plant and price data was sourced. This gave the generation of all plants for the year of 2018. The generation taken was post auxiliary losses and post transmission losses. This gave total generation in 2018 of 185,142,795MWh.

The revenue each plant would have earned if playing in the spot market was calculated by multiplying the generation by the NEM-wide 2018 spot prices for each 30-minute time period. The NEM-wide 2018 spot prices were calculated taking a weighted average of the spot price in each state (taking the average price weighted by the demand in each state for each 30-minute interval).

Note that this analysis utilises 30-minute data. This will gloss over potential intermittency issues which could be identified if 5-minute data (or even shorter time intervals) were used, but also will accentuate coal plant inflexibility in terms of ramping up and down more frequently.

2025 Renewables Generation

The 2025 projection for wind, solar and distributed PV was developed by scaling up 2018 profiles. A typical generation profile was created for utility scale solar PV and wind by removing any of the new plants coming on board during 2018. This gave a typical NEM-wide utility scale solar PV and wind generation profile. These profiles were then scaled by the 2025 generation predicted for utility scale solar and wind plants, which was developed by Green Energy Markets. The rooftop solar PV profile was taken from 2018 AEMO data, then scaled to meet Green Energy Markets' projected annual rooftop solar PV generation in 2025. This gave the generation profiles for renewable energy plants in 2025.

The Green Energy Markets' wind and solar projections include projects which are:

- **Under construction:** projects that have started construction but are not yet fully commissioned.

- **PPA not committed:** The project has secured a long-term contract to purchase its power at a secure price from a customer that is a low credit risk and therefore the project is very likely to be able to secure finance and be constructed.

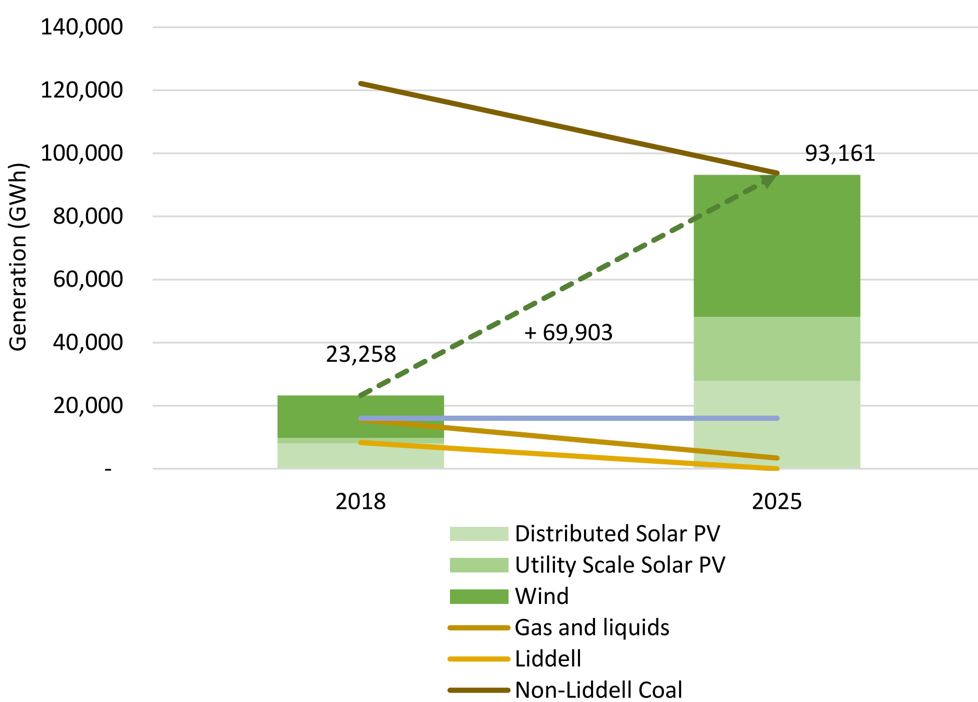
- **Government tender/program:** This accounts for future capacity that is likely to be built in order to satisfy a government program or tender that has announced a set amount of capacity or energy it will procure. For example, the Victorian Government has announced the intention to proceed with awarding contracts for 600MW of renewable energy capacity. It should be noted that this does not include capacity associated with government announced targets for which they are yet to put in place a mechanism to fund the new capacity to deliver on the target. So, while we include the 600MW Victorian Government tender, we do not include any capacity beyond this tender that might be needed to meet the Victorian Government's 50% renewable energy target by 2050.

- **EOI:** Commitments by private companies to install renewable. For example, Alinta Energy has publicly stated they will seek to contract 1500MW of renewables.

- **Tender underway:** Capacity that is likely to be induced by a procurement process announced by a significant electricity consumer or consortia of consumers to award a long-term power purchase agreement to a renewable energy supplier.

Between 2018 and 2025 there are plans to install 28GW of new variable renewable energy (VRE) announced in the market. This is equivalent to an incremental additional renewable generation of 69,903GWh to be added from 2018 to 2025 as shown in Figure 18.

Figure 18: Renewables Generation 2018 and 2025 (GWh)



Source: IEEFA analysis.

Table 8: Generation in the NEM 2018 and 2025

Generation (GWh)	2018	2025	Change
Consumption	**185,143**	**189,284**	**4,141**
Coal	130,401	93,757	-36,644
Gas + liquids	15,508	3,355	-12,153
Fossil fuels	**145,909**	**97,113**	**-48,797**
Distributed PV	8,090	27,828	19,738
Solar	1,674	20,281	18,607
Wind	13,493	45,052	31,559
Renewables	**23,258**	**93,161**	**69,903**
Spillage		-16,966	
Other (battery, bioenergy, hydro, pumped hydro)	15,976	15,976	0
Total generation (GWh)	**185,143**	**189,284**	**4,141**

Source: IEEFA analysis.

Table 9: Capacity in the NEM 2018 and 2025

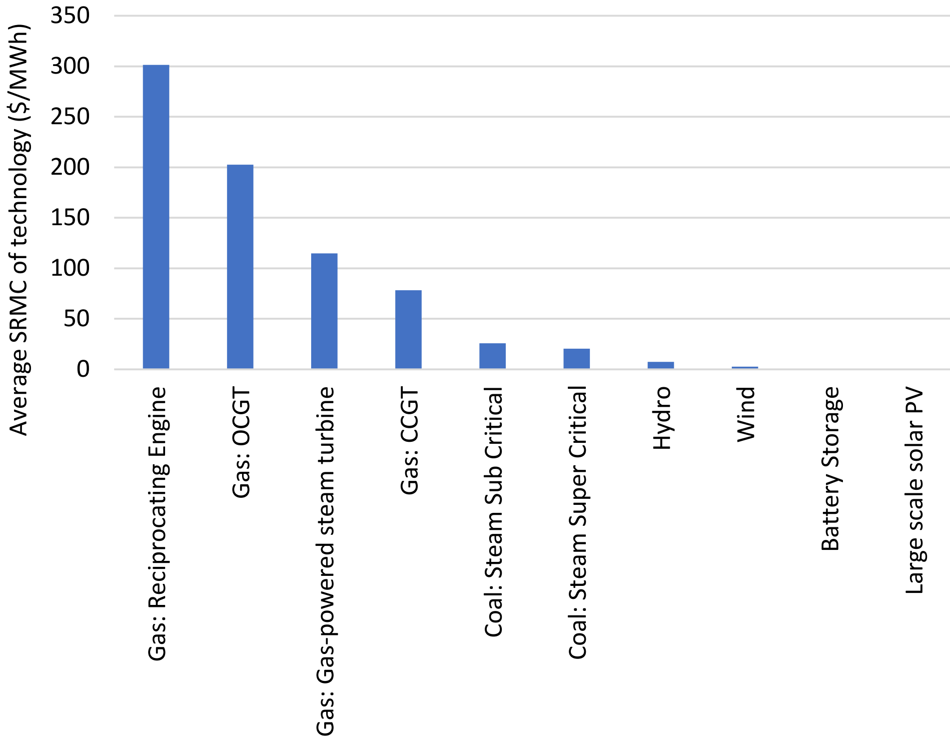
Capacity (GW)	2018	2025	Change
Distributed Solar PV	7	22	15
Utility Scale Solar PV	2	8	6
Wind	6	12	7
Renewables	**14**	**42**	**28**
Coal	23	21	-2
Gas + liquids	11	11	-
Fossil fuels	**34**	**32**	**-2**
Other (battery, bioenergy, hydro, pumped hydro)	4	4	-
Total Capacity (GW)	**53**	**78**	**26**

Source: IEEFA analysis.

Renewables Generation Has the Lowest SRMC

Wind and solar have the lowest short-run marginal cost (SRMC) out of key generators in the NEM, and usually bid into the market at low rates; renewable energy projects (other than hydro) frequently bid zero or even slightly negative prices. The marginal cost of wind and solar plants is low, as they have no fuel cost, only operation and maintenance (O&M) costs. The SRMC of each generator from AEMO's Input and Assumptions are shown in Figure 19.

Figure 19: SRMC of Each Technology in the NEM ($/MWh)



Source: AEMO.[46]

As renewables are the cheapest generation source in the NEM, it was assumed that any growth in renewables would be balanced out by either increased demand in the NEM, the Liddell exit, or by reducing down more expensive generation such as gas and coal. Note that batteries have been excluded from the analysis.

This is a potential manner in which generation would be dispatched, however, it is noted that the exact bidding strategy of generators is not possible to determine. Therefore, this is a potential manner in which 2025 could play out, but it cannot be completely accurately predicted.

Renewables Mostly Fill the Consumption Growth

Consumption growth was found using AEMO's Electricity Statement of Opportunities (ESOO) 2020. The consumption figures were found using AEMO's operational generation, subtracting auxiliary loads and transmission losses and adding rooftop PV, as shown in Table 10.

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[46] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator Summary - Existing, Committed and Anticipated Generators.

Table 10: 2025 AEMO Consumption Forecast from ESOO2020[47]

Region	Scenario	Year	OperationalGen	AuxiliaryLoads	Transmission losses	RooftopPV	Annual consumption (GWh)	Annual consumption (MWh)
NEM	Central	2025	183,782	9,876	4,302	19,680	189,284	189,283,811

Growth in consumption was then found taking the difference between the 2018 AEMO generation of all plants and the AEMO ESOO2020 consumption forecast. AEMO has forecast a consumption growth of 4,141Wh from 2018-2025 in the 2020 ESOO.

Table 11: Generation in 2018 and 2025

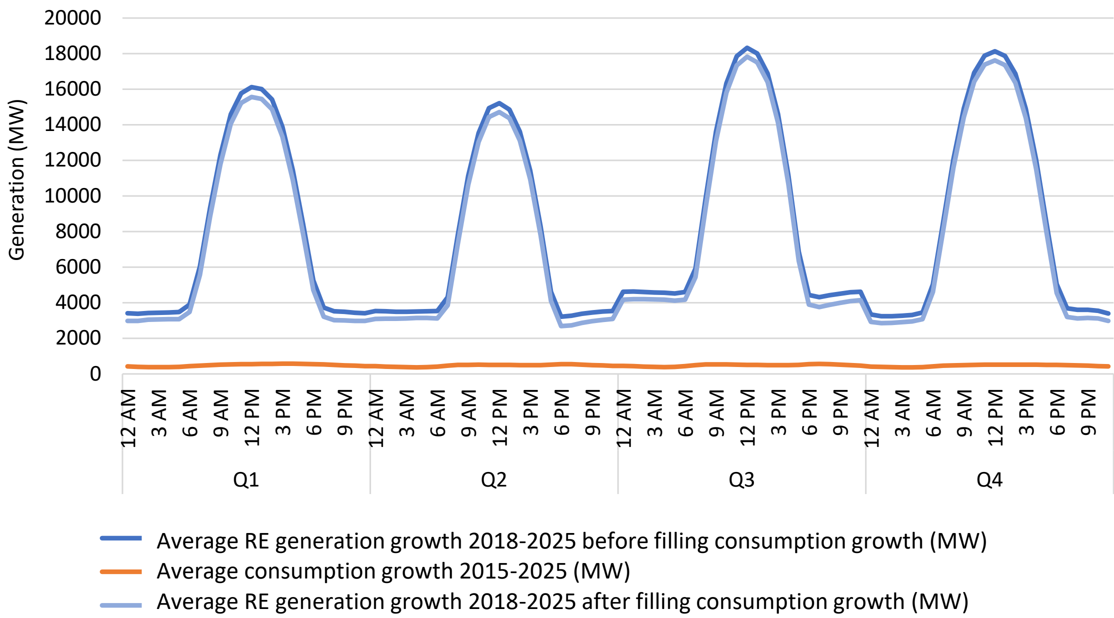
Generation (MWh)	2018	2025	Difference
Consumption	185,142,795	189,283,811	4,141,016

Note: 2018 AEMO generation (post auxiliary and transmission losses, including rooftop PV) vs AEMO 2025 demand forecast from ESOO2020 (operational generation minus auxiliary and transmission losses, adding rooftop PV).

This model has assumed that renewables, as the cheapest form of generation, will fill the consumption growth, and in time periods when this is not possible, it is supplied by gas. Using the 2018 yearly generation scaled up to create the 2025 profile, it is seen that renewables will fill 99.9% (4,138GWh) of the growth in consumption. The remainder will be filled by gas, accounting for 0.01% (4GWh) of the consumption growth. The gas is required in this case as there is growth in demand in some night-time periods in which there is not sufficient renewable energy. The average profile of additional renewable generation before and after mainly filling the demand growth is shown in Figure 20.

[47] AEMO. 2020 Electricity Statement of Opportunities (ESOO) – electricity consumption and demand forecasts used. 27 August 2020.

Figure 20: Renewables Generation Will Mostly Fill the Growth in Consumption

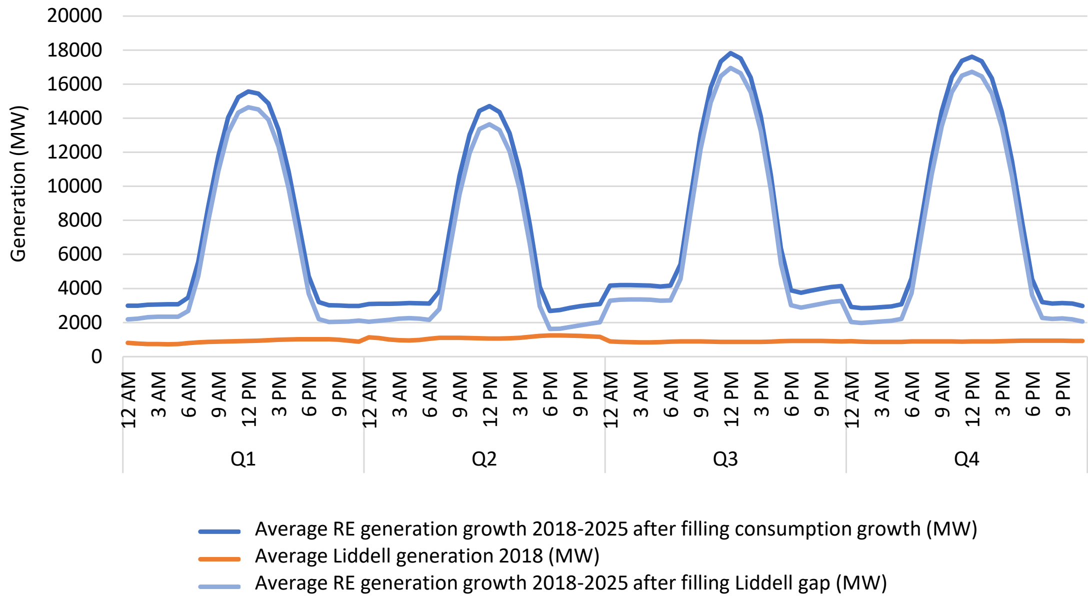


Source: IEEFA analysis.

Renewables Mostly Fill the Gap from the Liddell Exit

Liddell will be retired in 2023 leaving a gap of approximately 8,264GWh annually (based on 2018 generation). This gap must be filled by other generators on the market. As renewables are the cheapest supply, it is assumed renewables will fill this gap, accounting for 98% of the Liddell gap (8,096GWh). Even though solar and wind are variable in nature, the huge scale of what will be added means that on average it will deliver an amount of power equivalent to what Liddell delivered at the same time-of-day. However, there are some time periods, typically at night time, when there is no solar generation, and when the growth in renewable generation is not enough to fill the gap left by Liddell. In these periods it is assumed gas will be used, filling the remaining 2% of the Liddell gap (168GWh) (but note this could also potentially be filled by other committed battery energy storage projects, or other types of generation). The average profile of additional renewables before and after offsetting the Liddell gap is shown in Figure 21.

Figure 21: Renewables Will Mostly Fill the Gap Left by Liddell Exit



Source: IEEFA analysis.

This conclusion is in line with the Liddell Taskforce Report of April 2020 which found that committed projects and probable projects "would be more than sufficient to maintain a high level of reliability as Liddell exits".[48]

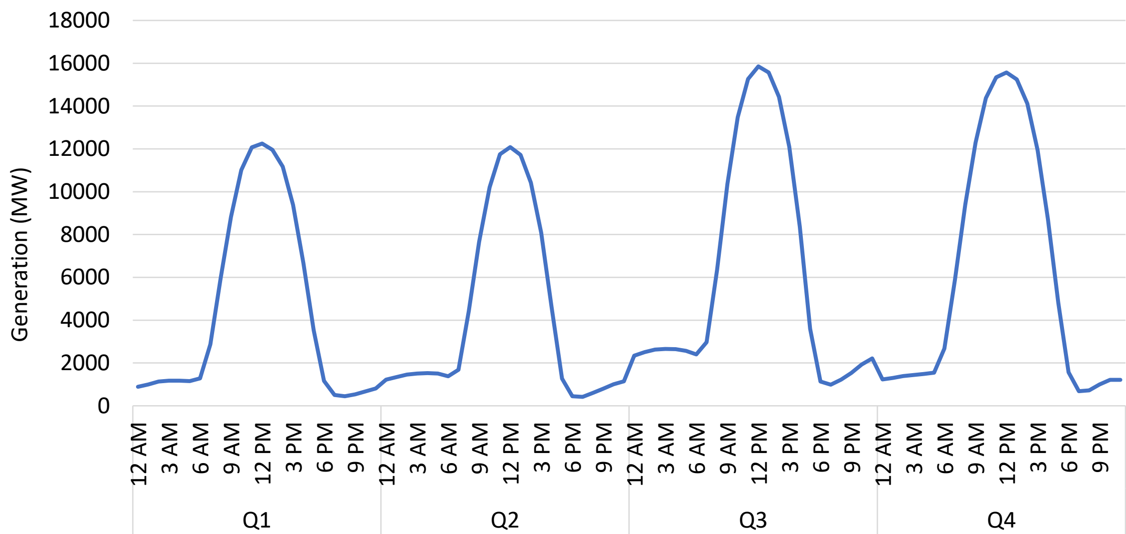
Note this analysis has been completed using a 30 minute period and therefore potential reliability issues seen on a shorter timescale – on a 5-minute period for example – will not be evident. Gas or batteries may be required to maintain energy balance in additional time periods to the aforementioned, if the analysis were completed on a 5-minute basis.

Even After Filling Consumption Growth and the Liddell Gap, Surplus Renewables Remains

Even after largely filling the consumption growth and Liddell gap, surplus renewables remains as shown in Figure 22. This totals 57,670GWh of additional renewable generation (added from 2018 to 2025 that does not fill the demand growth or Liddell gap). This will then go towards displacing forms of generation that are more expensive than wind and solar.

[48] Commonwealth of Australia and NSW Government. Report of the Liddell Taskforce. April 2020.

Figure 22: Surplus Renewables After Filling Demand Growth and Liddell Gap (MW)



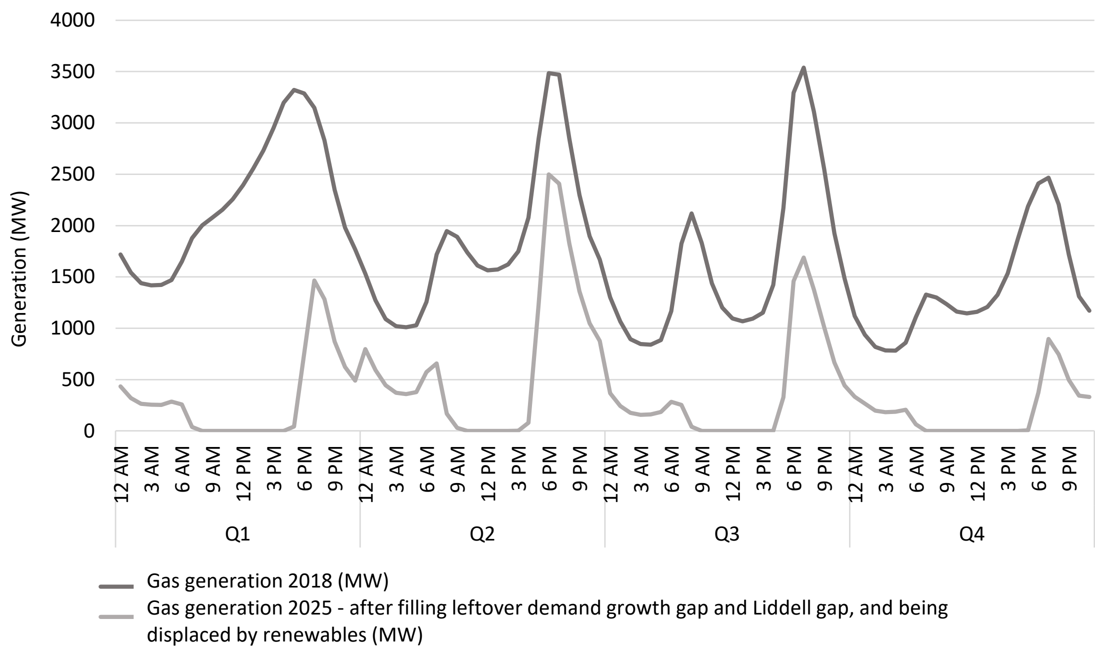
Source: IEEFA analysis.

Gas Is Displaced by Renewables

Renewable generation will price out gas first, as gas has the highest SRMC of all major generating technologies in the NEM. The renewable generation growth is so large it can be expected to displace gas generation across almost all parts of the day except for a narrow window between 5pm and 10pm. Gas generation contracts by 78% from 15,508GWh in 2018 down to 3,355GWh by 2025. The gas generation profile in 2018 and 2025 is shown in Figure 23.

There is a possibility that this remaining 2025 gas generation may be further displaced by batteries. Battery installation forecasts are not included in this analysis. Batteries can soak up the excess renewable generation (while gas sits idle) and discharge it later when it is needed, typically in the peak demand periods, competing with gas however with the added benefit of energy arbitrage. This may result in further reduction in gas generation that is not represented in this analysis.

Figure 23: Total Gas Generation Profile 2018 vs 2025 (MW)



Source: IEEFA analysis.

Coal Displacement

Even after the growth in renewables largely displaces gas generation across most hours of the day, there will still be further displacement of coal generators. Coal generators typically bid into the market at a higher price point than renewables to cover their SRMC (which is significantly higher than renewables).[49] Therefore, it is assumed that coal generation will also be displaced as more renewables are installed.

The reduction in coal plant generation was allocated according to SRMC i.e. the coal plants with the highest SRMC would reduce their generation first (to accommodate the growth in renewables). The SRMC and therefore order of displacement of each coal plant is shown in Table 12.

[49] Note that any coal plant may have a different bidding strategy and actually bid into the market at very low price points in order to be dispatched, but for the sake of this analysis we have assumed that they will not be dispatched over renewables. There are many factors influencing the bidding strategy of coal plants including international coal prices, the opportunity cost of burning coal in Australia vs exporting coal, competitive dynamics with other nearby generators, etc.

Table 12: Coal Plant Generator Information

Coal plants	State	SRMC ($/MWh)
Liddell	NSW	21
Eraring	NSW	42
Mt Piper	NSW	41
Vales Point B	NSW	39
Gladstone	QLD	29
Stanwell	QLD	27
Tarong	QLD	26
Callide C	QLD	25
Tarong North	QLD	25
Callide B	QLD	25
Bayswater	NSW	19
Kogan Creek	QLD	16
Millmerran	QLD	15
Yallourn W	VIC	13
Loy Yang B	VIC	12
Loy Yang A Power Station	VIC	12

Source: AEMO.[50]

Coal plants 2018 generation profile was used as the basis for the 2025 profile. The 2025 profile was calculated by taking the surplus renewable generation and reducing the coal plant down by that amount: however if this would reduce the coal plant lower than the minimum generation level then the generation for that interval would be taken as the plant's minimum generation levels, or the plant's historical generation (whichever was lowest.) Minimum generation levels from AEMO are shown in Table 13. It is assumed that coal plants are able to ramp up and down as required but note this may not always be technically feasible for a coal plant.

[50] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator Summary - Existing, Committed and Anticipated Generators

Table 13: Coal Plant Minimum Generation Levels

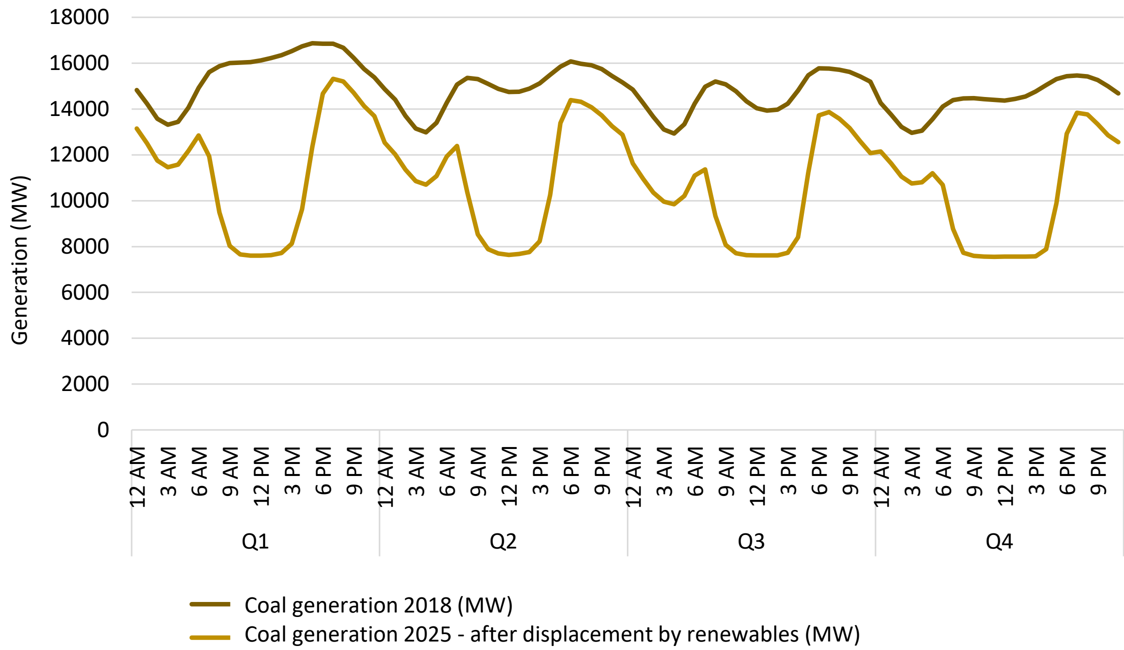
Plant	Min Stable Level (MW)
Bayswater	1000
Callide B	280
Callide C	242
Eraring	720
Gladstone	440
Kogan Creek	300
Liddell	440
Loy Yang A Power Station	1080
Loy Yang B	400
Millmerran	360
Mt Piper	480
Stanwell	540
Tarong	420
Tarong North	117
Vales Point B	500
Yallourn	780

Source: From AEMO Input and Assumptions Workbook, Tab: Generator operating limits and behaviours used in AEMO's Detailed Long Term (DLT) Model.[51]

Coal generation is likely to be displaced by 28% in total from 2018 to 2025. It is assumed that when there is a surplus in renewables, the coal plants will reduce down to their minimum generation levels.[52] This results in the coal plants frequently reducing down to their minimum generation levels in the middle of the day, especially during the sunnier months. This is demonstrated in Figure 24.

[51] AEMO. 2019 Input and Assumptions workbook. 5 July 2020. Tab: Generator operating limits and behaviours used in AEMO's Detailed Long Term (DLT) Model.
[52] AEMO. 2019 Input and Assumptions workbook. 5 July 2020.

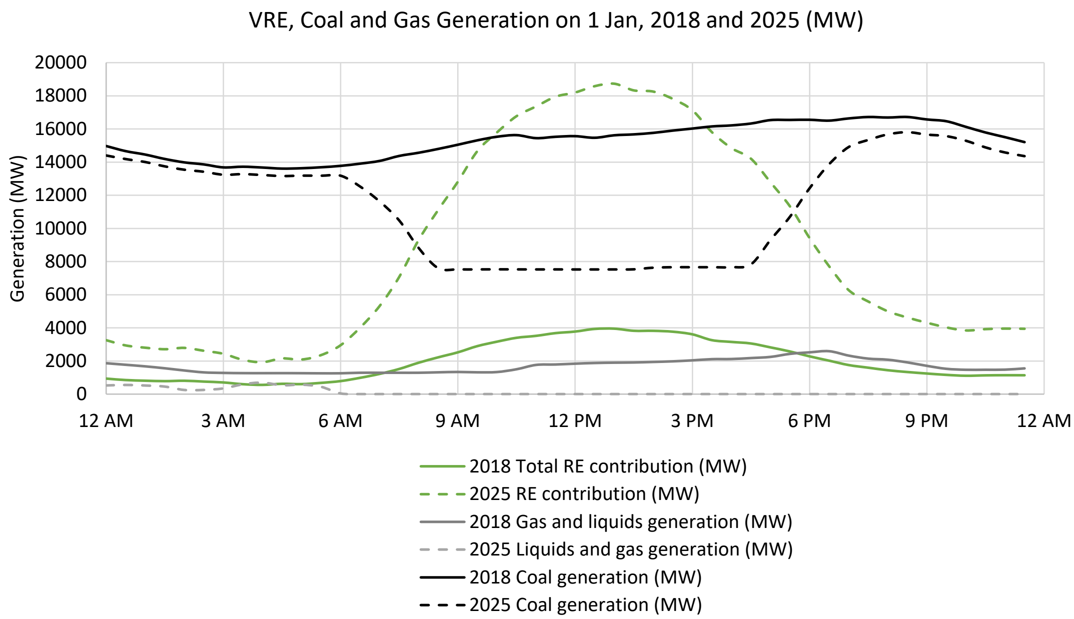
Figure 24: Total Coal Generation Profile 2018 vs 2025 (MW)



Example Daily Generation Profiles

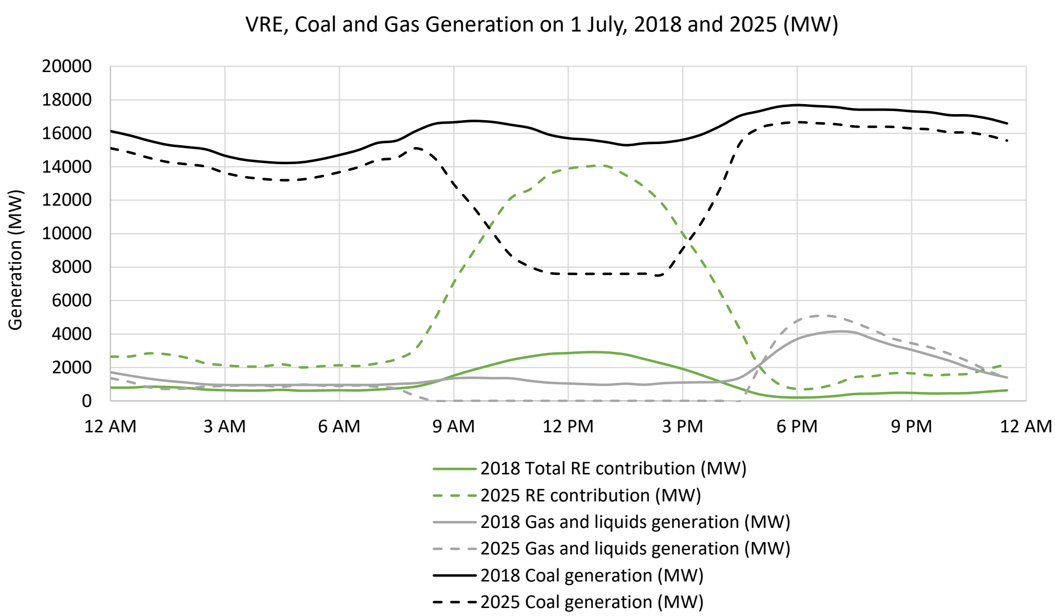
On a daily level, we see high amounts of variable renewable energy in the middle of the day leading to coal plants ramping down to their minimum generation levels, and gas plants ramping down to zero. Summer and winter example daily profiles are shown in Figure 25 and Figure 26.

Figure 25: Summer Generation Profile - 1 Day Example



Source: IEEFA analysis.
Note other generation and spillage is excluded from chart.

Figure 26: Winter Generation Profile - 1 Day Example



Source: IEEFA analysis
Note other generation and spillage is excluded from chart.

Notable Exclusions from the Analysis

Notable exclusions from the analysis are:

- Additional revenue from FCAS, SRAS, or any other services not included in consideration. Only spot market revenue has been considered.
- Analysed EBIT of coal plants only, rather than EBITDA. This is because the generator costs from AEMO's Input and Assumption Workbook do not indicate that D&A is included.
- All generators are modelled as 100% spot market exposed (rather than assuming various contractual arrangements). This provides a high-level revenue estimation from which EBIT can be found.
- IEEFA assumed that "other generation" remains the same from 2018 to 2025 (battery, bioenergy, hydro, pumped hydro).
- Hydro is not included in renewable generation percentages throughout this report (as the impact of hydro is largely ignored in this study).
- The impact of growing battery energy storage installations is not included in the analysis.
- IEEFA did not model taking off various units of coal plants, or pausing a plant then turning it back on (mothballing).
- IEEFA assumed no extra operational cost on coal plants from increased ramping.
- Gas generation stated throughout this report includes liquids.
- It is notable that 5-minute settlement, which will come into play on 1 July 2021,[53] has the potential to significantly change the profitability of generators in the NEM. This analysis has used 30-minute increments and has not explored the impact of 5-minute settlement.

Price Forecast

Price for 2025 has been modelled in this report by looking at the fossil fuel demand in 2018 and 2025 as an indicator of the prices. This is because historically the fossil fuel generators are typically the price setters, while the cheaper renewable energy is a price taker and will usually bid in at a very low price. However, this switches in periods of high renewable energy generation where renewable energy will set a low price and become the price setter for those periods. Fossil fuel demand amounts (i.e. gas + liquids + coal) in 2025 were matched up to the historical 2015-2020 fossil fuel demand level (in 50MW increments) and allocated the average price for that fossil fuel demand increment. However, there are time periods whereby the fossil fuel

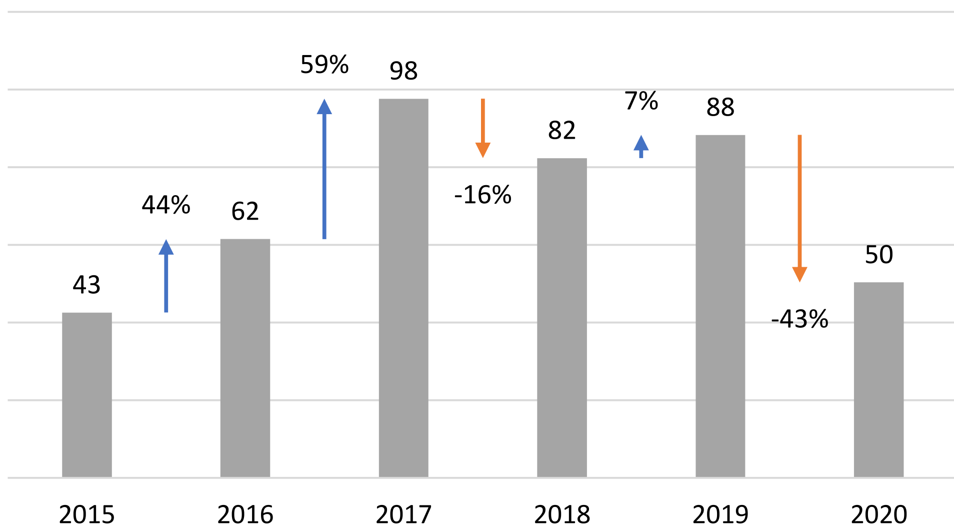
[53] AEMC. Five Minute Settlement. 28 November 2017.

generation is much lower than the minimum of the fossil fuel demand from 2015-2020: in these time periods, the average price for the lowest 2000MW of fossil fuel has been used, which was found to be $12/MWh.

Background on NEM Prices

From 2019 to 2020, the NEM-wide weighted average spot price decreased by 43% (from $88/MWh to $50/MWh) as shown in Figure 27.

Figure 27: NEM-weighted Average Spot Price ($/MWh)

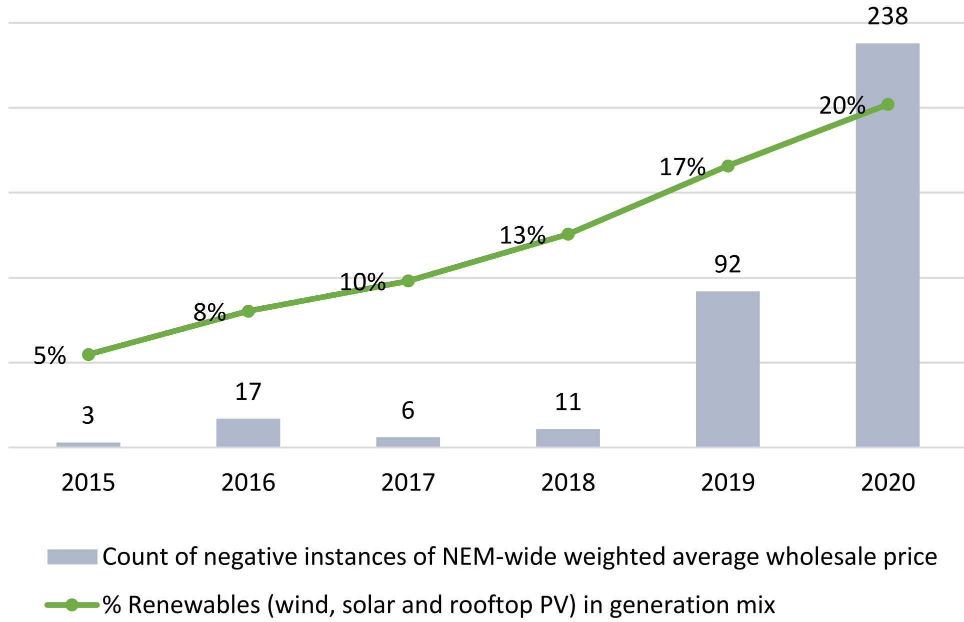


Source: IEEFA analysis. Based on AEMO generation and price data.

A key reason for this price decline is that as cheaper renewable generation is connected to the grid, the renewable generators mostly bid into the NEM at zero, or negative prices. This puts downward pressure on spot price. The increasing penetration of renewables corresponds with increasing numbers of negative price intervals as shown in Figure 28. On a state level, the state with the highest penetration of renewables – South Australia – has the highest negative price instances as shown in Figure 29. In 2020, South Australia had the highest penetration of renewables, with 59% of generation coming from wind, solar and distributed PV, and 1713 negative price instances. Other states with lower renewables penetration had less negative price instances than South Australia. An example day in South Australia (18 September 2020) shows price in reaching -$150 in the middle of the day as shown in Figure 30. While extremely low prices have become more frequent over time, extremely high prices have become less frequent.[54]

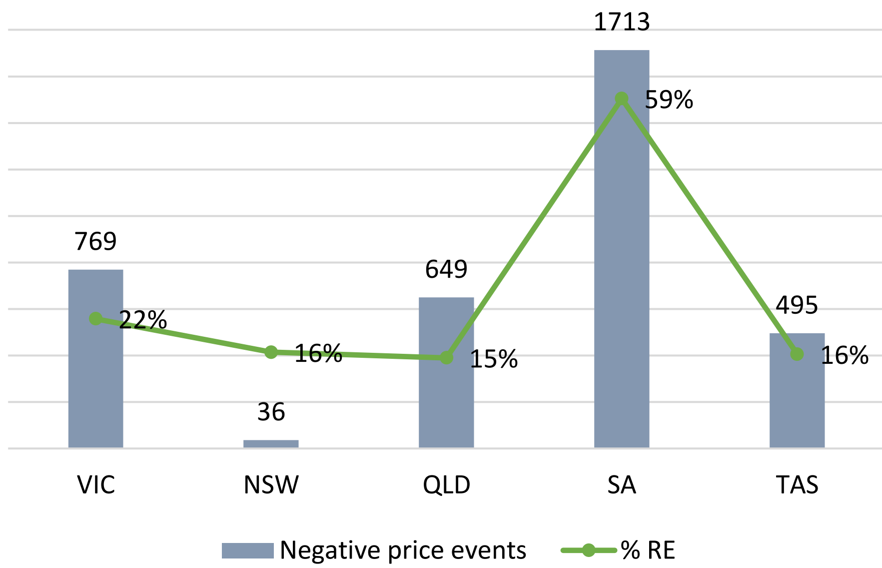
[54] Alan Rai and Oliver Nunn. On the impact of increasing penetration of variable renewables on electricity spot price extremes in Australia. 30 June 2020.

Figure 28: NEM-wide Weighted Average Wholesale Price Negative Instances vs RE Penetration



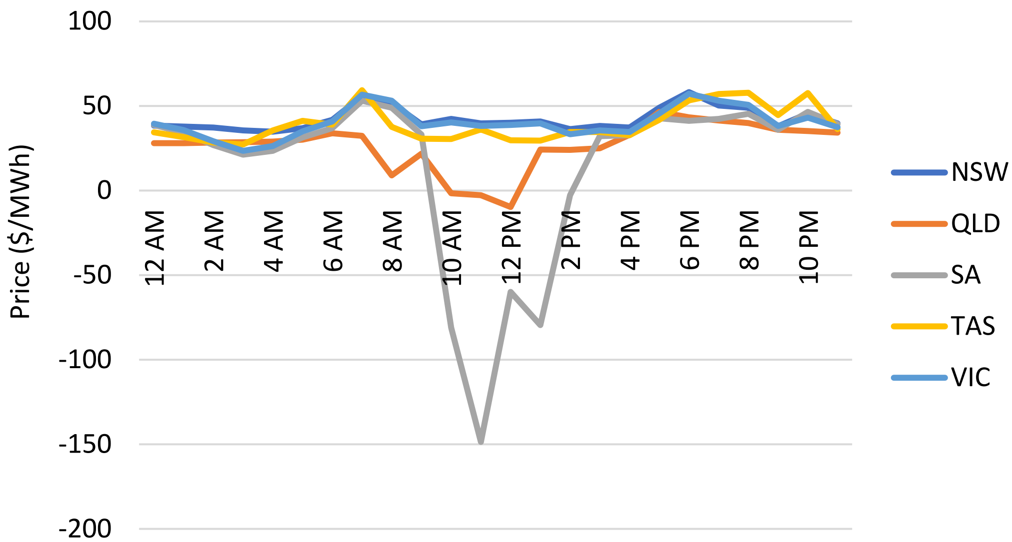
Source: IEEFA analysis. Based on AEMO generation and price data.

Figure 29: Negative Price Instances and Renewable Energy Penetration 2020 (Wind, Solar and Rooftop PV as % of Total Generation)



Source: IEEFA analysis. Based on AEMO generation and price data.

Figure 30: Negative Price Example - 18 Sept 2020

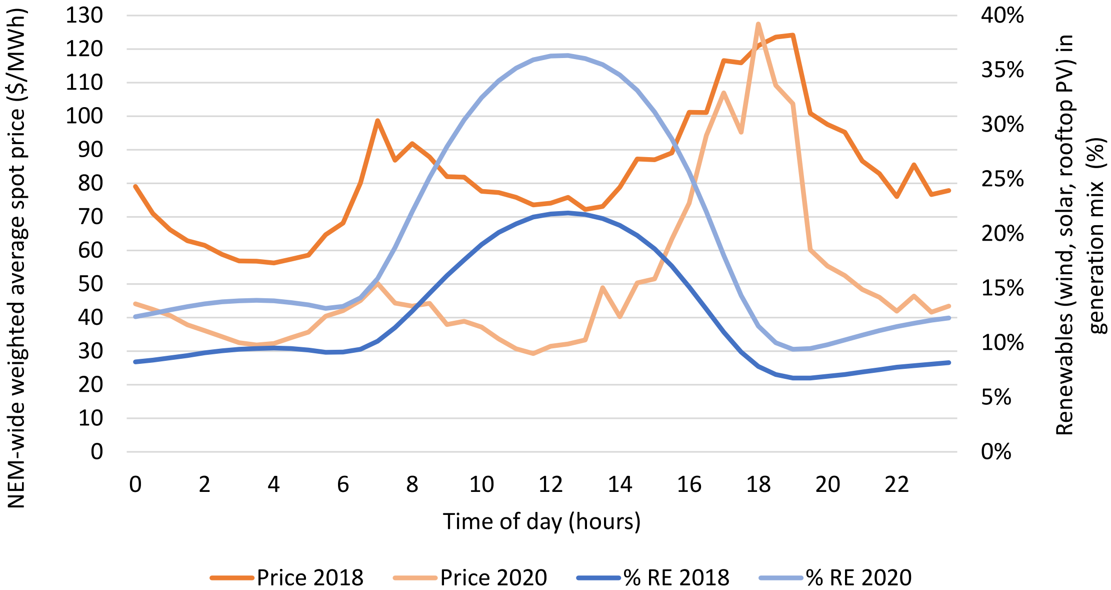


Source: IEEFA analysis. Based on AEMO generation and price data.
Note: This is not weighted by demand.

It is now seen that the lowest priced time-of-day is in the daytime, close to the point of maximum solar insolation, as shown in Figure 31. Renewable energy plants are bidding in at zero or negative price in the middle of the day and setting the price at that point. Since low-SRMC renewable energy generators will increasingly be price-setters as renewable energy penetration increases, prices will be low for an increasing amount of time.[55] Price is expected to continue to decline as renewable energy penetration continues to increase.

[55] Alan Rai and Oliver Nunn. On the impact of increasing penetration of variable renewables on electricity spot price extremes in Australia. 30 June 2020.

Figure 31: Average Renewables Penetration and Price Throughout Day



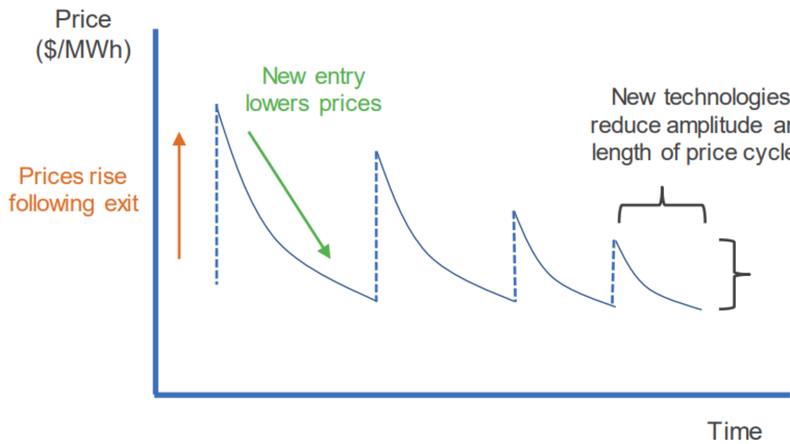
Source: IEEFA analysis. Based on AEMO generation and price data.

The wholesale electricity price reduction impacts all plants in the market. In particular, gas and coal plants will have their revenue eroded by 2025 through the double-hit to their top-line, as both the price and quantity of gas and coal generation reduces in line with reducing prices and increasing amounts of renewable generation installation. For utility scale solar and wind plants, revenue will also reduce due to these lower price events, which will impact on their financing. In order for *all* generators to recover their long-run costs, prices would have to be higher during periods where renewable energy generators are not the price-setters.[56]

While the increasing amount of renewables installed has a deflationary impact on price, the closure of coal plants has the potential to increase price. It is expected that with coal plant closures, supply will tighten, therefore price will increase, which is explained in Figure 32. For this reason the historical fossil fuel demand vs price curve has been creating by removing any shut coal generators from historical fossil fuel demand figures, in order to simulate prices with these coal plants closed.

[56] Alan Rai and Oliver Nunn. On the impact of increasing penetration of variable renewables on electricity spot price extremes in Australia. 30 June 2020.

Figure 32: Impact of Generator Exits on Prices in NEM

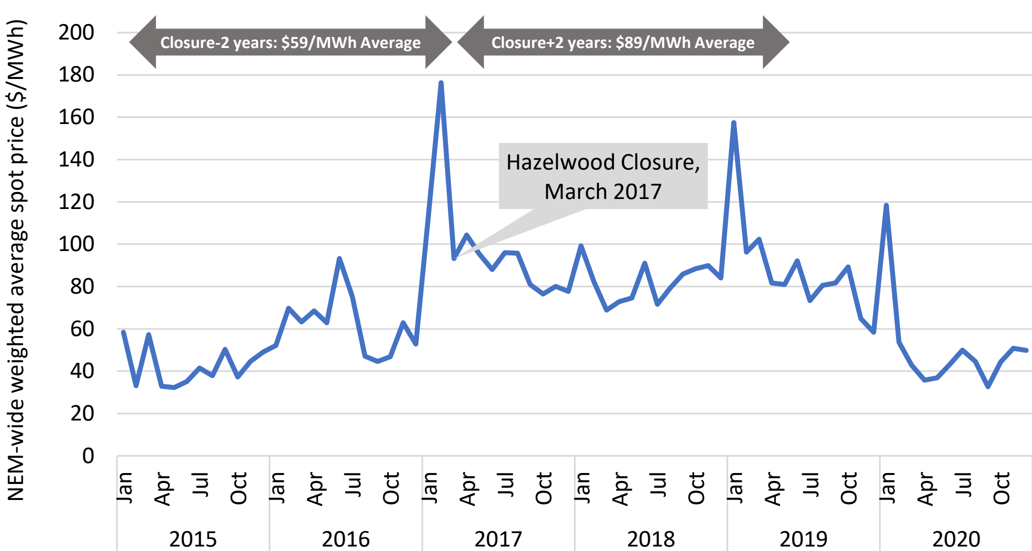


Source: Adapted from Frontier Economics 2019 – NEM structure in light of technology and policy changes. A report for the AEC.

Source: ESB.[57]

This impact has been seen in the past, when the closure of Hazelwood coal plant led to an increase in price. The NEM-wide weighted average spot price 2 years prior to the closure of Hazelwood was $59/MWh and after closure price increased dramatically, with a 2-year post closure average of $89/MWh – as shown in Figure 33. In order to prevent a similar price increase after the closure of Liddell in 2023, it is key to prevent supply shortfall.

Figure 33: NEM-wide Weighted Average Price, By Month, Including Hazelwood Closure Highlight in March 2017



Source: IEEFA analysis. Based on AEMO generation and price data.

[57] ESB. Post 2025 Market Design Consultation Paper. September 2020.

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

About Green Energy Markets

Green Energy Markets provides clients with information, analysis and advice about the current and future state of Australia's electricity and carbon abatement markets. Our aim is to assist clients to make informed investment, trading and policy decisions in the areas of clean energy and carbon abatement.

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Tristan Edis is the Director - Analysis and Advisory at Green Energy Markets. He assists clients including major energy companies, renewable energy project developers and suppliers, and government agencies to make informed investment, trading and policy decisions in renewable energy, energy efficiency and energy and carbon abatement markets more generally.

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