How *Battery of the Nation* can contribute to Victoria's energy needs and objectives

August 2019

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Foreword

Australia's National Electricity Market (NEM) is transforming. There is a significant challenge ahead to plan for, and implement, a timely and orderly transition.

Victoria has experienced firsthand the impacts of this rapid change in the supply–demand balance with the retirement of the Hazelwood coal-fired power station in 2017. This event contributed to sustained high prices and even loss of power to customers. Victoria has since depended increasingly on imports from other regions to meet demand at peak times.

Victoria recognises the need for reasonably-priced, clean and reliable electricity to support its economy and quality of life, and has strong targets for more renewable energy development. With more variable renewable energy generation comes the need for more capacity and storage, to bridge the periods when the weather restricts the ability of wind or solar to generate, and to make good use of excess generation when wind and solar are abundant. Victoria will need access to significant amounts of energy storage to ensure it can keep the power system reliable while meeting its renewable energy targets.

Tasmania's *Battery of the Nation* will unlock existing dispatchable hydropower capacity and new low-cost, long-duration pumped hydro energy storage to support variable renewable energy sources across the NEM. Further interconnection between Tasmania and Victoria will add energy supply diversity, increasing both reliability and competition. This will help manage the energy transition over coming decades by providing practical solutions that complement current Victorian renewable energy objectives.

The combination of Tasmanian and Victorian renewable energy sources can facilitate a smooth transition to the affordable, reliable and sustainable power system of the future.

Steve Davy

Hydro Tasmania Chief Executive Officer

August 2019

Since this paper was finalised TasNetworks has established that a 1500 MW link is technically feasible. The analysis remains valid. The increased capacity of the interconnector simply represents a large and more cost-effective opportunity.
-- October 2019

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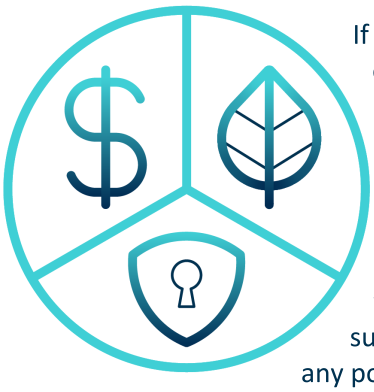
Executive summary

Victoria has recognised the need for affordable, sustainable, reliable electricity to support its economy and quality of life. The state government has strong objectives for renewable energy development which will deliver on these needs, when supported by cost-effective and reliable firming.

Victoria's transition to the future NEM

Following the retirement of Hazelwood coal-fired power station, Victoria has experienced firsthand the impacts of a rapid change in the supply–demand balance, including sustained high prices and even the loss of power to customers. These impacts are not localised to Victoria and have also been felt across the NEM. In response to high prices and market opportunity, the least-cost generation options have been developed: wind farms, solar farms and rooftop solar. This shift from thermal energy towards increasing levels of lower cost renewables reflects international trends. Renewable energy is now the lowest cost source of electricity generation, so power systems will be adapted to optimise their energy mix.



If the market is not reconfigured to manage the significant level of expected future coal retirements, the impacts of those retirements will not be limited to the region in which those coal-fired power plants operate. Planning for the orderly transition and transformation of the power system is a significant challenge.

For a successful and smooth transition towards greater proportions of variable renewable energy sources, the market needs investment in the right mix of technologies to support the achievement of affordable, sustainable, reliable energy for Victorian energy consumers and to avoid any potential adverse impacts.

Planning needs to be robust and not rely too heavily on specific assumptions

Coal-fired generators are approaching the end of their technical lives. Some may retire sooner than expected, due to economic, safety and technical factors, and may do so suddenly. The performance[1] of these ageing assets in the January 2019 heatwaves highlights the need for newer and more reliable options. Customers can't afford to be left in the dark. To avoid the economic and social impacts of a shortfall in supply, proactive and early investment is needed to ensure that alternative supply sources are already available when they become needed.

Renewable energy sources such as wind and solar are now the cheapest options for new electricity generation. Wind and solar can cost-effectively provide bulk energy, while hydro generation and storage can efficiently fill any gaps in supply. For an efficient transition of the power system, a combined response will be required from a range of technologies, including flexible supply[2], to deliver a cost-effective, reliable and low-emissions outcome.

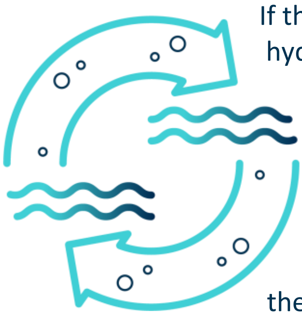
Clear Victorian and national emissions reduction and renewable energy targets will provide the market with confidence to undertake this transition.

[1] Both Yallourn and Loy Yang A were operating below capacity during the January 2019 heatwave that impacted 200 000 customers.

[2] Flexible supply has traditionally been provided by conventional hydropower generation and open cycle gas turbines; storage in the form of pumped hydro and batteries are expected to play an increasingly important role in the future.

Electricity prices in past years have been low, at times suppressed by oversupply as well as by sunk-cost assets running only at their operating cost (without delivering returns on capital). Wholesale electricity prices in the NEM are now rising due to high international gas prices, increasingly unreliable brown coal generation, and structural pricing shifts from black coal in the hands of a small number of market participants[3]. If the energy transition is not well-managed, prices could continue to increase significantly, especially if high temperature events become more frequent. Victorian power prices can be reduced through increased competition when flexible supply is required as well as increasing availability of wholesale contracts to retailers.

The flexible generation assets required by the future NEM need to be able to supply for the length of time required – be that half a day to complement the solar cycle or up to several days to complement wind and cloud patterns. This type of flexible, long-duration supply is referred to as ‘sustained capacity’ and will become more and more important as the power system continues to transform.



If the sustained capacity comes in the form of long-duration pumped hydro energy storage, this can also contribute to Victoria’s objectives for renewable energy development. The 2018 Integrated System Plan (ISP) produced by the Australian Energy Market Operator (AEMO) demonstrated that significant development of wind and solar generation is the least-cost outcome for the NEM, even if there is significant excess generation at times[4]. The NEM is designed to encourage electricity to be available when it is needed, and as such the spot price of electricity can be very low – even negative – when energy is abundant.

To be commercially viable, renewable energy developments need customers. For example, solar generation all occurs at roughly the same time, forcing prices down in the middle of every day while solar is at maximum production. Storage provides flexible demand which can support prices when variable renewable energy is abundant, and supply energy in times of scarcity to keep prices to consumers reasonable.

Storage makes prices more stable, giving confidence to renewable energy developers and investors while keeping overall electricity prices in check.

A pathway for a smooth transition to the future power system

If further retirements of thermal generation occur before replacement generation is built, customers will be at risk of high prices and potential energy shortfalls. However, during a market transformation, there is significant investment risk. The timing of coal-fired generator retirements is far from certain. Substantial carbon risk may also affect investment decisions. The Council of Australian Governments Energy Council (COAG) is currently considering medium-term changes to the design of the energy market to support a secure, reliable and lower emissions electricity system at least cost[5]. The compounding uncertainties make it difficult to finance long-lead-time, long-life investments without some kind of safety net. Yet, when the market is in transition is the time that investment is needed to ensure that important projects can be delivered before it is too late to avoid impacts on customers of high prices, load shedding or both.

[3] AEMO, February 2019, *Quarterly Energy Dynamics Q4 2018*: https://www.aemo.com.au/-/media/Files/Media_Centre/2019/QED-Q4-2018.pdf

[4] AEMO, July 2018, *Integrated System Plan – For the National Electricity Market:* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf

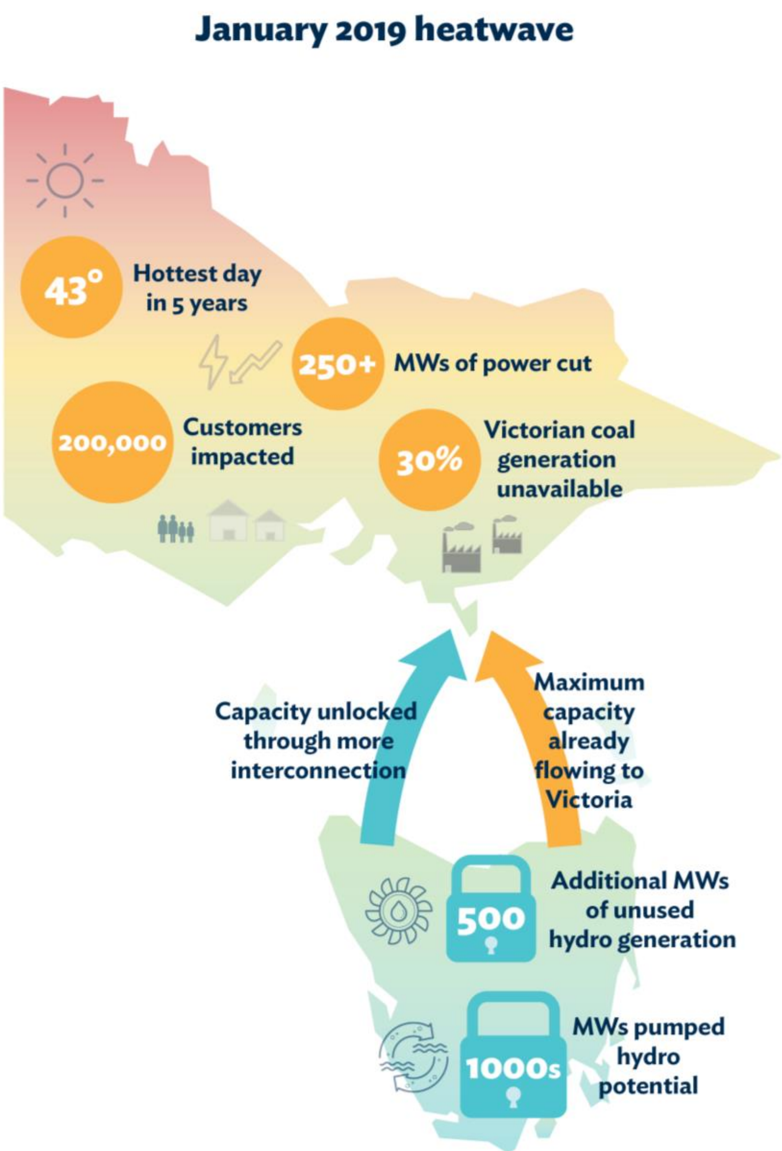
[5] COAG Energy Council, March 2019, *Post 2025 Market Design for the National Electricity Market (NEM):* http://coagenergycouncil.gov.au/publications/post-2025-market-design-national-electricity-market-nem

Battery of the Nation can help

The *Battery of the Nation* initiative is developing an integrated pathway to leverage Tasmania's untapped electricity resources to support Victoria and the rest of the NEM. This initiative leverages expanding interconnection with Victoria, utilising latent hydro capacity and modernising the existing hydropower system, augmenting this system with cost-effective pumped hydro energy storage, and unlocking complementary wind and solar generation in both Victoria and Tasmania.

Further interconnection between Victoria and Tasmania (Marinus Link[6]) will take advantage of the differences between the existing power systems and the complementary renewable resources for future development. Tasmania's hydropower system is capacity-rich (i.e. there is plenty of flexible capacity from a number of power stations), but at times is energy-constrained (i.e. the water needs to be managed to ensure there is enough electricity at all times of the year).

This fits well with the rest of the NEM, which is energy-rich (there is plenty of wind, sun and fuel) but at times capacity-constrained (not enough power station capacity available to efficiently meet demand). For example, during the January 2019 heatwave, more than 500 MW of Tasmanian hydropower was bid into the market, but not able to be dispatched because of insufficient interconnection.



In addition to leveraging up to 500 MW of latent capacity in the existing hydropower system with no or low investment, *Battery of the Nation* considers cost-competitive modernisations to existing hydropower plant, which can repurpose schemes to enhance their ability to complement wind and solar in the future electricity system. Hydropower is highly flexible,

[6] Marinus Link Pty Ltd is the proposed second interconnector (cable) between Victoria and Tasmania. The analysis and business case is being undertaken by TasNetworks: https://projectmarinus.tasnetworks.com.au/ .

going from standstill to full output in under five minutes – compared to an hour or more for ‘flexible’ types of gas generation and several hours for coal (even up to a day or two if they are cold)[7]. Modernising hydropower stations can optimise them to generate more electricity at times when wind and solar are scarce, and generate less when those sources are abundant.

Battery of the Nation could further expand flexible capacity with pumped hydro energy storage[8], combining existing infrastructure and new developments to best use Tasmania’s topography, leading to low-cost and highly-efficient energy storage. The opportunities identified could provide sustained capacity from 12 hours to two days[9] – complementing the availability of sun and wind.

A 1200 MW Marinus Link interconnector could enable Tasmania to provide a reliable supply of electricity into the NEM when needed (aggregated from conventional hydro, new pumped hydro energy storage and wind generation). This scale is comparable to the impact of the retirement of one of the smaller coal-fired power station. Further interconnection not only enables provision of electricity when wind and solar are scarce, but also enables a customer for solar and wind energy when it is abundant – increasing the amount of variable renewable energy which can be developed in both Victoria and Tasmania.

The interconnection required for the *Battery of the Nation* initiative will make it possible to connect Victoria with Tasmania’s complementary renewable energy resources. Victorian solar energy will be able to supply cost-effective energy to Tasmanian customers, freeing valuable hydropower generation to be used at times of relative scarcity. Tasmanian and Victorian wind resources are also complementary.

Tasmanian wind farms have a very high capacity factor (meaning lower cost to produce), and lower correlation to Victorian wind patterns than to wind patterns in other interconnected regions. This diversity of the wind resource means that when it is windy in Victoria, it is less likely to also be windy in Tasmania and vice versa. Interconnection would broaden the customer base for wind energy developments in both regions.

The *Battery of the Nation* initiative aims to leverage existing diversity of demand, existing assets and new supply options to deliver a lower cost, more reliable and cleaner power system to both Victorian and Tasmanian customers. Careful planning can manage avoidable risks to achieve a smooth transition to the future NEM.

The next steps to realise this opportunity are proactive support for interconnection (to get the electricity to where it is needed) and the timely development of market signals or de-risking mechanisms to promote investment (to ensure supply is available when it is needed).

Battery of the Nation can strengthen Victoria’s options to provide low-cost, reliable, renewable energy to future generations.

7 GHD, September 2018, *AEMO costs and technical parameter review:* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/9110715-REP-A-Cost-and-Technical-Parameter-Review---Rev-4-Final.pdf

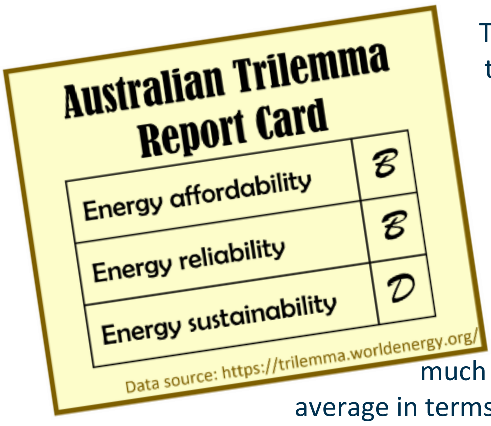
8 Electrochemical battery storage is projected to have value in the future NEM, yet will remain expensive for sustaining supply over many hours – pumped hydro has a strong cost advantage in providing the longer duration storage.

9 Hydro Tasmania, April 2018, *Tasmanian pumped hydro in Australia’s future electricity market: Concept study knowledge sharing report:* https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/pumped-hydro-knowledge-sharing-report.pdf

1. Victoria's transition to the future NEM

Victoria is arguably the hub of the NEM, connecting to three other regions via ~70% of the NEM's total interconnection capacity[10]. A strong Victorian region is critical to a stable NEM.

The NEM is on the brink of a rapid transition from heavy reliance on ageing coal-fired generators to a system dominated by low-cost variable renewable energy (from wind farms, solar farms and rooftop solar PV). Careful planning will be required to ensure that this transition is smooth, and that electricity cost, reliability and security are effectively managed.



The 'energy trilemma' is used to describe the challenge of attaining the desired characteristics of a modern electricity system: affordability, reliability and sustainability. At present, Australia ranks 38th on the World Energy Council index for the trilemma[11], scoring a B for security, a B for affordability and a D for sustainability.

Victoria's fleet of ageing coal-fired generation assets make the challenge of resolving the energy trilemma more difficult. In recent times, Victoria's electricity has been more expensive and less reliable than the average across the NEM[12]. Moreover, as much of Victoria's energy comes from brown coal, it also ranks below average in terms of sustainability.

Victoria is proactively addressing these challenges. Recognising that electricity is a critical part of its economy, Victoria is making plans to create an energy future that is sustainable both economically and environmentally. Victoria has strong renewable energy objectives and good natural resources for both wind and solar. These renewable energy resources have the potential to drive down electricity prices and emissions. To achieve reliability targets (the third aspect of the trilemma), additional assets will be needed to provide storage and firming.

1.1 Affordable energy

Affordability is an important component of the energy trilemma. An efficient and effective electricity system underpins a strong and competitive economy.

The final quarter of 2018 saw the highest October to December NEM-wide wholesale electricity spot prices on record. This occurred despite average mainland operational demand (after subtracting residential solar) falling to its lowest level since 2002, and comparably few spot prices above $300/MWh.

AEMO's Quarterly Energy Dynamics Q4 2018 report[13] identified a combination of factors that contributed to the high prices. Gas set the price substantially more often than the long-term average, and did so at higher prices. There has also been a structural shift in the pricing of black coal, with movement to higher prices between 2014 and 2018. Particular to Victoria, AEMO also noted that brown coal contributed less energy than in any quarter since the start of the NEM, due to planned and unplanned outages (and the retirement of Hazelwood in 2017). The reliability of brown coal is reducing and is also contributing to price increases.

[10] AEMO, November 2017, *Interconnector Capabilities:* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Congestion-Information/2017/Interconnector-Capabilities.pdf

[11] World Energy Council, 2018, *Energy Trilemma Index:* https://trilemma.worldenergy.org/

[12] Victoria's affordability challenges are shown by an average wholesale spot power price was more than $10 higher than the average price across the NEM in 2018. Victoria's reliability challenges are highlighted by both the power cuts during the January 2019 heatwave as well as the need to call upon the Reliability and Emergency Reserve Trader (RERT) mechanism.

[13] AEMO, February 2019, *Quarterly Energy Dynamics Q4 2018:* https://www.aemo.com.au/-/media/Files/Media_Centre/2019/QED-Q4-2018.pdf

High electricity prices have persisted into 2019. Even excluding very high prices[14], the average Victorian spot price for Q1 2019 was 20% higher than for Q4 2018, and 37% higher than Q1 2018, a structural change in wholesale pricing.

1.1.1 The influence of generation on consumer energy affordability

While this paper addresses the transformation of wholesale generation, this should be viewed against the broader context of the entire electricity sector. Over recent years, the cost of electricity in Australia has risen substantially. The Australian Competition and Consumer Commission (ACCC) estimates that between FYE08 and FYE17, retail prices per kWh increased by 56%, representing a real increase in cost of 35%[15]. There are five main contributors to the cost of electricity, which are defined and approximately quantified in Table 1.

Table 1. Cost categories that make up the average residential power bill in the NEM

Cost category	Description	Contribution to cost[16]
Transmission	Bulk transfer of energy to centralised substations. Costs largely based on fixed-cost investment^	10%
Distribution	Delivering the energy from the substation to the customer. Costs largely based on fixed-cost investment^	40%
Retail	Supplying electricity to end consumers including billing, marketing and servicing customers. Costs also include hedging and risk premiums	20%
Wholesale	Producing the electricity	20%
Environmental	Policies that support clean energy or consider the costs of emissions	10%

^ Consumption-based tariff structures do not adequately reflect the nature of the fixed-cost investment

The wholesale generation sector is undergoing a transformation as Australia's coal-fired generation fleet is approaching end of life (due to technical or economic reasons). Decisions made now about how to respond to this transformation will affect electricity cost, reliability and sustainability for decades to come. The scale of the impending and uncertain coal retirements will dominate the sector's supply-side challenges. To a smaller extent, developments in demand-side response, residential batteries and electric vehicles will add further complexity to the transformation and new challenges for networks.

For most customers, the cost of electricity is set by a tariff from their retailer, which is usually locked in for some period of time. However, over time, the retailers' prices must reflect the costs in the market. A rising wholesale price will affect retail prices. Therefore it is useful to understand how wholesale prices are established.

[14] Prices capped at $300 for this comparison, as short periods of very high prices can skew analysis. Including super-peaks, the average price Q1 2019 was more than 60% higher than the Q4 2018 or Q1 2018 average.

[15] ACCC, 2018, *Electricity supply and prices inquiry*: https://www.accc.gov.au/regulated-infrastructure/energy/electricity-supply-prices-inquiry/final-report

[16] These are only approximate since every region has slightly different cost profiles and different reports give different numbers. The following link provides a useful overview and references to several reports: https://www.cleanenergycouncil.org.au/consumers/electricity-prices
The AEMC *2018 Residential Electricity Price Trends Review* provides a separation of transmission and distribution costs: https://www.datocms-assets.com/6959/1545274459-2018-residential-electricity-price-trends-final-report.PDF

Understanding dispatch and price setting mechanisms in the NEM

The setting of price in the NEM is based on the marginal unit – i.e. the last unit to be dispatched. According to the theory of the market design, all generators should bid into the market at the lowest price at which they are willing to generate. If they are the marginal unit, they are approximately breaking even. If they are dispatched and another, more expensive, option is the marginal unit – then they make a margin. Complexities such as constraints and the co-optimisation between energy and frequency control ancillary services markets build upon this basic principle.

Figure 1 shows a conceptual bid stack with Generator E as the marginal unit being partially dispatched. The spot price is set at $70/MWh for all generators. In theory, this encourages generators to bid in at their real short-run marginal cost.

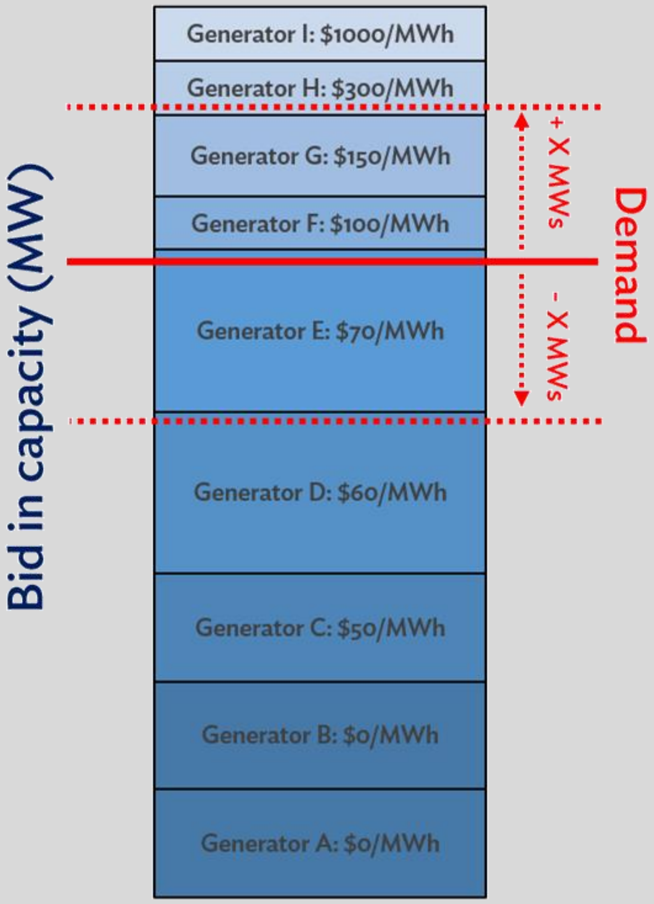


Figure 1. Demonstration of a bid stack

The figure also shows the relative impact of varying demand. A decrease in demand by a certain amount would result in a small reduction in price, reflecting the non-linear yet an increase in demand by the same amount would result in a substantial price increase, reflecting the nature of the supply–demand balance.

Generator E is paid what they bid. Withdrawing even a small amount of capacity can change the price, as can rebidding in at a higher price. To keep the high prices in check, a healthy market should have substantial competition to be the market price setter to ensure that the marginal price is set as low as possible.

Introducing more flexible generation options into the market would provide greater security and reliability and also help manage this risk to affordability through increased competition.

1.1.2 Affordable prices through competition for the marginal price setter

Electricity prices in past years have been low, at times suppressed by oversupply and by existing sunk-cost assets running at their operating cost (without delivering returns on capital). Wholesale electricity prices in the NEM are now rising as circumstances change. If the energy transition is not well-managed, prices could continue to increase. Victorian power prices can be reduced through increased competition when flexible supply is required.

Since the price is set by the marginal unit, understanding the generation mix is critical. As the supply options become more variable, the need for flexible generation to fill the gaps becomes more important and contributes more to the average price.

The final quarter of 2018 saw the highest Q4 NEM-wide spot prices on record in the wholesale spot market. Further analysis of the data shows that although flexible generation only set the price 25% of the time, this accounted for 60% of the cost in the Victorian market. The key drivers for these high prices came from:

- high gas prices
- reduced availability and output of gas generators
- planned and unplanned outages of Victorian coal-fired generators at times when the market was undersupplied
- shortage of available hydropower generation (manifested as higher priced offers)[17].

Analysis of publicly available data shows that the Victorian market price was infrequently set by a Victorian-based asset. Victoria already participates strongly in the NEM and trades energy to achieve the lowest cost outcomes from across the NEM. This is demonstrated in Figure 2. Similar analysis shows that while the price setter in Victoria is determined across the entire NEM, there is presently limited competition in terms of ownership. Three market participants set prices that accounted for almost two-thirds of the total annual cost of the system. The figure shows that Victoria is a market with some, although limited, competition and plenty of inter-regional trading to achieve economic efficiencies.

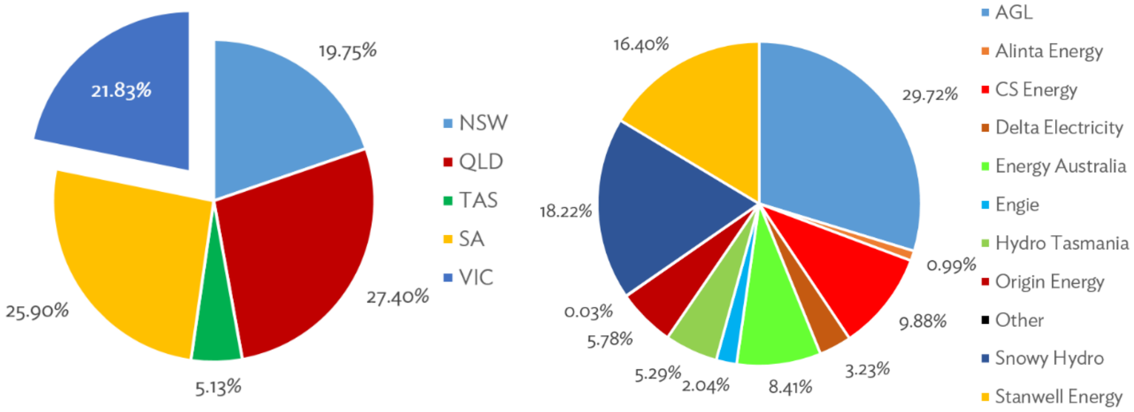


Figure 2. Price setting assets for the Victorian market in 2018, location of the asset (left) and owner of the asset (right)

Restricting the analysis to times where the price was set by flexible generation shows a concentration of supply options in South Australia and Victoria, Figure 3. This concentration also resulted in reduced competition to be the price setter. Two participants are setting the price for more than two-thirds of the total cost in Victoria (when flexible supply is needed).

[17] For each generation type there are different considerations in the bidding process. Fossil fuel is typically approximated as being infinitely available at a given price: price is fixed and generation varies according to market price. Conventional hydro generation has fixed 'fuel' (water) no matter what the price, so available energy generation is fixed and price varies with the market price to ensure that the target amount of energy is dispatched. In each case, different behaviour is required for an efficient market and to minimise the settled market price.

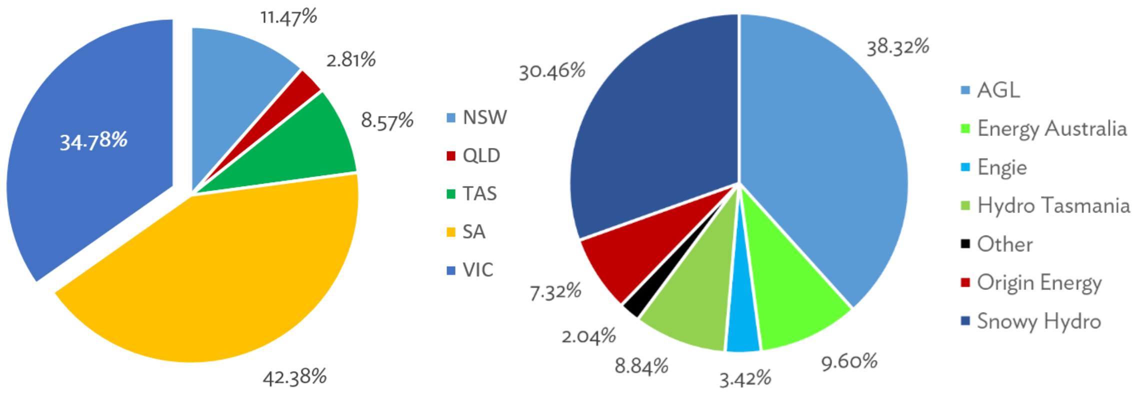


Figure 3. Price setting assets for the Victorian market during times where flexible generation was required in 2018, location of the asset (left) and owner of the asset (right)

As noted above, while flexible generation set the price only 25% of the time, this accounted for 60% of the Victorian market cost. Introducing competition for flexible supply is likely to have a substantial impact on the price in the Victorian market.

The impact of increased competition on wholesale prices

It is possible to quantify the impact of increased competition on wholesale prices by segmenting the price data to explore the key drivers of wholesale price. From October to December 2018, the average price per MWh was $98.29 for the Victorian region. Analysis of the impact of changing the bid price of marginal units in each half hour shows the following outcomes.

If there was increased competition for *non-flexible* generation that reduced the price of the marginal non-flexible generator by 10%, the total average price would have dropped to $94.57. If there was increased competition for *flexible* generation that reduced the price of the marginal flexible generator by 10%, the total average price would have dropped to $92.18. A comparison is shown in Figure 4.

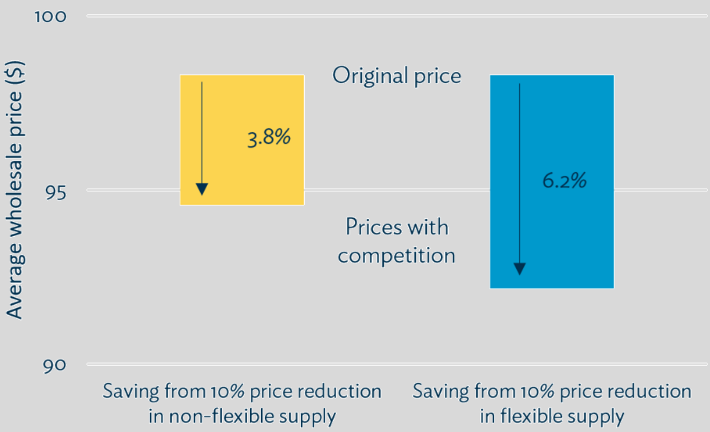


Figure 4. Indicative price reductions from increased competition

Increasing competition for flexible generation would have had a much greater impact on price[18]. Moreover, price volatility is greater at the higher prices. A 10% saving from competition for flexible supply is easier to achieve with the existing energy mix because even modest increments in supply options can substantially increase competition and reduce the price.

[18] It is important to understand that simply increasing baseload or variable generation does not necessarily reduce the need for flexible generation. Responsive options are required to help manage the supply–demand balance. Some of this may be able to be sourced from demand-side response and some will need to come from flexible supply. For the purposes of this analysis, these two outcomes both result in increased competition for flexible response – which is represented as competition for flexible supply since there is yet no explicit market for demand-side response.

1.1.3 Contract market liquidity

While all electricity in the NEM is traded through the spot market, operated by AEMO, the majority of the energy is already committed under longer-term contracts. These contracts underpin the prices that retailers can offer. The availability of these contracts underpins competition amongst retailers, ultimately affecting the prices paid by consumers in the NEM.

The spot market reflects the price of supply every five minutes and is settled against an average over 30-minute intervals. The spot price can be highly volatile. Market participants (both generators and retailers) manage this risk through financial contracts. These contracts take a range of forms, yet they are all fundamentally an agreement to buy or sell energy at a given price under certain conditions, see Figure 5. This results in a 'contract for difference' where the counterparties agree to exchange money outside the spot market to achieve the contracted price. Some contracts also include a fixed payment known as a 'premium'. Both of these approaches reduce exposure to variations in market price, and the price is struck according to the relative value that each counterparty places on managing their exposure to the risk[19].

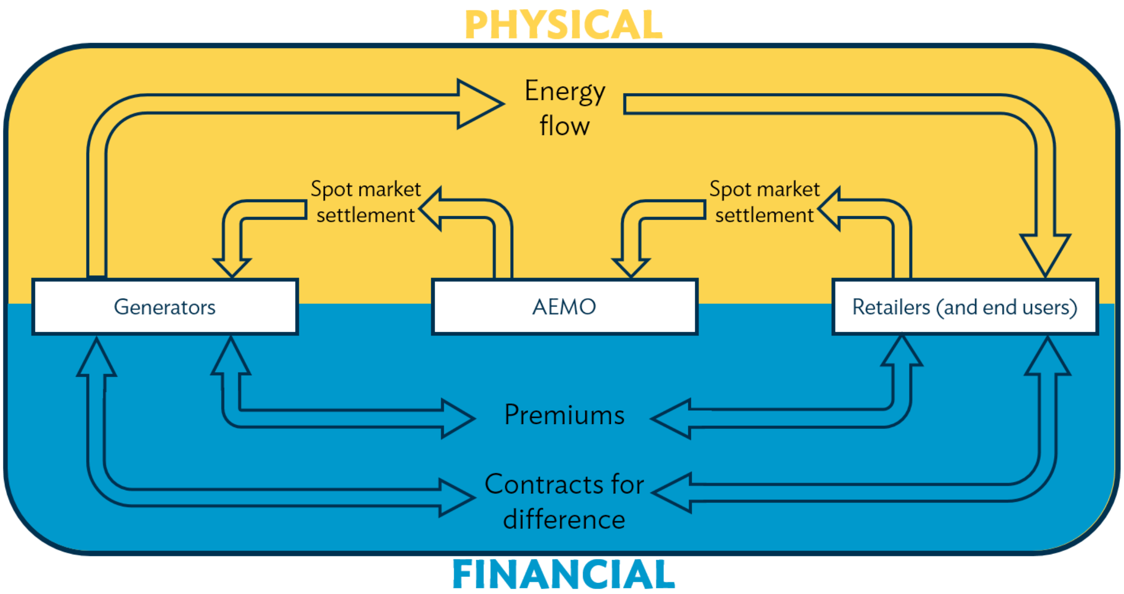


Figure 5. Financial contracts help manage exposure to physical market risk

For the contract market to be effective and efficient for risk management, there must be sufficient volume in the market to encourage competition for contracts; this can be called market 'liquidity'. In a report on retail electricity pricing[20] the ACCC noted observations that the liquidity of the contract market has been declining in recent years. This lack of liquidity raised concerns about access to contracts, particularly for smaller retailers who may be limited to fewer trading partners. The ACCC noted this was particularly consequential in Queensland and Victoria where the three largest retailers consistently had access to lower prices for over-the-counter contracts[21]. This will tend to concentrate market power and result in reduced competition and higher prices.

[19] Generators and retailers also have the choice to buy or sell directly on the spot market. This means that the forward price for contracts is typically considered to be representative of the expected price in the spot market. Long-term planning typically favours spot market modelling as it represents the cost drivers behind the contract prices.

[20] ACCC, 2018, *Electricity supply and prices inquiry*: https://www.accc.gov.au/regulated-infrastructure/energy/electricity-supply-prices-inquiry/final-report

[21] Vertical integration allows companies to own a large portion of the supply chain and manage risk through access to both supply and demand.

Options are being considered, such as the Market Liquidity Obligation, which seek to improve liquidity in the market and thus help manage prices. However, more fundamentally, more supply options, particularly more flexible supply options, will introduce more competition into the contract market, directly increasing liquidity and reducing the concerns raised by the ACCC report.

1.2 A reliable and secure system

In simple terms, system reliability means continually meeting the supply-demand balance during times of normal operations over extended periods. Security refers to the ability for the system to return to an acceptable state after a disruptive event occurs, such as the loss of a major power station or power line. Both system security and system reliability must be maintained for consumers to have consistent access to power at all times.

1.2.1 Balancing the system

The traditional challenge of the power system has been managing variable demand with the available supply options. Supply in Victoria, and across the NEM, has been dominated by coal, supported by hydro, gas and interconnection for flexible supply options. Interconnection has also essentially provided a source of flexible demand when considered on a region-by-region basis. In more recent years, wind and solar have started to contribute to the energy mix and this is changing how the system operates.

Over many decades, Australia has developed expertise and experience in managing a fossil-fuel-dominated power system to deliver stable and reliable power. Figure 6 illustrates the current composition of the NEM, using the generation and demand for the first week of the 2018/19 summer as an example.

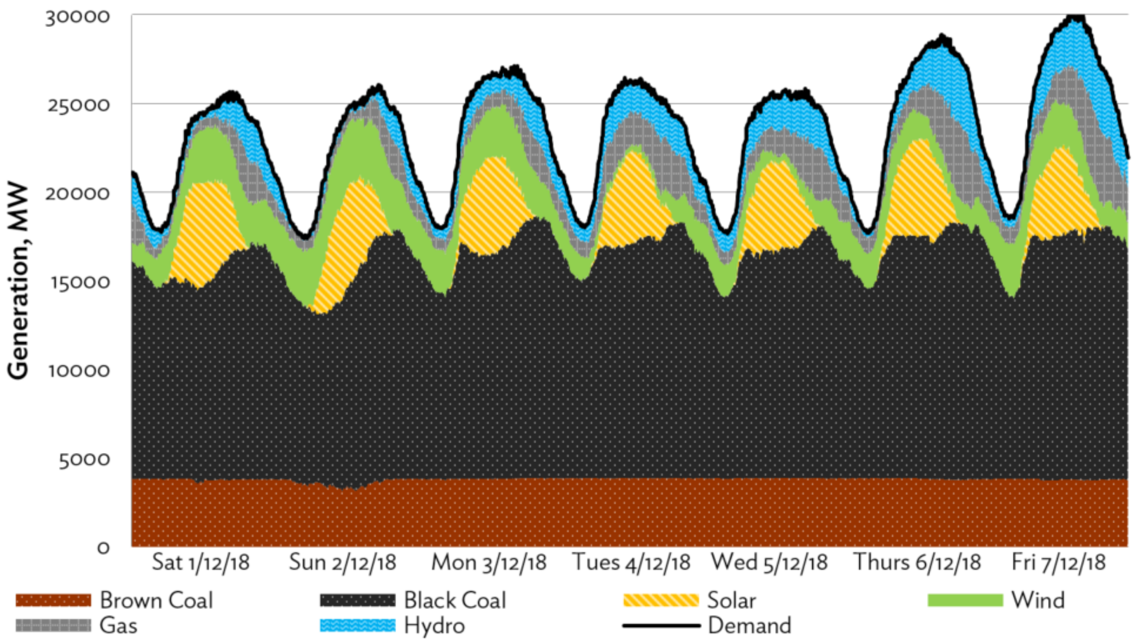


Figure 6. NEM-wide generation and demand over first week of December 2018[22]

[22] In this document, solar generation includes both utility-scale and rooftop solar photovoltaic generation unless otherwise stated.

Historically, the challenge in the NEM was trying to meet varying demand. The supply was largely consistent, with a great deal of baseload generation. The actual variation in the supply–demand balance was driven primarily by variation in demand (with the exception of asset failures). This can still be seen in recent data; for example, Figure 7 illustrates Victorian generation and demand in the first week of the summer of 2018/19.

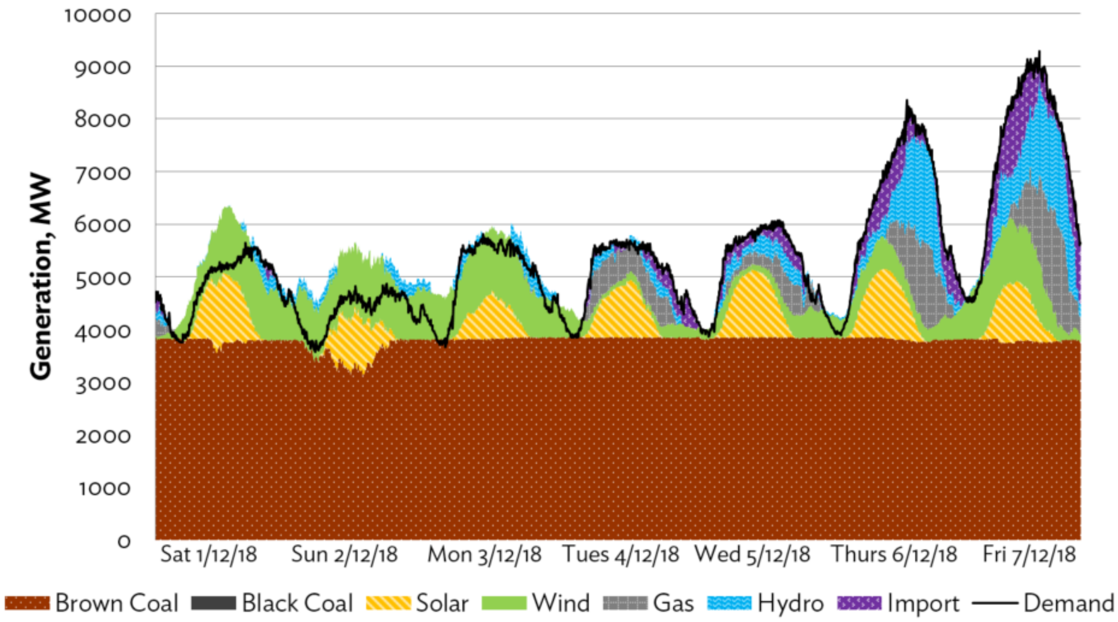
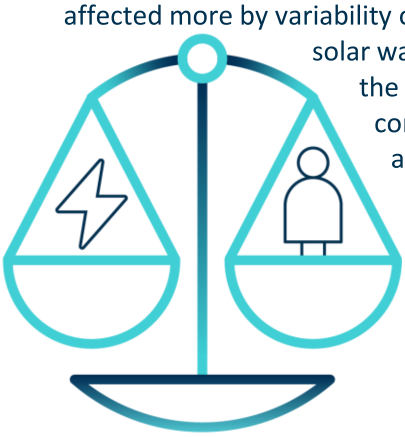


Figure 7. Generation, demand and imports for Victoria, first week of December 2018

The installed capacity of coal-fired power stations is scaled to meet the minimum demand and variability has been typically driven by demand. However, even in Figure 7 it is possible to see that variable renewable generation is starting to change the operations. During a period of low demand, the brown coal generation moved away from its ideal operating point because strong wind and solar outcompeted the coal-fired generation. It is also worth noting that wind generation is variable from day to day. The claim that 'it is always windy somewhere' is not strictly true, due to the nature of weather systems. On Tuesday 4 December, a large high-pressure zone over much of the NEM suppressed wind generation. This is evident in both Figure 6 and Figure 7.

As the power system transitions to the future market, it is likely that price variance will be affected more by variability of supply than demand-side variability. For example, if Victorian solar was able to contribute 5000 MW during the day but nothing during the night, the need for flexible supply would be much greater. This is conceptualised in Figure 8. The highest average demand (at 7 pm) is about 2000 MW more than the lowest average demand (at 4 am). The highest average solar output (at midday) is about 5000 MW more than overnight – and the variation is rapid. In this situation, solar generation would have a much greater impact on the supply–demand balance than variation in demand.



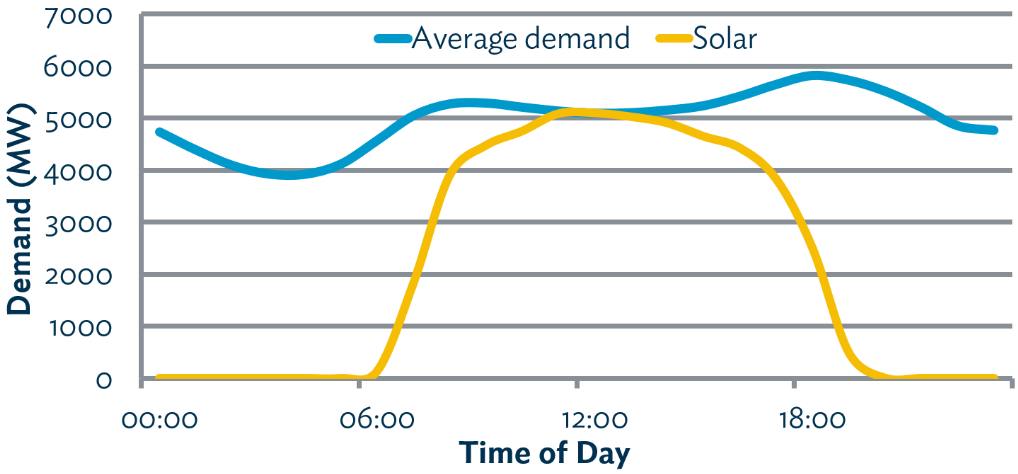


Figure 8. Conceptual plot of average Victorian demand and 5000 MW of hypothetical solar generation

Overlaying the variability of wind will sometimes counteract some of the solar variability, but at other times may increase it. For example, 5000 MW of wind may help manage night time supply, but will also supply during the day. This could potentially result in 5000 MW of surplus generation (plus any 'must-run' generation) that would need to be stored or shared – or wasted.

1.2.2 Coal generation availability and forced outages

Until recently, coal generation was perceived to be a highly reliable generation source. However, increasing forced (unplanned) outages in recent years are leading to the re-evaluation of this assumption. For example, during Victoria's January 2019 heatwave, 200 000 customers were affected by rolling brown-outs. During load shedding events, Victorian coal plants were at just 73% of their expected summer capacity[23]. Further, due to cooling issues experienced in higher ambient temperatures, the summer capacity of Victorian coal is normally reduced by 304 MW.

AEMO's 2018 Electricity Statement of Opportunities (ESOO) recognised this shift by assuming an increase in coal forced outage factors. For example, the brown coal forced outage factor assumed in the 2017 ESOO was 4.1%, which increased to 5.3% in the 2018 ESOO. In light of the declining reliability of Victoria's brown coal fleet, alternative sources of reliability are required.

The Victorian Annual Planning Report 2018[24] notes that since the retirement of Hazelwood power station in March 2017, Victoria has increasingly depended on imports from other regions to meet demand at peak times. It also noted that during the summer of 2017/18, AEMO was required to activate Reliability and Emergency Reserve Trader (RERT) on two occasions to balance supply and demand. RERT was once again activated in the summer of 2018/19, but was insufficient to prevent involuntary load shedding in January 2019.

Customers expect to have electricity supply at all times. While a recent Grattan Institute report[25] noted that 97% of customer outages are attributable to network outages rather than supply shortfall, it acknowledged that these outages would be prohibitively expensive to

[23] Based on data from AEMO's generation information page: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information and AEMO's Market Management System: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Market-Management-System-MMS

[24] AEMO, 2018, *Victorian Annual Planning Report*: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/VAPR/2018/2018-Victorian-Annual-Planning-Report.pdf

[25] Grattan Institute February, 2019, *Keep calm and carry on: Managing electricity reliability*: https://grattan.edu.au/report/keep-calm-and-carry-on/

prevent. While network-related outages are typically localised, supply-related outages are typically widespread and occur at times of high demand – when energy use is most important to customers.

As the NEM transitions to increasing proportions of variable renewable energy, the need will increase for system security services that are able to respond rapidly to events such as the loss of a large generator or transmission line.

1.2.3 Flexible and dispatchable supply

Demand varies and no generator can supply its maximum output at all times; therefore, supply options are needed that can respond to the changes in the system. To meet the net customer demand, Victoria needs a combination of energy sources that, together, can reliably supply sufficient electricity at all times. The key point here is that it is the entire system, not any individual generator, which delivers reliable supply, and this is not a new requirement[26].

For any given region, a reliable system needs:

- sufficient energy to meet the overall electricity demand (at an affordable price)
- sufficient dispatchable capacity to meet the maximum demand and manage the system
- sufficient flexibility to respond to (rapidly) varying supply and demand in real time.

Table 2 summarises the characteristics of the major market-facing assets currently available in the NEM. Pumped hydro, batteries and interconnection all have the potential to be dispatched (controlled) as either generation load.

Table 2. Characteristics of different supply options in the NEM

	Energy	Dispatchability	Flexibility	Low emissions
Coal	Y	Y	N	N
Combined cycle gas turbine	Y	Y	N	N
Open cycle gas turbine	N	Y	Y	N
Hydro	Y	Y	Y	Y
Wind	Y	N^	N^	Y
Solar	Y	N	N	Y
Pumped hydro	N	Y	Y	Y
Batteries	N	Y	Y	Y
Demand response	N	Y	Y	Y
Interconnection	Y	*	*	*

^ Some wind farms are able to deliver limited flexibility and dispatchability

* Depends on connected region

[26] Some of the key concepts of the changing power system are addressed in the white paper 'Understanding reliability in the future NEM': https://www.hydro.com.au/clean-energy/battery-of-the-nation/future-state

Costs of wind and solar generation have fallen dramatically and continue to reduce. AEMO's 2018 Integrated System Plan (ISP) identified that the transition to renewables is justified on the basis of costs alone, even without considering other potential benefits. Considering Table 2, it is clear that a reliable low-emissions electricity system can be delivered through a combination of energy sources coupled with dispatchable and flexible options.

Current Victorian supply is in transition towards low-emissions energy sources with ongoing development of considerable wind and solar generation. To maintain reliability and security, flexible and dispatchable supply options must also be actively sourced. This is recognised through proposals under consideration, for example the Retailer Reliability Obligation[27].

It is the need for flexibility and dispatchability that will drive the next stage of the transition from simply providing low-cost clean *energy* to delivering a lowest-cost reliable *system*.

1.2.4 Sustained capacity

The variability of wind and solar resources requires management of the supply–demand balance, especially when low wind or solar availability coincides with high demand. The concept of 'sustained capacity' was raised in the '*Battery of the Nation* Analysis of the Future National Electricity Market'[28] and expanded in 'Understanding reliability in the future NEM'[29].

Batteries with storage of about an hour are providing valuable services in the NEM, but they will not be able to cost-effectively manage all the needs in the system. During sustained periods of low wind output and/or overnight where there is no solar generation, firming options with longer duration will be required. Table 3 lists the indicative duration of impact of a number of likely power system challenges. The first three challenges in the table are the traditional challenges in the power system, which are already in evidence. The latter three are all based on broad, unavoidable weather patterns. The 'duck curve'[30] is the early evidence of the requirement for daily balancing of the solar cycle. The latter two challenges in Table 3 are also starting to arise. As the penetration of variable renewable energy increases, it will become increasingly important to be able to address weather-based challenges. A mix of supply options, such as diverse wind and solar, will help to mitigate some of these challenges. Nevertheless, it will be important to have options that can efficiently and effectively supply the sustained capacity needed to meet the longer-duration challenges.

Table 3. Challenges the power system is likely to face

Examples of challenges to system supply–demand balance	Indicative duration
Brief variations in load or supply	0–1 hrs
Contingency events (spikes in supply–demand imbalance)	0–2 hrs
Managing load uncertainty and supply constraints	6–8 hrs
Daily balancing of solar cycle	10–14 hrs
Large cloud bands in a system with substantial solar reliance	24–48 hrs
Successive days of minimal wind generation	24–72 hrs

[27] In the present form, this will drive reactive market outcomes rather than those in the best long-term interests of the customer.
[28] Hydro Tasmania, 2018, *Analysis of the Future State National Electricity Market*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/future-state-nem-analysis-full-report.pdf
[29] Hydro Tasmania, 2018, https://www.hydro.com.au/clean-energy/battery-of-the-nation/future-state
[30] AEMO, 2018, *Operational and market challenges to reliability and security in the NEM*: https://www.aemo.com.au/-/media/Files/Media_Centre/2018/AEMO-observations_operational-and-market-challenges-to-reliability-and-security-in-the-NEM.pdf (page 6)

The information provided in Table 3 aligns with work from the International Energy Agency (IEA) highlighting that as the penetration of variable renewable energy increases, the flexibility requirements will change, as shown in Table 4. At present, the NEM is largely considered to be in Phase 2. Some regions have very high penetrations of variable supply, although the longer-term flexibility requirements are generally provided by interconnection. As wind and solar continue to establish themselves as the cheapest energy source and their total penetration in the NEM continues to increase, it is expected that the need will continue to increase for more sustained flexible supply[31].

Table 4. An excerpt from IEA paper 'Status of Power System Transformation 2018'[32] showing the varying requirements for flexible generation changing with variable renewable energy penetration

Phase	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Becomes a main priority	Typically no system flexibility issues	Short-term flexibility	Short-term flexibility Medium-term flexibility	Ultra-short-term flexibility Medium-term flexibility Long-term flexibility	Long-term flexibility Very long-term flexibility	Very long-term flexibility

1.3 Support for Victoria's renewable energy development objectives

Victoria has strong renewable energy development objectives and the State Government has policies designed to increase the supply of low-cost wind and solar generation. The benefits of increased renewable energy generation in Victoria will rely on variable generation being efficiently integrated into the system.

It is generally acknowledged that firming[33] is required to ensure that a system rich in variable renewable energy is secure and reliable. However, renewable energy developers may be challenged more by over-supply than by scarcity. Business cases for renewable energy are sensitive to the value of their generation.

A product with a very low cost to operate can cover costs even during hours with very low prices. However, if the very low prices occur frequently, this can challenge the long-term return on investment. In a power system with deep renewable energy penetration, it is possible that there may be surplus supply driven by weather patterns. This is the counterpart of the challenges presented in Table 3.

Table 5 shows the challenges faced by renewable energy developers trying to negotiate a power purchase agreement.

[31] This was recognised in AEMO's 2019 Insights paper, Building power system resilience with pumped hydro energy storage: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

[32] IEA, 2018, *Status of Power System Transformation 2018*: https://webstore.iea.org/status-of-power-system-transformation-2018

[33] Firming can be considered flexible supply which will fill the gaps when wind and solar energy is insufficient.

Table 5. Challenges for development of wind and solar

Development challenge	Indicative duration of impact
Surplus solar generation (daily pattern)	8–10 hours
Surplus wind generation (low pressure systems)	24–72 hours

Much like in Table 3, these weather-driven effects are not isolated. Low wind energy output during the day may relieve some of the solar surplus, but if a high wind event occurs in the late afternoon/evening, it may also extend the surplus period in the market – even without an extended low pressure system.

Transmission congestion, a localised form of over-supply, is already causing substantial changes to the marginal loss factors from transmission lines for some renewable energy projects and is having material financial implications for market participants and investors[34].

Case study of high-penetration solar generation

Solar photovoltaics are the cheapest source of energy in Australia and, on this basis, it would be reasonable to assume that as fossil-fuel generators retire, a significant proportion of electricity will come from solar PV. This case study considers the scenario of 50% of Victoria's energy needs being supplied by solar. Most of the energy generation occurs at the same time of the day, represented in Figure 9.

- >80% of the generation occurs over 7.5 hours – covering ~33% of the demand
- >95% of the generation occurs over 10.5 hours – covering ~44% of the demand

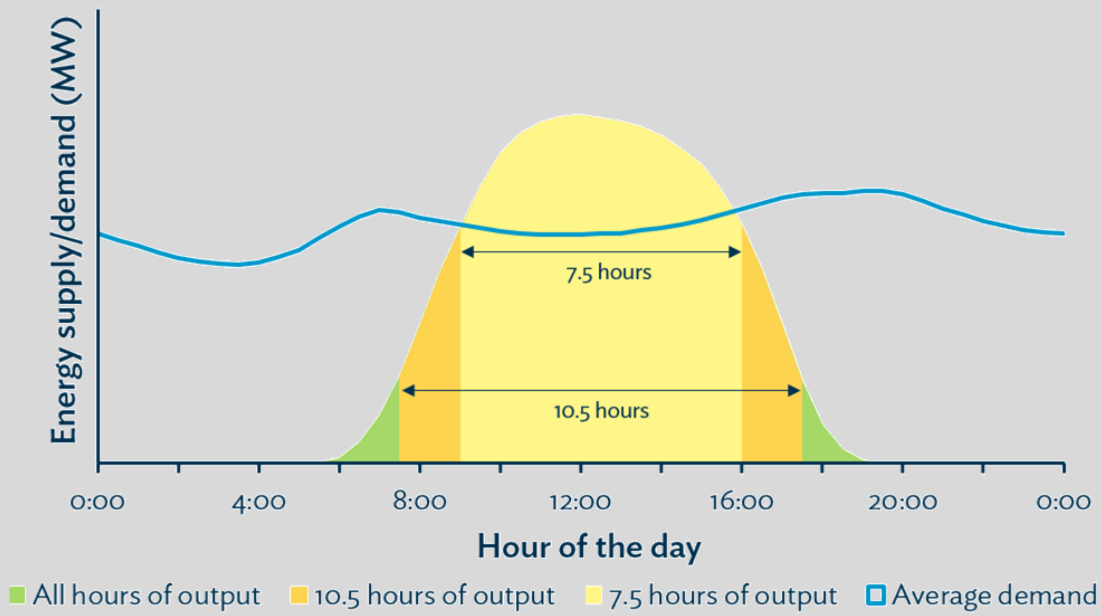


Figure 9. Conceptual comparison of solar generation and demand profile

[34] More information about marginal loss factors can be found on AEMO's website: https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Security-and-reliability/Loss-factor-and-regional-boundaries

To produce sufficient energy to meet the target in the proposition, there will be surplus generation, and this surplus will occur during the times of highest production. Unused surplus and competition will force the wholesale price to zero (or indeed negative). Figure 10 demonstrates that the first MW of consistently surplus generation will mean all solar in the active market loses value. It also means that the next solar development opportunity will find it very difficult to achieve a sufficient power purchase agreement.

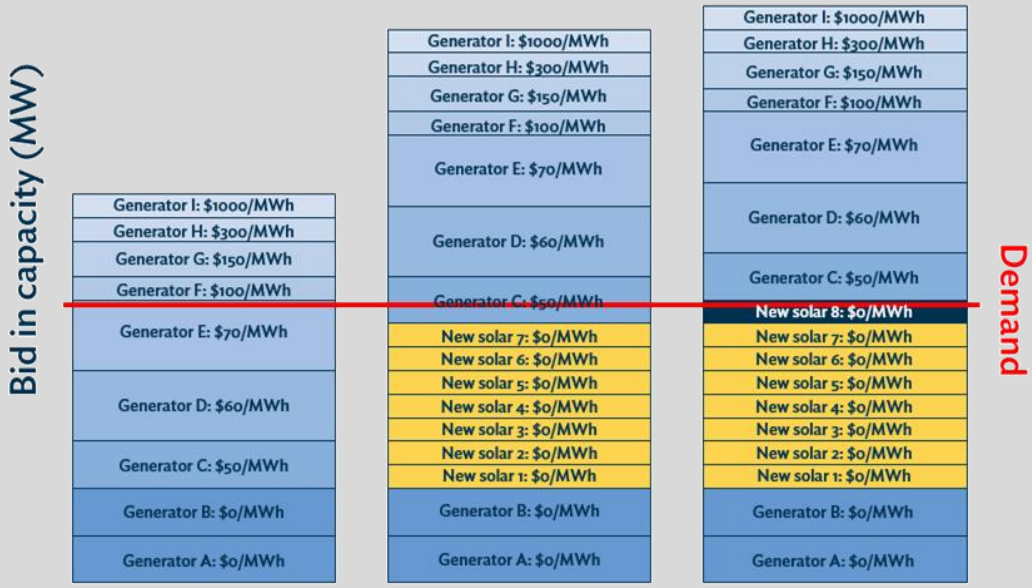


Figure 10. Bid stack from Figure 1 with increasing penetrations of solar generation

It is worth noting that despite spilled energy (wasted surplus), some level of overbuild would be the most efficient way to meet the supply requirements as recognised in AEMO's 2018 Integrated System Plan (ISP) for both wind and solar. Figure 11 shows a plot of under-utilised wind and solar generation from page 36 of the ISP, which models an optimised energy mix. However, without proper market signals, the least-cost outcome produced by the ISP may not be a commercially viable outcome.

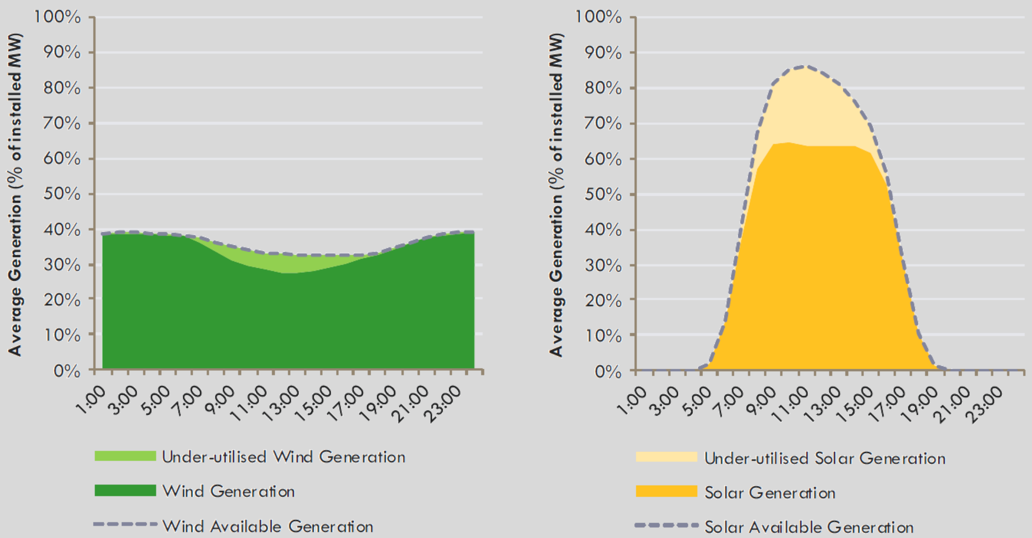


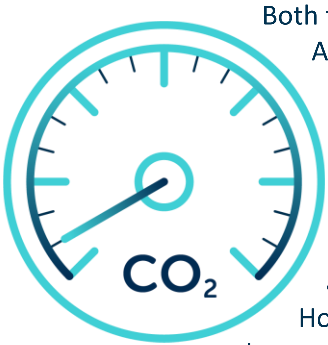
Figure 11. Average utilisation of utility-scale renewable energy generation (page 36, ISP 2018)

While the 50% solar scenario is presented as a hypothetical case study, there are already solar farms in some places in Australia that are curtailed most days.

Victoria's renewable energy objectives will lay the foundations for a strong role in the future NEM. However, to commercially achieve the desired outcomes, renewable energy developers will need a positive business case. The commercial risk of income being insufficient when renewable energy is abundant can be mitigated by a customer willing to pay for the under-utilised generation. This could be through an expensive underwriting arrangement guaranteeing income to under-utilised generation, or it could be through flexible loads capable of responding to market signals. If this flexible load comes in the form of storage, it will also be able to provide reliability and security services back to the market. Regardless of the form they take, the flexible loads must be able to continuously consume sufficient energy to resolve the issue of regularly surplus supply.

1.4 Protection from carbon risk

With growing international recognition of the impacts of climate change[35], it is becoming increasingly likely that there will be a cost on carbon of some form in the future. The timing and nature of the potential policies are uncertain, but investors are already factoring climate change resilience into the value of an organisation.



Both the Australian Securities and Investment Commission (ASIC) and the Australian Prudential Regulation Authority (APRA) have highlighted that company directors need to consider the impact of climate change in order to properly manage risk. Regardless of the acceptance of the science of climate change, a future where carbon may be priced is credible and it is important to consider and prepare for such scenarios.

Victoria is already positioning itself strongly through support for wind and solar generation and a target for zero net emissions by 2050. However, wind and solar will require firming to meet demand at times of low supply. If Victoria relies on firming provided by carbon-emitting technologies, there is a risk of emissions-related cost pressures that would inevitably impact customers and may threaten the achievement of the targets.

[35] More information can be found on the Intergovernmental Panel on Climate Change website: https://www.ipcc.ch/

2. A pathway for a smooth transition to the future power system

The projected rate of retirement of coal generators over coming decades will necessitate careful planning to ensure a smooth transition to the new energy system. Some components of the least-cost future power system, such as interconnection, take longer to build than the proposed retirement notice periods (and the proposed Retailer Reliability Obligation trigger period).

Furthermore, emerging technical or safety issues could mean that a generator is simply unable to meet such commitments. The capacity must be available in the system before it is too late; trying to get the timing 'perfect' is simply too large a risk, and waiting for 'triggers' for investment will preference projects with short construction times, not least-cost solutions.

According to AEMO's 2018 ISP, an average of 1300 MW of coal generation is projected to retire from the NEM every year between FYE 2029 and 2037 – even without any economic retirements.

Coal-fired generation is expected to come under increasing economic pressure and so more may retire early, simply on commercial grounds rather than due to technical or safety reasons. Strong state or federal renewable energy targets, such as Victoria's target of 50% renewables by 2030, could be expected to help manage this change. The potential impact of each nominal 1300 MW could be as impactful as the retirement of Hazelwood's 1600 MW of generation in 2017 unless sufficient new flexible capacity is in the market in time.

To continue to meet electricity demand, retiring coal plant will need to be replaced with an energy mix that is affordable, reliable and sustainable. The 2018 ISP projected that this mix is likely to consist of a mixture of wind, solar and storage – a total of over 50 000 MW of new generation and storage by 2040.

To ensure that consumers aren't left in the dark, dispatchable and flexible capacity must be available before it is needed, not after.

The decision to invest, especially in large infrastructure, comes with risk and needs to be carefully considered. Over-investment is inefficient, but under-investment can result in shortages and challenges meeting the supply–demand balance. Early investment comes with the risk of periods of over-investment; late investment comes with the risk of periods of under-investment. It is practically impossible to precisely determine the optimal timing of investment for an orderly transition of assets in a dynamic market environment. It is therefore important to understand the consequences of early versus late investment.

For a smooth transition, Victoria needs investment in a suitable asset mix. A well-functioning market has competition; early investment introduces more options and therefore reduces prices – even though there is also inefficiency in over-investment during the time of transition. By contrast, late investment will result in shortages, high prices and high profits for incumbents.

According to the latest analysis on the value of customer reliability[36], the cost of unserved energy is several hundred times greater than the cost of energy. On that basis, most of the shortfall will likely be filled, but filled with technologies prioritised by speed of deployment rather than long-term least cost. The cost and reliability penalties of late investment are high and will compound as market changes accelerate.

It is in the interest of consumers to enjoy the benefits of early investment; yet in the current market structure, it is not in the interest of investors themselves. Early investment can result in excessive competition and suppressed profitability – potentially even putting solvency at risk. This is especially true for large-scale, long-lead-time investments that need to invest before the market signals are clear.

By contrast, lack of competition raises prices, which is a poor outcome for consumers but can be a positive outcome for the bottom-line of a business – especially if it has a large portfolio. The downside of late investment is a potential loss of opportunity. Missed opportunity is typically much easier for a business to manage than loss-making assets.

The interests of consumers and the interests of investors do not align in terms of investment timing – at least in a purely financial sense. During a market transformation, it is critical for developers to have confidence to invest in order to maintain a healthy market. Earlier investment can be encouraged by de-risking the potential for loss. The investor is exposed to opportunity and consumers benefit from increased competition.

With the right structures, it is even possible to design the underwriting as a form of market insurance that would only be called upon in unexpected circumstances. This would minimise market interference and minimise the cost of the underwriting while still avoiding unacceptable risk to investors while future market structures are unclear.

2.1 Barriers to timely investment

Victoria needs timely investment to ensure a smooth transition to the future NEM. However, power system assets typically require large capital investments and must be considered carefully and market barriers must be overcome in order to make the decision to build.

When considering a business case, a generator will consider the uncertainties in the investment environment. Currently, electricity is highly topical – and that brings risk, both positive and negative.

[36] AEMO, 2015, *Value of Customer Reliability* – (note that this is due to be refreshed shortly): https://www.aemo.com.au/-/media/Files/PDF/AEMO_FactSheet_ValueOfCustomerReliability_2015.pdf

Public sentiment and concern can lead to political involvement with new policies and regulations. These may support a new development, but equally, they may not. A lack of policy certainty discourages project developers from committing to particular technologies. The lack of an enduring national approach to emissions, in particular, is contributing to a wait-and-see attitude from many potential developers. For a potential investor, a missed opportunity is much less damaging than a stranded asset.

A market undergoing a transformation is likely to be disrupted in some way and presents opportunities for companies willing to adapt and innovate. This means that the conventional wisdom and understanding of the market may become less accurate. Investments based on these fundamentals may be another potential cause of stranded investments, yet new understandings have yet to be tested and also introduce risk.

Another major uncertainty is the impact climate change will have on the power system. Substantial changes in temperature may result in more demand spikes, accompanied by more overheating failures of assets. Climate change may also impact generation, especially as the technologies move towards weather-driven renewables. The nature of the change may include a change in the long-term average output – yet a change in the frequency and severity of extreme events could potentially be even more impactful.

Extended periods of reduced wind or rain could affect system reliability – as could extended periods with substantial cloud cover. While the science is clear that the climate is changing, it is not yet fully possible to accurately predict the change for specific times and locations, particularly in terms of extreme events. From a business case perspective, best practice is to be aware of the range of potential impacts of climate change and treat it as yet another uncertainty.

From a purely commercial point of view, there is a concern that significant early construction of new generation could also lead to a temporary situation in which oversupply would suppress wholesale prices. This could lead to a feedback effect where subsequent development is delayed or cancelled (as the price signal for new development disappears).

The alternative is that new generation is operated at a level that doesn't suppress the wholesale price, but this would make the new generation unlikely to be profitable for those important early years of operation. The nature of large-scale investments means that stable returns are critical. Few companies can afford to ride through a few years of unprofitable operation – especially if the wholesale price is suppressed across a large portfolio.

Finally, no investment is successful without access to customers. In the case of power systems, generation investment requires access to transmission infrastructure to get to market. Insufficient transmission capacity will limit the opportunity for development. Expanding or building new transmission can be a costly and difficult process to navigate with long lead times to get to market. While it is important to manage and understand the cost implications for a whole-of-system solution, those making generation investment decisions do not have control over transmission investment decisions. Thus lack of access to market becomes a key risk to investment.

Generation businesses have a high asset-value-to-income ratio compared to many types of businesses. Generation investments tend to have long lives with long payback periods leading to a low appetite for investment risk. The uncertainties described above make investment in generation infrastructure difficult.

Victoria is exposed to the changing market from assets in both Victoria and New South Wales. Clear market signals are required to overcome the barriers to early development and encourage sufficient development across the NEM to mitigate the risks of unplanned closures of coal plant. While market reform is underway, interim measures are likely to be necessary.

2.2 The timing of the transformation

While it is expected that existing coal-fired generators will close at some time in the next couple of decades, there is considerable uncertainty about the timing for each individual plant. As the closure of Hazelwood in March 2017 showed, the decision to close can occur with little warning and be implemented in a fairly short time frame. To manage this risk, rules requiring a minimum notice period for intended closure of three years have been put in place across the NEM[37]. Such an agreement or policy could not be enforced in the face of physical danger, so if the reason for the closure is the result of plant failure or safety issues, closure could be effectively instantaneous.

Figure 12 shows AEMO's proposed base case assumption for its 2019 ISP analyses[38] (retirement at 50 years), along with an alternative assumption that coal power plants retire at 43 years[39] (based on the average age of coal generators retired in the NEM since 2012). This alternative assumption, while by no means the most extreme plausible retirement outcome, results in a comparative reduction of remaining coal plant of an extra 4.5 GW by 2025, and 11.3 GW by 2031.

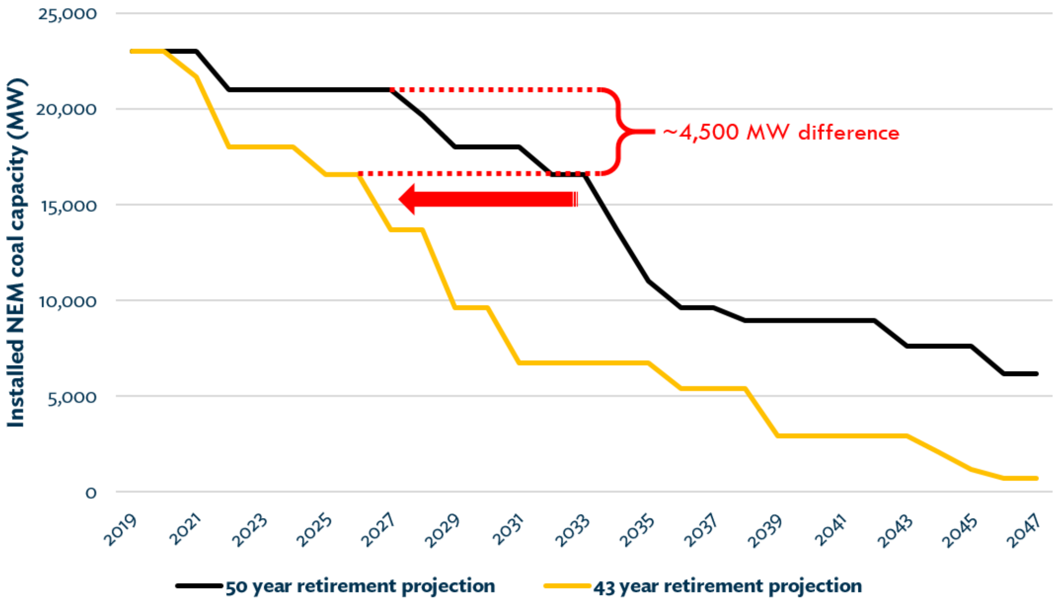


Figure 12. Cumulative capacity of coal-fired generation in the NEM under different assumptions

It is also important to note that Hazelwood was not unique amongst Australia's (and particularly Victoria's) ageing coal generators. A case study in AEMO's recent Insights paper[40] showed that it could be prudent to invest early, even if there is as little as a 20% chance of early retirement. Similar drivers that led to the decision to close Hazelwood could lead other plant owners to the same decision. Moreover, failures are already occurring at times when these assets are most needed (see case study in section 3.2). Reliance on these assets must reduce to maintain expected reliability.

[37] As part of an arrangement to extend the mining leases Yallourn and Loy Yang A are committed to providing a five year notice of closure. https://www.premier.vic.gov.au/certainty-for-workers-and-communities-in-the-latrobe-valley/

[38] Australian Energy Market Operator February, 2019, *2019 Input and Assumptions workbook*: https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation#archive

[39] For simplicity, 43 years from commissioning of the youngest unit was plotted. Liddell power station is allowed to reach its announced retirement age of 49 years.

[40] AEMO, 2019, Building power system resilience with pumped hydro energy storage: https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

A hypothetical case study of coal retirements

A gradual reduction of reliance on ageing coal generators is likely to smooth the transition to the future NEM. If the market waits for the technical end of life (which may occur for a variety of reasons), the transition is unlikely to be ideal. If there are no market signals to smooth the transition away from coal, there are two likely outcomes:

1. **Coal-fired power stations stay online until it is too costly or dangerous to maintain the plant; this could result in rapid retirements that will be difficult to manage**

   The ISP 'neutral' scenario showed a need for 14 GWs of pumped hydro to be built over the foreseeable future, most of which is required over a few years in the late 2030s. Even following an ideal coal retirement projection, it is unlikely that this rapid increase in pumped hydro construction will be possible and the broader economics of a boom-bust investment cycle could be damaging.

   If the coal-fired generators have technical issues which force early retirement and there is limited forward planning, they are likely to be replaced with options with short build cycles. Both batteries and gas peakers can be built swiftly – but both are expensive for managing large needs for electricity supply over extended periods. The 'fast change' scenario from the ISP projects 1000s of MWs more storage would be needed and also needed much earlier than the 'neutral' scenario[41].

   Both of these scenarios raise the risk of transition periods in which Australia endures significant energy shortfalls while such construction occurs. This would lead to high prices as higher-cost generation such as gas and diesel are used more regularly, or where involuntary load shedding is increased to manage shortfalls in supply.

2. **Incumbents preserve the status quo by influencing the timing of asset replacement**

   This could potentially be less damaging than trying to replace failing assets at an unsustainable rate, but would limit competition to a small number of market participants for the next 40 to 50 years based on the life of potential assets.

Ideally, there would be market signals to develop options that reduce reliance on coal-fired generation before physical issues force the timing.

There is general market sentiment that coal generators may retire due to economic pressure, but without sufficient competition in the market (i.e. depth of supply options) incumbent coal will continue to operate even after it is no longer the least-cost option. Coal may be exposed to negative prices during the day, yet could remain commercial by raising prices during high price periods sufficiently to cover losses during the low price periods. AEMO's Quarterly Energy Dynamics Q4 2018 report noted that there has been a structural shift of offers from black coal to higher prices.

A large price spread between high and low spot prices (over a period of days) creates a signal for storage; yet during the transition to the future market, investment in storage is risky, especially in an energy-only market. For this reason, even though the business case looks positive on today's market, there has been little development of pumped storage.

Victoria (and the NEM) needs a smoother alternative. Market reform is critical to achieve long-term cost-effective outcomes. Shorter-term initiatives to help manage risk will also be essential to encourage early investment in the interim. The more certain and more decisive the market signals, the earlier the transition can start, allowing for a smoother replacement of retiring coal assets with cost-effective solutions.

[41] Comparing the 'fast change' to the 'neutral' scenarios: by 2026–27, 1300 MW of additional storage may be required; and by 2031–32, 7800 MW of additional storage may be required (only five years later).

2.3 The case for early investment for the market

There is a very clear asymmetry in the risks between building 'too early' compared with building 'too late'.

For the broad market, the risks of late development are both more immediate and more costly than the risks of early development. The sudden loss of significant supply could result in temporary closure of large (industrial) electricity consumers; commercial and residential blackouts; extreme price outcomes; system instability; and knock-on economic impacts. Any temporary closure of a large industrial electricity user could easily become a permanent loss of industry and associated jobs. The primary impact of late investment is borne by the customer.

Identifying the 'perfect' time to invest is essentially unachievable – especially with long-lead-time developments. There are too many uncertainties in the market, the condition of existing assets, fuel supplies and even project construction to be confident of achieving a perfect timeline.

Early investment meets the precautionary principle and proactively manages risk. The cost of not building could be extreme if sudden plant closures occur. Any response to sudden closure is likely to be sub-optimal (and very expensive) due to the time pressure to respond quickly.

Even if the timing of retirements could be perfectly foreseen, the rate of retirement would require a huge acceleration of construction of infrastructure. Therefore it will be important to start building early to allow efficient sequencing.

The commitment to building early can help drive the market reforms that are needed to ensure an efficient and orderly transformation of the electricity market towards a system that is affordable, reliable and sustainable. The risk of early investment can also be managed through incremental developments where possible.

Market-based initiatives that seek to manage supply risk by underwriting or de-risking (as opposed to subsidising) timely investment are a suitable mechanism to incentivise positive outcomes for customers while protecting investors from potential economic inefficiencies.

3. *Battery of the Nation* can help

Battery of the Nation is an initiative that will strongly support Victoria's needs in a transforming electricity market.

By increasing interconnection between Victoria and Tasmania, and leveraging the efficiencies of cross-regional resource sharing, the power systems in both states can be optimised for the future NEM. The initiative particularly looks to take advantage of Tasmania's latent potential in existing hydropower stations, strong opportunities for cost-effective and long-duration pumped hydro energy storage, as well as unlocking valuable solar generation (primarily in Victoria) and wind generation (in both states) by leveraging the diversity of the loads and the generation.

Analysis shows that Battery of the Nation can efficiently and effectively address many of the future challenges in the Victorian market to help deliver affordable, reliable and sustainable energy.

Planning is underway to capitalise on Tasmania's opportunities to provide strong benefits to the NEM – and more directly to Victoria. Tasmania's power system is in a strong position compared to the rest of the NEM, with few assets approaching end of life and a high degree of flexible generation that suits the needs of the future power system.

Battery of the Nation aims to respond to the challenges facing the rest of the NEM and to meet the needs of its potential customers across the NEM.

3.1 Beneficial resource sharing

It would be cost-effective to share resources between regions with complementary generation and load profiles through increased interconnection, as highlighted in section 1.1.

Interconnection is expected to be an increasingly vital contributor to ensuring security of electricity supply throughout the NEM, some of which is discussed in section 1.2. A key option to achieve lower prices at acceptable reliability is through increased resource sharing to maximise efficiency.

There would be benefit in a more connected NEM. Interconnection can be used to share surpluses and there are already times where each interconnector in the NEM has been constrained. However, interconnection is most valuable when it allows regions with different strengths and different challenges to support each other during times of relative shortage. Considering data from the last two years (2017 and 2018), it is possible to see the relative contribution of interconnected regions to Victoria's demand when Victorian prices are very high (above $300/MWh) – see Table 6.

Table 6. Effectiveness of interconnection in supplying Victoria during times of prices above $300/MWh

2017–2018	Average flow (MW)	Interconnection capacity utilisation	Commentary
Average supply from NSW	120	9%	
Average supply from SA	–139	–17%	The negative flow indicates that Victoria was exporting to SA during high price periods
Average supply from Tas	405	85%	

The NSW support to Victoria is very limited, even considering thermal constraints on the interconnection. Typically, NSW has little excess generation capacity during the times when Victoria needs support, and additional interconnection will not change that[42].

Exporting to South Australia often *causes* the high Victorian prices. While Victorian prices are above $300/MWh, Victoria is usually exporting to South Australia. Increasing interconnection to South Australia is not expected to help manage supply shortfall in Victoria.

In contrast, Tasmania is often supplying electricity to Victoria at full interconnector capacity at times of high Victorian prices.

There is benefit to be gained from expanding the interconnection between Victoria and Tasmania. TasNetworks is undertaking a thorough cost–benefit assessment of new interconnection via Marinus Link.

[42] It is expected that the development of Snowy 2.0 will have a notable impact, but this will largely replace the dispatchable capacity from Liddell power station.

3.1.1 New South Wales summary

New South Wales electricity is predominantly supplied by black coal: 78% of its 2018 energy consumption was supplied by black-coal-fired generation. Liddell power station, which represents 19% of New South Wales's coal capacity, is forecast to retire in 2022[43]. By 2035, just 14% of New South Wales's existing coal fleet is projected to be in operation – even without accounting for early closure due to economic, technical or environmental factors.

New South Wales is a strong importer; a net 9% of its 2018 electricity needs came from interstate. In the context of rapid retirements of most of its energy fleet over coming decades, New South Wales faces a considerable challenge just to manage its own electricity needs, particularly its needs for flexible dispatchable capacity. Initiatives such as Snowy 2.0 and the WaterNSW pumped hydro roadmap will be critical for New South Wales to manage its own energy transition. The structural challenge New South Wales is facing could further limit its ability to provide support to Victoria during a system security event or high price periods.

3.1.2 South Australia summary

South Australia's electricity sector substantially benefits from interconnection with Victoria. South Australia has developed a strong renewable energy portfolio and at times more than 100% of its local load is produced by non-synchronous generation (wind/solar/battery). Interconnection facilitates exports from South Australia during times of excess and imports during times of scarcity.

Analysis shows that the flow between Victoria and South Australia is strongly driven by the relative availability of renewable energy generation in South Australia, not by price in Victoria[44]. Figure 13 shows that when South Australia's variable renewable energy generation is high, South Australia is typically exporting to Victoria, whereas when South Australia's variable renewable energy generation is low, South Australia is typically importing.

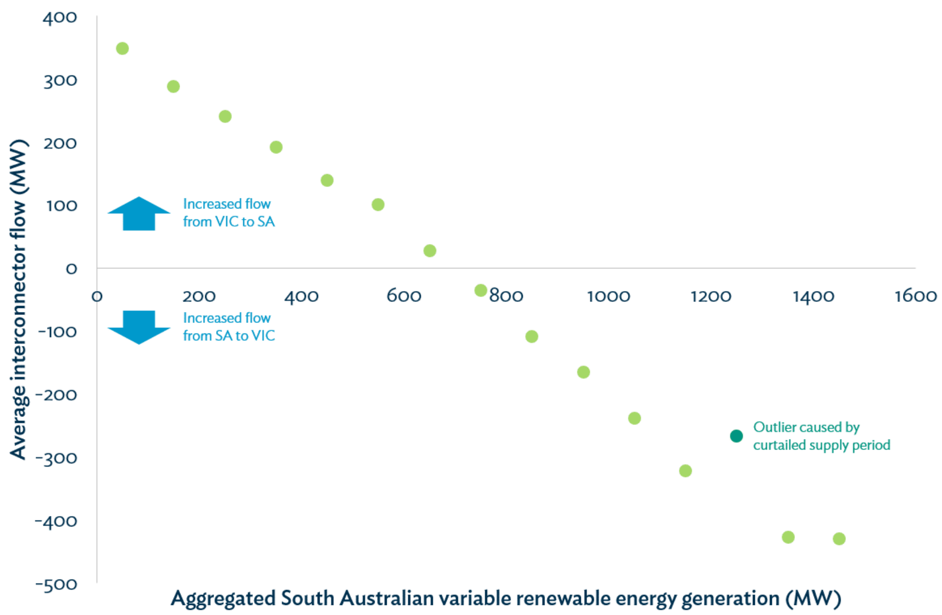


Figure 13. Average interconnection flows between Victoria and South Australia plotted against variable renewable energy generation in South Australia (2017–18)

[43] Based on AEMO's generation information page, accessed 2019: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

[44] Analysis of data from AEMO's Market Management System: http://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Data/Market-Management-System-MMS

Solar is highly correlated across the NEM, and wind in South Australia is highly correlated with wind in Victoria (see section 3.4.2). Highly correlated variable renewable energy means that when Victoria is producing strongly, South Australia will normally be looking to export to Victoria and when Victorian supply is scarce, South Australia will normally be looking to import from Victoria. Victoria would gain limited benefit from further interconnection with South Australia.

While there may be limited value in additional interconnection between South Australia and Victoria, the proposed interconnector between South Australia and New South Wales has been assessed to have net benefit[45]. Resource sharing between these regions would reduce South Australian gas generation at times of low variable renewable energy output, increase opportunities for variable renewable energy export, support South Australia's security of supply and further mesh the NEM.

3.1.3 Tasmania summary

Tasmania's energy mix is distinct from the rest of the NEM; the majority of electricity comes from hydropower generation – a flexible source of supply. The Tasmanian power system is capacity-rich, although at times it can be energy-constrained (this is further expanded in section 3.2).

Tasmania's annual maximum demand occurs in winter rather than summer – the reverse is true for every other region. This means that Tasmanian assets are well-placed to assist when hot temperatures in Victoria result in high demand and may challenge Victoria's electricity supply options.

Tasmania also has valuable options to expand its supply portfolio. Due to the differences in the generation mix in both regions, these developments would be largely complementary to Victoria's plans.

Tasmania has been recognised as having highly competitive pumped hydro opportunities[46] and is currently assessing the viability of over 2500 MW of new pumped hydro opportunities that could be developed at very competitive costs due to excellent topography and integration with Tasmania's existing hydroelectric system[47].

Tasmania also has strong wind resources that are more complementary with Victorian wind generation than any other interconnected region (this is further expanded in section 3.4).

Tasmania's strengths and challenges are complementary to those in Victoria and the rest of the NEM, increasing the value of further interconnection.

[45] ElectraNet, 2018, *Interconnection with NSW to deliver customer savings* (accessed 2019): https://www.electranet.com.au/interconnection-with-nsw-to-deliver-customer-savings/

[46] AEMO, 2019, *2019 Input and Assumptions workbook*: https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation#archive

[47] Hydro Tasmania, April 2018, *Tasmanian pumped hydro in Australia's future electricity market: Concept study knowledge sharing report* https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/pumped-hydro-knowledge-sharing-report.pdf

Resilience to climate change

A common question regarding the *Battery of the Nation* initiative is whether climate change may challenge Tasmania's ability to deliver electricity when it is most needed. Hydropower generators around the world have published research on how the inflow patterns will vary with climate change. Some of these variations are significant, yet these studies primarily show the consequence of hotter temperatures resulting in earlier snow melt. Hydro Tasmania has very little reliance on snow for storage and the climate change impacts relate more to rainfall patterns.

Climate change impacts are complex to predict and rainfall is one of the most challenging aspects to model. 'Climate Futures for Tasmania'[48] and 'Climate Change in Australia'[49] both project that winter rainfalls could increase and summer rainfalls could decrease – although substantial uncertainty remains. At least in the short term, natural variability is expected to have a stronger signal than any projected changes. The Bureau of Meteorology continues to work in this area to increase confidence in the projections.

Regardless of potential climate change impacts on rainfall patterns, the *Battery of the Nation* initiative is inherently resilient to climate risk. Pumped hydro opportunities recirculate water. They are not a net drain on the resource and will still be able to effectively deliver as required. The opportunities being explored through *Battery of the Nation* also utilise a high 'head' (change in elevation) which minimises the water storage required and will have minimal impact on the existing hydro system. In fact, for Tasmania, *Battery of the Nation* will provide access to new sources of generation, both locally and from Victoria, reducing reliance on rainfall for energy security.

3.1.4 Potential for congestion relief

Victoria has strong ambitions for development of renewable energy. In recent years, some developments have congested transmission lines resulting in high marginal loss factors and curtailments. Congestion occurs when an element of the network reaches its nominal capacity, limiting its ability to carry more electricity. This technical limit must not be exceeded and other parts of the network must adjust to compensate.

Congestion can occur within a region and between regions, and reflects an inefficiency in the market (although sufficient transmission to remove all congestion is unlikely to be commercially sound). New transmission can be used to relieve congestion depending on the actual connection points and the characteristics of the generation/load mixes being connected.

Depending on the final connection locations[50], interconnection between Tasmania and Victoria could potentially relieve congestion issues in Victoria, allowing deferral of transmission upgrades. For example, connection into the Geelong area may relieve constraints in Western Victoria. When Victorian variable renewable energy generation is high, it is likely that it would be economical for long-duration pumped hydro to consume the excess and relieve the constraint. When Victorian variable renewable energy generation is low, the transmission through to Victorian load centres is underutilised and this is the time when *Battery of the Nation* could supply.

Similarly, connection near Tyabb could access a rapidly growing load centre. The ability to deliver power into that load centre may relieve future constraints.

[48] More information can be found on the Climate Futures for Tasmania website: http://acecrc.org.au/climate-futures-for-tasmania/

[49] More information can be found on the Climate Change in Australia website: https://www.climatechangeinaustralia.gov.au/en/

[50] The *Initial Feasibility Report* for Marinus Link presented that the indicative favourable routes would connect to the Victorian power grid in the Latrobe Valley: https://projectmarinus.tasnetworks.com.au/initial-feasibility-report/

3.2 Latent capacity

Hydro Tasmania is the largest contributor of renewable energy in the NEM. Hydro Tasmania is also the largest contributor of flexible generation in the NEM, although its contribution to the NEM is limited through constrained interconnection, reducing competition in Victoria. Hydro Tasmania generates ~40% of the flexible supply in the NEM, shown in Figure 14.

The *Unlocking Tasmania's Energy Capacity*[51] report demonstrated that there is already around 400 MW of latent hydro capacity in Tasmania. Further interconnection will unlock this potential and make the capacity available to Victoria at little or no additional cost. A further 340 MW could be developed at minimal cost.

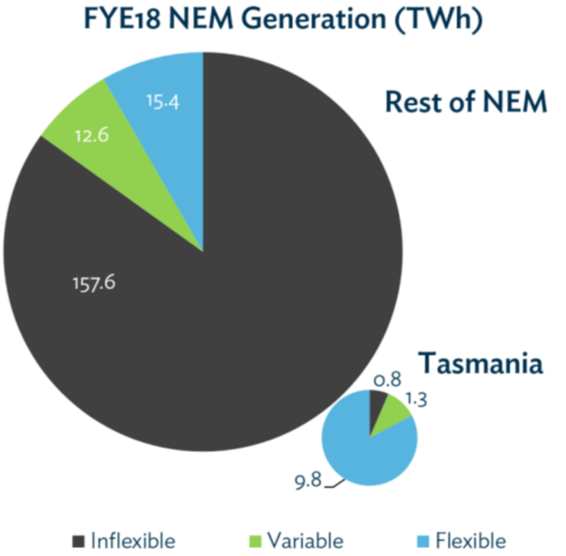


Figure 14. Contrasting (energy) generation mix in Tasmania against the other regions in the NEM

These opportunities are low cost and low risk, but have not been pursued as yet because the limited existing interconnection does not necessitate additional capacity. This is a clear example where removing existing constraints, and thus increasing the utilisation of existing assets, is a low-cost option for providing additional generation capacity.

Hydro Tasmania's current assets, including 54 major dams and 30 hydropower stations, can be operated to retain water when energy is plentiful and then deliver strongly when energy is scarcer, powering Tasmania and Victoria when needed. At present, this latent capacity is not exposed to the broader NEM due to constrained transmission. Constraints of this type are well understood to be a form of economic inefficiency, and lifting those constraints will lead to better outcomes for both regions. If both regions can better access low-cost supply[52], customers will benefit.

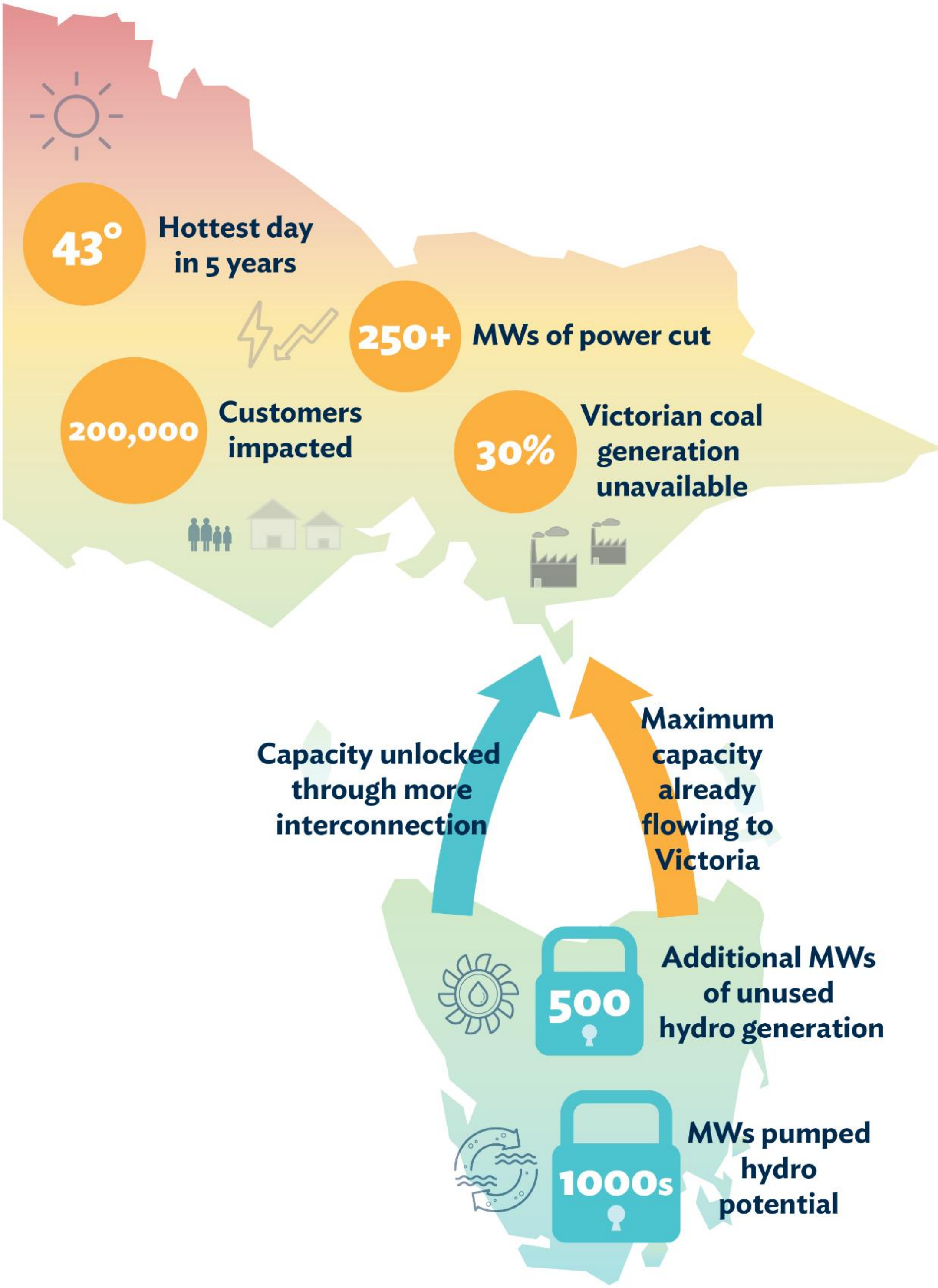
A case study of the 2019 heatwave in Victoria

In January 2019, there was a significant heatwave in Victoria causing high demand at a time when the coal generators had substantially reduced availability. On 24 and 25 January, AEMO directed over 250 MW of load shedding for several hours each day[53]. On the 24th, this was achieved through load reductions at a large smelter, whereas on the 25th, this was effected through rolling involuntary load shedding of a total of 200 000 customers.

Victorian customers lost power to their homes and businesses due to insufficient supply, yet more than 500 MW of Tasmanian hydropower was available to the market but not able to be supplied due to insufficient interconnection[54]. Additionally, there was at least 150 MW of hydro generators on planned outage, as well as 308 MW of gas plant not in use on these days. With better access to market for additional capacity, Tasmania's generation assets could have been managed differently, and the available capacity could have potentially been even higher.

[51] Hydro Tasmania, December 2018, *Unlocking Tasmania's energy capacity*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/unlocking-tasmania's-energy-capacity_december-2018.pdf
[52] Solar can be supplied from Victoria to Tasmania and hydro can be supplied from Tasmania to Victoria.
[53] AER, March 2019, *AER reports on high wholesale electricity prices in Victoria and South Australia on 24 and 25 January 2019*: https://www.aer.gov.au/communication/aer-reports-on-high-wholesale-electricity-prices-in-victoria-and-south-australia-on-24-and-25-january-2019
[54] Based on the availability of unused generation during periods where Victoria needed to shed load and brown-out customers over the two days.

January 2019 heatwave



Fully utilising latent capacity provides strong financial benefits by avoiding unnecessary investment. Better utilising the latent capacity in hydropower generation with long storage capability also increases reliability and sustainability.

Across the NEM, electricity consumption is higher during summer months while Tasmania's peak demand occurs during winter; thus, a natural efficiency can be gained from cross-regional resource sharing. The value of several TWhs of conventional hydropower storage is indispensable for securing a reliable supply during sustained periods of limited output from variable renewable energy.

3.3 Sustained flexible capacity

As the power system transforms, there will be a need for increased flexible capacity, especially for sustained flexible capacity. Victoria will need access to sustained flexible capacity to drive down prices through competition (section 1.1), and maintain a reliable supply (section 1.2). Victoria will also benefit from long-duration storage, both conventional and pumped hydro, to provide customers for its development objectives (section 1.3). *Battery of the Nation* leverages existing and modernised conventional hydropower, cost-effective new pumped hydro and complementary wind resources to deliver flexible sustained capacity to the NEM.

3.3.1 Filling the gaps – supplying while energy is scarce

In today's power system, supply challenges are mainly associated with short-duration events caused by extreme heat and/or asset failures. Over time, this is expected to transition to longer duration events (detailed in section 1.2.4). The power system must maintain the supply–demand balance at all times. The emerging challenges will be supplying during (reasonably common) periods of wind and solar scarcity. *Battery of the Nation* offers cost-effective options which can flexibly supply electricity for extended periods and help manage these emerging challenges.

The *Battery of the Nation* initiative has produced a range of reports and papers that detail options to expand Hydro Tasmania's current capabilities. There are strong pumped hydro opportunities that leverage Tasmania's existing hydropower system and highly suitable topography to deliver low-cost pumped hydro projects with significant optionality. Thousands of MWs of opportunities consisting of individual projects up to 800 MW have been identified from a list of 14 sites[55].

[55] Hydro Tasmania, April 2018, *Tasmanian pumped hydro in Australia's future electricity market: Concept study knowledge sharing report:* https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/pumped-hydro-knowledge-sharing-report.pdf

The development of Tasmania's large potential for pumped hydro energy storage can be seen as part of the next stage of resource sharing between Tasmanian and Victoria. These opportunities can be reconfigured at the design stage to deliver the optimal storage duration, by varying the power station MW capacity connected to a given storage opportunity.

There are also extensive existing conventional hydropower generators with storage durations ranging from a few hours to over a year which can provide long-term sustained capacity to complement new assets[56]. Some of the existing assets are also attractive options for repurposing to better suit the requirements of the future power system[57].

3.3.2 A customer for plentiful generation

Battery of the Nation offers sustained flexible capacity through substantial hydropower storage capability: both conventional and pumped hydro. The nature of energy storage indicates a finite resource where decisions must be made about the best time to supply. The corollary to that is also recognising the best times to store – either actively through a pump or passively through simply holding back water. The decision to store creates a space for other supply options – a customer. Without a customer, there will be natural limits to variable renewable energy development since the excess generation cannot be valued (detailed in section 1.3). Effective utilisation of excess energy is one of the key benefits of pumped hydro storage. The solar resource in Victoria is significantly better than in Tasmania and *Battery of the Nation* is a potential customer (consumer) of solar generation, see section 3.4.

Storage also has the potential to provide additional financial and commercial services to variable renewable energy generators. During times of excess generation, the spot price could be zero (or even negative) for extended periods of time. This creates risk for generators, both in terms of long-term commercial viability, but also for maintaining a positive cash-flow. To manage revenue risk, solar generators could establish commercial arrangements to stabilise their revenue. Storage providers, such as pumped hydro, are well placed to effectively manage the risks of a highly volatile market. There are many possible arrangements that could protect the solar generator from low prices and give the storage provider access to low-cost energy to be stored and used at more opportune times – resulting in lower prices for customers.

3.4 Complementary variable renewable resources

Battery of the Nation will unlock some of the nation's least-cost variable renewable energy resources. This will put downward pressure on prices in Victoria. In combination with the other assets that make up *Battery of the Nation*, the variable renewable energy will also be part of a firm supply of energy managed through a variety of power stations and storages with synergistic characteristics.

Given the quality of the wind resource unlocked through *Battery of the Nation*, there may be a concern that this could reduce the opportunity for development in Victoria; however, the resources that are unlocked are likely to complement Victoria's development objectives. Tasmanian and Victorian options for renewable energy development add diversity and reduce cost in both regions.

[56] Hydro Tasmania, December 2018, *Unlocking Tasmania's energy capacity*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/unlocking-tasmania's-energy-capacity_december-2018.pdf

[57] Hydro Tasmania, 2018, *Hydro system improvement*: https://www.hydro.com.au/clean-energy/battery-of-the-nation/hydro-system-improvement

3.4.1 Solar

Australia has some of the richest solar resources in the world. Northern Victoria is competitive in the NEM using current development costs. AEMO's ISP assumptions book[58] for the 2019 modelling indicates that there are sites in New South Wales and South Australia that are slightly more competitive, although these would be unlikely to displace Victorian development once losses are included. Since solar is expected to be the cheapest new electrical energy source, it is likely that most states will build out their solar resource to the extent that it remains commercially viable. Through *Battery of the Nation*, Victoria can leverage its strong solar resource, substantially better than Tasmania's, as an export commodity. Interconnection will expose Victorian solar development to more opportunity through Tasmanian customers. Moreover, substantial long-duration pumped storage will have the ability to be a customer for low-cost renewable electricity, unlocking more solar opportunities in Victoria.

3.4.2 Wind

It is likely that there will be substantial competition for wind development across the NEM. Tasmania was found to have the NEM's highest wind capacity factors, and therefore lowest cost of wind. This represents a strong opportunity to leverage the cheapest wind resource in the nation to reduce costs. However, wind has much greater diversity than solar and development in one region will not entirely displace the same amount of development in another. Due to this diversity, higher capacity factors and longer generation periods, wind energy will require less 'firming' investment than would be required by solar.

Modelling wind is notoriously difficult, yet there is sufficient wind generation in the southern states to use actual generation data[59]. Data from the past two years (2017–18) was used to develop the correlations shown in Table 7.

Table 7. Correlations of normalised half-hourly wind generation between Victoria and interconnected regions (2017–18)

Wind correlation	SA	NSW	TAS
VIC	62%	51%	43%

Considering regions connected to Victoria, Tasmania has the lowest correlation for wind generation. It is still positively correlated, meaning that when it is windy in Victoria, it is more likely to be windy in Tasmania too, but Tasmanian development will be more complementary than the other states with Victorian development options. This diversity provides opportunities on both sides of the link. Table 8 shows a range of operating states. Tasmanian wind generation is the least correlated state in the NEM.

The additional Tasmanian wind generation unlocked by *Battery of the Nation* is also beneficial for Victoria in terms of timing. Tasmanian wind farms often produce significant output in the later afternoon and early evening. This is in contrast to most wind farms around the NEM whose output diminishes at that time[60]. Typically, as demand is increasing, wind generation is decreasing across the NEM. Tasmanian wind generation counters this trend; reducing the need for fast response and flexible generation and will ultimately help to manage prices.

[58] Australian Energy Market Operator February, 2019, *2019 Input and Assumptions workbook*: https://www.aemo.com.au/Stakeholder-Consultation/Consultations/2019-Planning-and-Forecasting-Consultation#archive

[59] The past two years were used to obtain a sufficiently long period to be considered representative, while also trying to ensure sufficient assets were operational to provide a realistic representation of the correlations between regions.

[60] Hydro Tasmania, 2018, *Analysis of the Future State National Electricity Market*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/future-state-nem-analysis-full-report.pdf

Table 8. Wind generation and potential market responses across Victoria and Tasmania

		Victorian wind generation		
		High	Medium	Low
Tasmanian wind generation	High	**Surplus across regions** Low prices Export to other NEM regions (SA & NSW) Reserve water for later hydropower generation Store water in pumped hydro	**Limited energy transfer** Low prices Possible export to other regions (SA & NSW) Reserve water in some hydropower storages Possibly store in pumped hydro	**Tasmanian export to Victoria** Medium prices Reserve water in some hydropower storages Possibly store in pumped hydro
	Medium	**Potential Victorian export to Tasmania** Low prices Reserve water in most hydropower storages Possibly store in pumped hydro	**Limited energy transfer** Medium prices Reserve water in some hydropower storages	**Limited energy transfer** Medium-high prices Reserve water in high-value hydropower storages
	Low	**Victorian export to Tasmania** Medium prices Reserve water in some hydropower storages	**Potential Victorian export to Tasmania** Medium-high prices Reserve water in high-value hydropower storages	**Scarcity: Tasmanian flexible generation required** Medium-high prices Expend water stored through other operations

3.4.3 Increasing the development opportunity for Victoria

A critical accompaniment to least-cost modelling is the requirement for revenue sufficiency, particularly for critical, but less frequently used, assets.

The Council of Australian Governments (COAG) Energy Council has recently tasked the Energy Security Board (ESB) with developing advice on a revised market framework to support investment in reliability for the energy transformation[61]. This market redesign is intended to be ready for the mid-2020s and the review and recommendations are expected to be completed by the end of 2020.

In the absence of finalised market reforms, it is reasonable to assume that the capital forecasts remain valid and the bulk energy sources must be economical. On this basis, simplified internal modelling was undertaken to check the maximum amount of wind and solar that could be built in Victoria under certain scenarios while maintaining revenue sufficiency.

Methodology

A simple dispatch model considering the existing generation mix and limited interconnection[62] was used to establish a market price for Victoria. Technologies were bid in at fixed prices. Conventional hydropower was the exception, varying its bids in order to manage the limited water supply. Hydropower was split into three categories to represent short-duration hydro with limited flexibility (reasonably low price), medium-duration hydro with better controllability (reasonably high price) and long-duration hydro which can generate into the best prices from across the year (prices equivalent to the short-run cost of open cycle gas generation).

Existing generation mix (coal-dominant) and no further interconnection

In this scenario, approximately another 300 MW of wind/solar would be commercially viable in Victoria without excessive reliance on exporting to other regions. Heavy reliance on other regions (outside *Battery of the Nation*) is unlikely to be effective. The other regions also have development ambitions; solar is unlikely to be diverse between regions and Victorian wind has a high correlation with South Australia and also a fairly high correlation with New South Wales.

Retirement of a coal-fired power station and no further interconnection

This scenario looks at the opportunity for wind and solar development in Victoria with the retirement of Yallourn (projected to be the next coal-fired generator to retire in Victoria) and no further interconnection. Around 3450 MW of additional wind and solar generation could be developed and still be commercially viable (considering revenue sufficiency[63]). This relies heavily on gas to manage the supply–demand balance and the economics of selling excess generation to neighbouring regions at very low cost. This could potentially be construed as subsidising other regions with variable renewable energy at below the cost of production.

Retirement of a coal-fired power station with further interconnection

This scenario looks at the opportunity for wind and solar development in Victoria with the retirement of Yallourn and 1200 MW of further interconnection with Tasmania. Under this scenario, the Victorian and Tasmanian regions are essentially considered to be one region. Around 4000 MW of additional wind and solar generation could be developed in Victoria and still be commercially viable (considering revenue sufficiency). This modelling relies heavily on Tasmanian hydropower to manage the supply–demand balance, including a 600 MW pumped

[61] COAG Energy Council – Energy Security Board, March 2019, http://www.coagenergycouncil.gov.au/publications/post-2025-market-design-national-electricity-market-nem

[62] The interconnection was assumed to be with similar markets and limited opportunity to export/import due to low diversity between regions.

[63] These are calculated based on AEMO's widely-consulted assumptions developed for the 2019 Integrated System Plan.

hydro with 24 hours of storage. It has a reduced reliance on export at low prices to New South Wales and South Australia. In this scenario, an additional 1150 MW of Tasmanian wind generation is also developed. Because of the diversity of demand, wind resources and the utilisation of rich hydropower resources and storage, both Victoria and Tasmania can develop new renewable energy assets whilst remaining commercially viable and reducing power prices.

Comparing Victorian development options in the two retirement scenarios, in the second scenario (with further interconnection) wind development is slightly more limited (250 MW less), but solar development is much greater (800 MW more). The net outcome is a 550 MW increase for Victorian variable renewable energy development.

3.5 Cost-effective outcomes

Underpinning the *Battery of the Nation* concept are strong competitive advantages that produce a cost-effective outcome for the NEM. To date, no integrated solution has been proposed that can deliver the same range of options and services, let alone at a comparable price.

When it comes to providing flexible, sustained capacity, the *Battery of the Nation* suite of opportunities is more cost-effective than the leading alternatives: batteries, gas and mainland pumped hydro[64].

Better efficiency: sharing complementary demand profiles and latent capacity

Battery of the Nation joins two regions that have different supply and demand characteristics. At times, it will be possible to better manage imbalances simply through sharing resources. *Battery of the Nation* also leverages the latent capacity in existing hydropower assets, converting from baseload provision to higher value firming services. There are also significant opportunities to cost-effectively modernise these assets that have not been developed to date due to limited access to the market[65].

Interconnection between regions with different supply and demand characteristics also brings its own benefits.

New flexible supply options

The future power system is going to need new sources of flexible supply and *Battery of the Nation* can unlock some of the most cost-effective options in the NEM. Gas prices are expected to stay high, limiting the cost-effectiveness of gas-fired generation[66]. Electrochemical battery storage is projected to have value in the future NEM, yet remains expensive for sustaining

[64] Hydro Tasmania, 2018, *Analysis of the Future State National Electricity Market*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/future-state-nem-analysis-full-report.pdf
[65] Hydro Tasmania, December 2018, *Unlocking Tasmania's energy capacity*: https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/unlocking-tasmania's-energy-capacity_december-2018.pdf
[66] AEMO, July 2018, *Integrated System Plan – For the National Electricity Market:* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2018/Integrated-System-Plan-2018_final.pdf

supply over periods longer than two hours. AEMO's 2018 ISP projected that pumped hydro will play a critical role in the development of the future NEM because of its ability to provide the longer duration storage that will be needed.

The *Battery of the Nation* pumped hydro opportunities make use of existing hydropower infrastructure along with ideal topography to deliver some of the most competitive pumped hydro energy storage opportunities in the NEM. The most promising projects[67] make use of steep and tall hills to improve cost-efficiencies and store more energy per unit of water.

Pumped hydro efficiency

As the details of pumped hydro developments become clearer, differences between options are emerging. To date, the comparisons between potential pumped hydro projects have mainly been on the basis of capital expenditure. Some of the more sophisticated comparisons have also included valuation, or at least differentiation, of storage duration. There has been little comparison of operating costs or efficiency. Traditionally, supply-side technologies have had fairly standard operating costs and so this has had little influence on choices between competing projects. Pumped hydro is different, and has four major capital cost drivers:

- civil works for the storages
- civil works for the conveyances (pipes and tunnels) and powerhouse
- electrical/mechanical works for the generators/pumps
- miscellaneous supporting infrastructure (e.g. roads, transmission, etc.)

The civil works for the conveyances can be a very large contributor to cost and this offers an opportunity for optimisation. The challenge is that the optimisation plays off capital investment today against operational cost in the future and is highly site-dependent. A smaller diameter tunnel will cost less, but will also be less efficient. The cyclic efficiency of pumped hydro can be estimated with the following equation:

$$\frac{(Machine\ Efficiency)^{\wedge}2}{(1 + Head\ Loss\ \%)^{\wedge}2}$$

Both the capital cost and the head loss are directly related to the length of the conveyance and the diameter of the conveyance. Shorter conveyances will naturally cost less, all else being equal. This means that a shorter conveyance can have a larger diameter and deliver lower head loss while still managing the capital costs. Assuming a fixed machine efficiency of 92%, head losses ranging from 1% to 10% would result in cyclic efficiencies ranging from 83% to 70%. This can change the amount of energy consumed each year by almost 20%.

This additional energy must come from other sources, most likely additional wind and solar generators. Assuming the pumped hydro supplies 25% of the time, the difference between the highest and lowest efficiencies could require an additional $0.25 million to be spent on wind or solar for every MW of installed pumped hydro. Short, steep conveyances have substantial value in minimising the total cost of the system.

Most Battery of the Nation pumped hydro storages have efficiencies in the low 80s – and are therefore some of the most efficient options in the NEM.

[67] More information can be found on Hydro Tasmania's website: https://www.hydro.com.au/clean-energy/battery-of-the-nation/pumped-hydro

New variable renewable energy

In addition to cost-effective firming, the *Battery of the Nation* proposition unlocks complementary wind resources that will provide value to the NEM. Tasmanian wind has a high capacity factor, effectively reducing the cost per MWh. It also has lower correlation with other wind generation across the NEM, reducing the amount of flexible generation required and optimising the total cost of the system.

3.5.1 Increased competition for flexible supply options

Victoria needs competition for cost-effective supply of energy, particularly at times where energy is scarce and flexible generation is required. Victoria presently has little competition for flexible supply and this is driving up prices. *Battery of the Nation* can introduce low-cost, flexible capacity into the market to increase competition in the spot market, particularly at times when variable renewable energy is scarce throughout the NEM.

The ACCC noted that introducing supply not owned by the ‘big three’ retailers is likely to encourage the availability of contracts to smaller retailers.

More access to flexible generation through Battery of the Nation could increase market liquidity, particularly for firming contracts, and increase retail competition. It will ultimately be good for customers in Victoria, and also more broadly across the NEM.

3.5.2 Scalable options for parallel development

Along with a range of possible future wind farm developments, there are multiple possibilities for pumped hydro storage systems ranging in size up to hundreds of MWs of supply with storage capacities ranging from a few hours to several days. More options allow for multiple development pathways and better risk management.

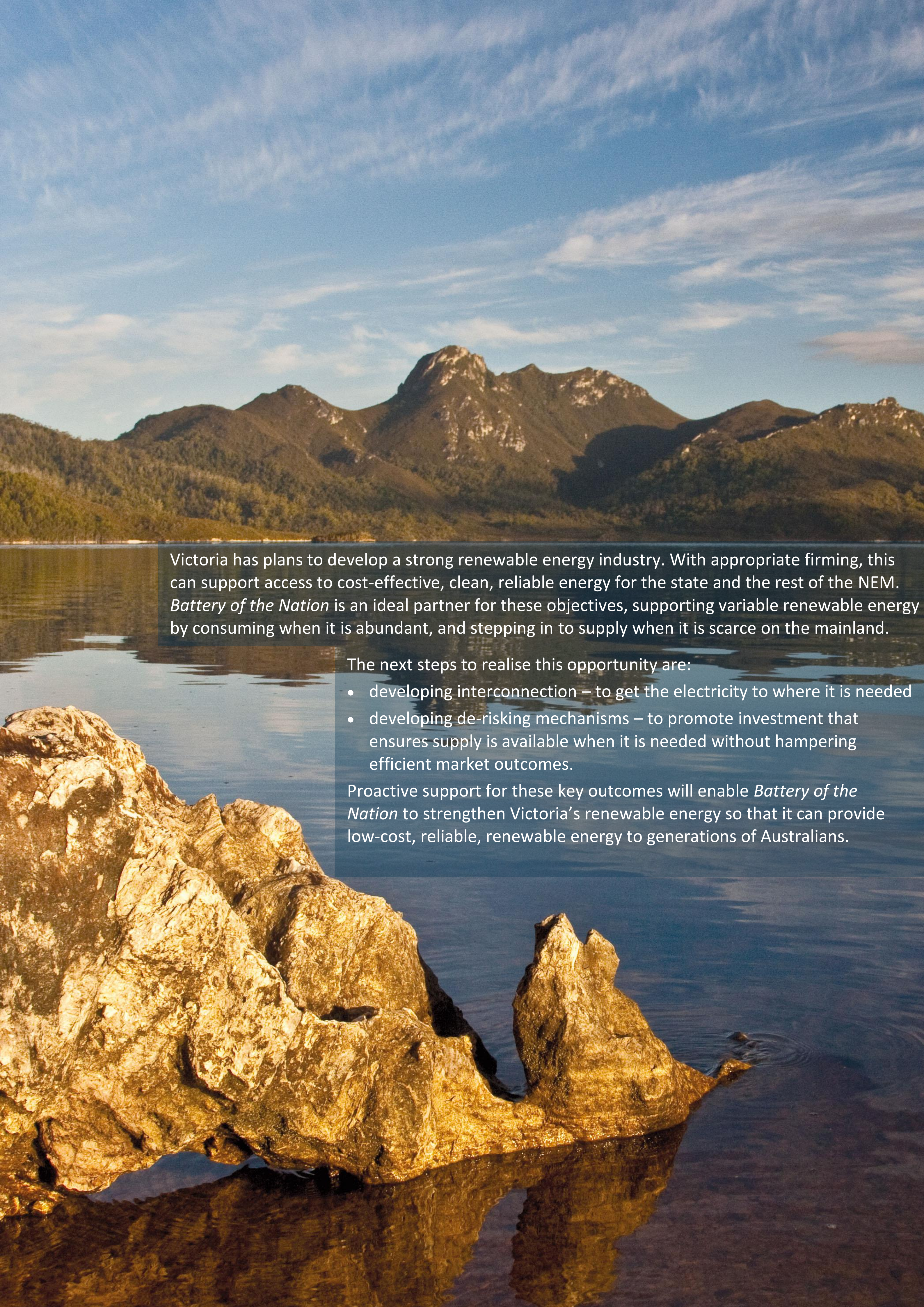
The timing of coal-fired power station retirements which will drive the transformation of the NEM is uncertain. Victoria needs optionality to help manage a smooth transition.

In a system undergoing a major transformation that is expected to continue for decades, the best options are those that are flexible and able to respond to how the market actually evolves over time. With a range of development options available, the *Battery of the Nation* initiative is well-placed to provide what the market needs, regardless of what the future needs may be.

3.5.3 Lower risk of delivery

Pumped storage projects in Tasmania not only achieve lower costs, but also carry a lower delivery risk. Reusing existing storages and other supporting infrastructure, such as roads and transmission lines, simplifies the projects and removes some potential obstacles that can add more time, cost and complications. Moreover, existing legal agreements such as Hydro Tasmania’s water licence increase certainty compared with other locations.

Hydro Tasmania has more than a century of experience in developing, operating and managing hydropower projects in Australia while managing environmental and social outcomes. This experience and a clear understanding of the importance of social licence provides strong foundations for introducing new pumped hydro developments into already existing hydropower schemes.



Victoria has plans to develop a strong renewable energy industry. With appropriate firming, this can support access to cost-effective, clean, reliable energy for the state and the rest of the NEM. *Battery of the Nation* is an ideal partner for these objectives, supporting variable renewable energy by consuming when it is abundant, and stepping in to supply when it is scarce on the mainland.

The next steps to realise this opportunity are:

- developing interconnection – to get the electricity to where it is needed
- developing de-risking mechanisms – to promote investment that ensures supply is available when it is needed without hampering efficient market outcomes.

Proactive support for these key outcomes will enable *Battery of the Nation* to strengthen Victoria's renewable energy so that it can provide low-cost, reliable, renewable energy to generations of Australians.