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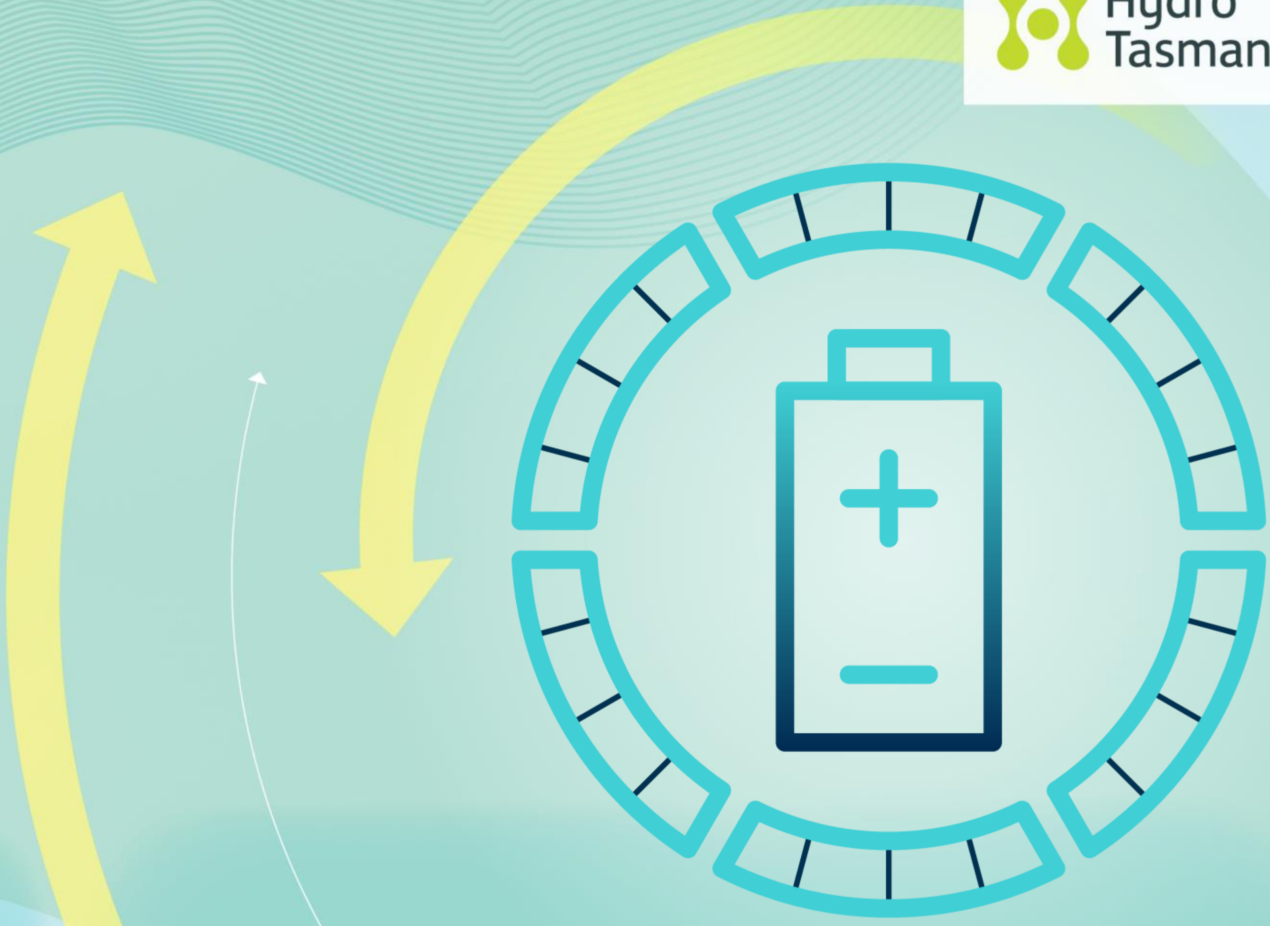

Battery of the Nation

Unlocking investment in storage for a reliable future NEM

November 2019

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Authors: Pippa Williams, Cameron Potter, Prajit Parameswar

Email: batteryofthenation@hydro.com.au

Important Notice

Foreword

The National Electricity Market (NEM) is changing rapidly. The future NEM is expected to have different characteristics to today and there is a need for timely investment in strategically valuable projects to achieve a smooth transition.

A range of studies show that variable renewable energy such as wind and solar are likely to be the lowest cost energy source in the future NEM, and that energy storage (both electrochemical batteries and pumped hydro) is likely to be critical in the managing the variability of these sources. Storage can utilise the energy generated during times of plenty and provide it back at times of relative scarcity. However, the various services that storage provides to the NEM are not all remunerated.

The Energy Security Board is reviewing the present market structures and will propose future market structures that incentivise strategically important assets for the future NEM. However, investment decisions are needed now to ensure solutions are available in advance of a market shortfall – particularly if generator retirements occur earlier than expected.

Timely investment will help to minimise future reliability problems and price issues for customers. De-risking of strategic opportunities can give investors confidence to bring forward necessary investments. If this de-risking adopts a minimalist approach, this can minimise the risk of distortions or any unnecessary costs to energy customers.

Tasmania's *Battery of the Nation* initiative presents a strong opportunity for strategic investment for a smooth and least-cost transition to the future NEM. With the right investment signals, this suite of developments could contribute strongly to a cost-effective, reliable electricity system.

Steve Davy

Hydro Tasmania Chief Executive Officer

November 2019

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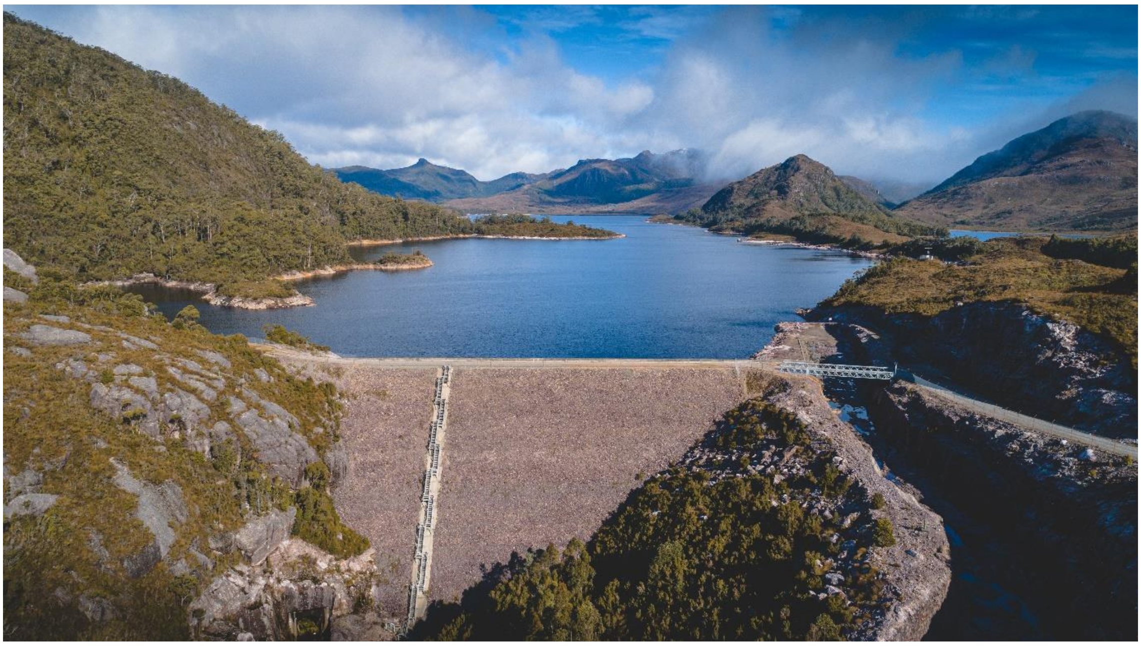
Executive Summary

The National Electricity Market (NEM) is undergoing unprecedented change through the rapid transformation of its generation mix. This transition is bringing significant uncertainty and risk to both generators and customers. The Australian Energy Market Operator (AEMO) has identified that thousands of megawatts of pumped hydro and battery energy storage will be needed as part of a least-cost generation mix in the future NEM. However, current market structures do not adequately value the flexibility and price stabilisation that storage brings. While there are a number of processes currently underway to identify solutions to address these challenges, there is a risk that these will be too late to incentivise investment in new generation in time for the retirement of aging incumbent generation.

Investment decisions are needed now to ensure solutions are available in advance of a market shortfall – particularly in case generator retirements occur earlier than expected. Timely investment will help to minimise future reliability concerns and price issues for customers. The energy industry requires sufficient price signals, and confidence of a commercial return, to invest in the dispatchable, flexible capacity that will underpin Australia's smooth transition to the future NEM at the lowest possible cost.

This paper explores various markets, services and contract options to highlight the investment risks and opportunities for energy storage[1]. Most of today's revenue opportunities are designed to efficiently optimise bulk energy supply while maintaining enough capacity to be able to meet peak demand – albeit at high short-term cost. However, the power system is becoming more variable; flexible and dispatchable supply is being needed far more often. High short-term costs are driving a greater proportion of the total system cost and timely targeted investment has the opportunity to reduce prices to the customer. The Grattan Institute found that supply constraints caused by the retirement of uncompetitive coal generators have caused a $6B increase in the total annual cost of electricity in the NEM since 2015[2].



[1] For the purpose of this paper, the term 'storage' is defined as energy-limited dispatchable supply, including pumped hydro energy storage and batteries. Many of the benefits identified apply equally to conventional hydropower which does store energy as well, although it does not consume energy from the power system to supply back at a later time.

[2] The Grattan Institute 2019, *Mostly Working: Australia's wholesale electricity market*. https://grattan.edu.au/wp-content/uploads/2018/06/905-Mostly-working.pdf

Wholesale electricity prices are at record highs, and yet investment in cost-effective flexible capacity (such as storage and upgrades to conventional hydropower) that can help manage these prices has been slow and difficult to commit. Much of the price signal is driven by scarcity, and is therefore inherently unpredictable over long time periods. This makes it difficult to invest in long-life, long-lead-time assets. Market restructures are required to provide confidence to invest in the assets that are valuable to the market, without need for external influence or support.

Market redesign is currently underway[3], but investment must be progressed in the meantime to address scarcity and prevent further shortfalls. This paper proposes, that in the interim, de-risking of strategic assets is required to progress immediate investments to help manage reliability and prices in the market. A de-risking mechanism is suggested that operates on the principle of a 'safety net', only seeking a minimum level of revenue certainty for the proposed projects, to give proponents the confidence to invest. By adopting a minimalist approach, no payments would be triggered if the future market adequately rewards the services provided. This minimises the risk of creating market distortions or any unnecessary costs to energy customers.

A comparison case study is also provided, analysing options to produce and deliver a firm supply of energy in the future NEM. Tasmania's *Battery of the Nation* initiative, supported by the Australian Renewable Energy Agency (ARENA), is highlighted as offering a unique opportunity to provide more flexible, reliable dispatchable renewable energy, particularly in terms of both cost-effective long duration pumped hydro and repurposing the existing hydropower assets through greater interconnection.

1. Revenue for energy storage in the NEM

In its 2018 Integrated System Plan (ISP)[4], AEMO forecast that up to 17 000 MW of pumped hydro and utility-scale battery storage will need to be developed as part of a least-cost transition of the electricity sector. This is almost 20 times the current level of storage in the NEM[5].

Storage brings significant benefit to the NEM and reduces the total cost of the system. It stabilises volatility, increases reliability and decreases price during times of relative scarcity. Storage can also capture potential energy spill and thus better utilise the low-cost variable renewable energy that is becoming an increasingly large influence on the market.

The ISP has identified utility-scale storage as a significant part of a least-cost NEM supply mix of the future. Storage provides benefits which flow throughout the entire NEM, and moderates extreme prices for all market participants. In order to invest, storage developers need to be confident that they will derive sufficient value from the benefits delivered for a commercial return.

[3] Council of Australian Governments Energy Council Energy Security Board 2019, *Post 2025 Market Design for the National Electricity Market (NEM)*. http://coagenergycouncil.gov.au/publications/post-2025-market-design-national-electricity-market-nem

[4] Australian Energy Market Operator 2018, *Integrated System Plan for the National Electricity Market*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2018-Integrated-System-Plan

[5] Australian Energy Market Operator 2019, *Generation Information*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information

Many of the benefits and income streams of energy storage, particularly pumped hydro energy storage, also apply to conventional hydropower. Although this discussion will focus on storage, most of the concepts in terms of benefits, revenue opportunities and investment context are broadly applicable to upgrades to conventional hydropower as well.

1.1 Spot market revenue opportunities in the existing market

The NEM is an 'energy-only' market with five minute dispatch[6]. This means that generators submit bids to provide electricity, and every five minutes the lowest bids are accepted which will meet demand while ensuring acceptable electricity flows. This is called the electricity spot market. Storage assets can obtain revenue from spot markets for both energy and frequency control ancillary services in the NEM.

All generators are paid the spot price. The spot price is set by the price of the highest accepted bid in the region or the cost of importing from a neighbouring region. This is intended to incentivise generators to bid their true short-run marginal cost. Although very few generators in the NEM are operated in isolation – most are part of a larger portfolio. As such, decisions made about the management and operation of a single generator in the NEM cannot be predicted by simply considering its short-run marginal cost with reference to the spot price. Nevertheless, the spot price underpins the vast majority of NEM interactions, and therefore is a useful starting point from which to consider these interactions.

The spot price is inherently volatile as it seeks to reflect the short-term supply-demand balance and incentivise generator response. However, this volatility can pose significant financial risk to spot market participants. Generators face a risk of low prices impacting earnings, while retailers face a risk that prices rise, reducing margins or even causing a net loss. Market participants generally manage their exposure to volatility by entering financial contracts that lock in firm prices for the electricity they intend to produce or buy in the future[7].

1.1.1 Spot market arbitrage

Storage operators can purchase electricity from the spot market when it is relatively abundant (low price), store it, and then sell the electricity when supply is relatively scarce (high price). This process of buying and selling is called 'arbitrage' and is exposed to merchant risk from the volatility of the spot market. It is possible to manage the financial risks through contracts, and examples of this are covered below.

Capturing and repurposing surplus energy

Storage benefits the grid by capturing surplus energy that would otherwise be wasted. High winds, sunny conditions over solar projects, high inflows into short duration hydro storages and inflexible generation unable to respond to changes in the supply-demand balance can all cause 'energy spill'. Storage can capture this energy and shift it to a time when it is needed. This can save fuel costs, save emissions and result in a more efficient NEM.

The introduction of storage can underpin the introduction of new low-cost energy sources and so minimise the total cost of the system. The key to obtaining value from this service is having sufficient storage duration to capture as much of the spilled energy as possible and then shift it to a time when energy is required.

6 This is supported by co-optimised frequency control ancillary services, including regulation and contingency markets. There are also a number of contracted ancillary services, such as black start. Remuneration is currently settled on a 30-minute basis, but this will shortly transition to 5 minute settlement to align with the dispatch interval.

7 The Australian Energy Regulator's *State of the Energy Market* reports contain a more detailed overview of these concepts. The 2009 version is particularly clear: https://www.aer.gov.au/system/files/Chapter%203%20%20Electricity%20financial%20markets%202009.pdf Every annual report since 2007 is published here: https://www.aer.gov.au/publications/state-of-the-energy-market-reports

1.1.2 Spot market ancillary services

Apart from buying and selling electricity in the spot market, there are a number of other services which are sold in parallel markets or via direct contracts. Storage operators have an opportunity to provide some of these services to diversify their revenue. In fact, real experience from the market shows that this might provide a very large proportion of the revenue for certain kinds of storage. Analysis from Energy Synapse[8] showed that Hornsdale Power Reserve made $3.4m in *market* revenue in September 2019 (excluding contracted services) and almost 95% of that revenue came from ancillary services.

The Frequency Control Ancillary Services (FCAS) markets remunerate the ability to quickly ramp generation up or down. Regulation FCAS refers to continuously balancing supply and demand over periods of less than the five minute dispatch period. Contingency FCAS refers to committing to respond within specified timeframes when there is an abnormal imbalance between supply and demand, for example when a generator, major power line or large load trips off.

1.2 Contract market revenue opportunities in the existing market

While all energy in the NEM passes through the spot market, market participants often choose to manage their risk and increase their certainty through contracts. Wholesale electricity contracts can be exchange-traded futures for standardised agreements. They can also be 'over-the-counter' contracts, which are often bilateral and confidential. Contracts present a potential revenue opportunity for storage. However, selling contracts also holds risk. Failure to deliver a contracted service can be costly.

It is possible for electricity contracts to be sold in the NEM on a purely financial basis with no generation backing, although mostly the contracts manage financial exposure with physical backing from supply sources. This means that sellers of contracts make sure they are able to generate when spot prices are high, so that they receive these spot prices and are able to use them to pay their contract liabilities.

All supply options have characteristics that need to be considered when signing contracts, to appropriately manage risk. Like all supply options, storage needs to consider speed of response, start-up time, transmission availability. Storage has the additional need to consider its duration[9]; limited energy in storage constrains the ability of the storage to supply for extended periods.

Operators of storages with a shorter duration (e.g. an electrochemical battery with one or two hours' storage) may carry increased risk due to the increasing likelihood that high price periods in the market could extend over many hours.

8 Energy Synapse 2019, *Hornsdale Power Reserve revenue from energy arbitrage and FCAS in September 2019*. https://reneweconomy.com.au/wp-content/uploads/2019/10/HPR-Sep19-revenue.png

9 Storage duration is the maximum time for which a storage can supply at full output before recharging.

Storage levels during a sustained period of energy shortage

Variable renewable energy is playing an increasingly important role in the NEM and helping manage this variability will be a key role for storage. Solar photovoltaic panels are expected to provide the cheapest energy, although there is little diversity and no supply at night. Wind will therefore play a major role too, yet the wind has periods of sustained low production across the entire NEM. Storages of varying durations will perform differently during periods of sustained energy shortage. Figure 1 illustrates this concept with a simplified example of the operation of rechargeable storages (e.g. pumped hydro and batteries) during a wind drought.

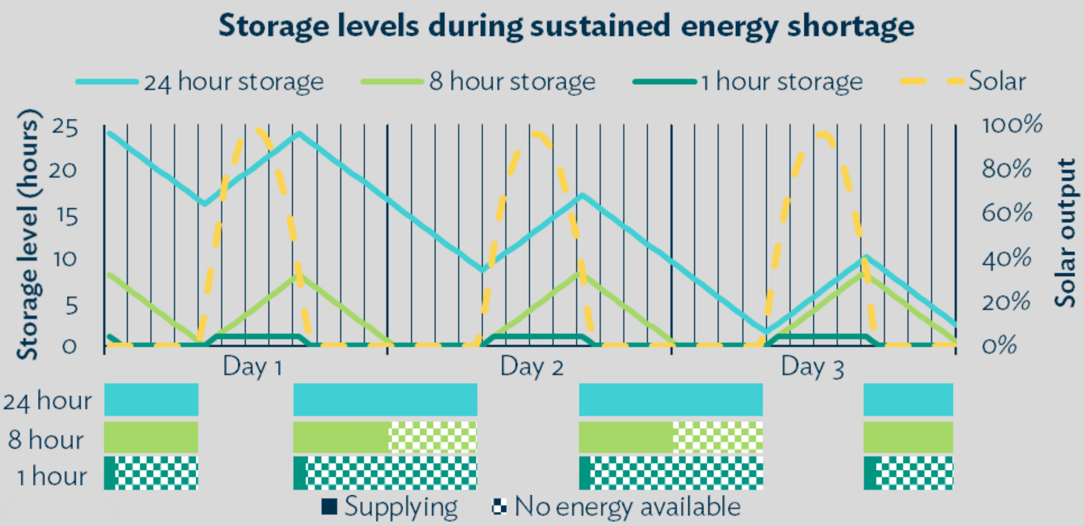


Figure 1. Simplified example of supply from various duration storages during a wind drought

In the NEM, spot price variation is generally a reflection of supply-demand balance. As energy becomes more abundant, spot prices reduce; similarly, when energy is scarce, prices will be high. In the future NEM, high prices are increasingly likely to occur when wind and solar output are low. In this simple example of a wind drought, solar power is available during the daytime resulting in prices that could be low enough to allow the storage operators to recharge. During the night, there is no solar power available (and little wind during the wind drought), so the prices are high and the storage operator wants to supply. This example includes three storages, with 24 hours, 8 hours and 1 hour storage duration respectively. All the storages happen to be full at the start of the wind drought.

The 24 hour storage supplies when prices are high (wind and solar are scarce), and partially recharges during the day, when solar brings the spot price down. It recharges for just over eight hours each day, and therefore still has some energy left in storage at the end of three days.

The eight hour storage supplies for the first eight hours and recharges fully during the day. However, for the subsequent days, it can only supply for eight hours of the low-solar period.

The one hour storage can only supply for an hour, and then has to wait for the following day for prices to drop enough to recharge.

Of course, in reality, the prices would vary somewhat within these periods, and storage operators will try to pick the highest price times to supply. However, if prices are high over a sustained period, this will still mean times of high price when a short duration storage cannot supply – either because their storage is empty, or because they are holding the storage full in anticipation of even higher prices at a later time.

Furthermore, storage operators do not have perfect foresight. If high price periods are unforeseen (for example, if exacerbated by an unforeseen transmission or generation outage), shorter duration storages may well have no energy available when it is most needed and prices are very high. Analysis[10] has shown that storages with longer durations are much more robust to forecast uncertainty than those with shorter durations. Storages with a 1 hour duration were found to lose value at around four times the rate of storages with 24 hours' duration.

All storage operators, even conventional hydro[11], are exposed to these risks, yet the shorter the duration, the more significant the risk. A storage operator must consider these risks when selling or pricing a contract.

A range of other contract types are traded in the NEM, such as floor contracts, peak and off-peak contracts, and variable-volume contracts. However, for simplicity this paper primarily considers the two most common contract types: swaps and caps. Ancillary service contracts and firming contracts are also included as they are particularly relevant for potential storage revenue models.

1.2.1 Swap contracts

A storage operator / developer may choose to manage exposure to the volatility of the spot market by entering into a swap contract. Swap contracts take the form of an agreement between two parties for an effective price for a given volume of generation. If the spot market price is higher than the agreed price, then the seller (usually a generator) will pay the buyer (usually a consumer or retailer) enough to cover the difference between the swap contract price and the price of energy sourced from the spot market. Conversely, if the spot market price is lower than the agreed price, then the buyer will provide the seller the difference via a direct payment. This helps market participants to manage financial risk and operate to set budgets. Note that these financial commitments (to pay the price difference for a given volume) remains whether or not the electricity is actually generated or used.

Depending on the nature of the load, a storage that enters into a swap contract will usually be exposed to 'asset-backed risk'. Energy storage must consume energy from the power system, normally for at least as long as it intends to supply. Therefore, there would be times where a storage could not back a swap contract with physical supply. It is possible that this could be complemented with energy from the storage operator's own portfolio or contracted other means. Alternatively, the operator could choose to be exposed to the spot market when their storage is not supplying, taking the risk that spot prices will be below the swap price a sufficient proportion of the time and that the storage could capture the highest price periods, protecting the operator from the highest periods of payout.

1.2.2 Cap contracts

A storage operator / developer may choose to trade opportunity for high revenue periods for a more stable revenue stream by entering into a cap contract. Cap contracts are essentially insurance products. The seller (usually a generator) is paid the 'cap price' throughout the year as a form of premium. The buyer (usually a consumer or retailer) receives certainty that they will not have to pay more than the 'strike price'[12]. During times when the spot price rises

[10] Hydro Tasmania 2019, *Understanding realistic operation of storages without perfect foresight.* https://www.hydro.com.au/clean-energy/battery-of-the-nation/future-state

[11] Conventional hydro generation also has limited energy in storage – yet the challenges are usually addressed during design. The incoming energy is provided by rainfall into their catchments, meaning that there is less choice about when to fill. Equally, the storages tend to be much larger and in some cases, have enough storage to be classed as "inter-annual" – with the ability to effectively shift energy between years. The other major difference between conventional hydro and pumped hydro or batteries is that the storage can replenish (and often do) at the same time that the hydropower generator is operating.

[12] In the NEM, cap contracts are assumed to be for a strike price of $300/MWh unless explicitly stated otherwise.

above the strike price, the contract essentially operates as a one-way swap contract. The market prices could be extremely high and the seller is responsible for making this payment during the highest price periods. This becomes significant risk to the seller and this is why sellers of cap contracts usually cover these contracts with available generation capacity, ensuring that they supply into prices higher than the strike price, at least to the volume of their cap contracts, to avoid paying the high spot prices.

Cap contracts assist in managing the risk of the most volatile part of the price curve. Although spot prices are normally less than the usual cap contract strike price ($300/MWh), the spot price may reach the market price cap (>$14,000/MWh) for short periods. This is called 'scarcity pricing' and is intended to send a signal to the market for investment in new capacity when the supply-demand balance becomes tight.

The nature of scarcity pricing is that small variations in supply or demand can result in very large differences in spot market price. This presents significant cost risks to energy retailers and consumers, and significant income uncertainty to generators. Cap contracts could be used by storage operators to obtain income certainty, and can significantly contribute to the business case of a storage project.

Finally, if the storage is unable to supply into all the high price events, this could represent a substantial financial risk. For example, during the Victorian heatwave on the 24th of January 2019, a two hour storage may have been able to cover the first two hours of high prices, but would then have been exposed to the remaining 4.5 hours before the spot price reduced. In such a situation, if the storage provider had sold a cap contract backed only by the two hour storage, they could have been exposed to over $60,000 per MW of cap contract in a single day. These risks would need to be carefully considered before a storage operator / developer chose to sell a cap contract, particularly if their storage only had a duration of a few hours.

1.2.3 Contracted ancillary services

The most commonly considered ancillary services are those traded on the frequency control spot markets, yet there are also services that can earn revenue through direct contracts.

System Restart Ancillary Services (SRAS)

System Restart Ancillary Service (SRAS), or 'black start' service, is a contractual arrangement between a generator and AEMO (the system operator). Most utility-scale generation requires some electricity from the grid to start up. If all generation is lost (a very rare occurrence), black start capability allows the power system to be restored by starting specifically enabled generators. Hydropower, both conventional and pumped hydro, are well-placed to provide black start services if suitably incentivised. In recent years, it has also been successfully demonstrated that battery-based energy storage can achieve this as well.

Network Support and Control Ancillary Services (NSCAS)

Network Support and Control Ancillary Services (NSCAS) are non-market ancillary services that may be procured by AEMO or transmission network service providers to maintain power system security and reliability, and to maintain or increase the power transfer capability of the transmission network. For example, this mechanism can be used to remunerate market participants for services that help manage the voltage of the power system or fault level requirements. It is possible that storage, particularly synchronous generation or pumping, could be remunerated via this mechanism, provided there is a system security issue that needed to be addressed. At this stage, these arrangements are considered on an as-needs basis and are typically localised in nature, therefore cannot necessarily be factored into a business case.

1.2.4 Firming contracts

New products are likely to emerge in the NEM to address the changing market characteristics with increasing penetration of variable renewable energy. Firming contracts are an example of these new products and would aim to complement wind and solar by providing coverage when variable renewable energy output is low or zero. At the right price, firming contracts may be attractive to a wide range of buyers, for example the contracts could provide a consumer access to stable energy costs or a renewable energy developer the ability to on-sell swap contracts from variable energy sources.

Being a relatively new product offering, there is relatively little experience with these contracts, although examples are starting to appear in the market. For example:

- In 2018, TFS Green announced a solar firming contract[13], which appears to target customers looking to manage their electricity costs via a solar power purchase agreement (PPA). The firming contract provides a stable price for the times when solar is not abundant.
- At a similar time, AGL announced it was making available a “Wind Product Firming Unit”[14]. This contract type targeted wind operators, offering energy supply in situations where wind output was less than forecast when prices were high.
- In July 2019, ERM power announced a solar firming product, claiming that the first trade in this product was finalised “within days” of release[15].

A storage operator / developer may consider selling a firming contract to improve revenue certainty and mitigate financial risk regarding spot market uncertainty. Similarly to a cap contract, backing the contract with the operation of physical plant may mitigate the risk of holding a financial contract linked to spot market prices, but the ability of the storage to sustain supply to fully cover the contract produces asset-backed risk. Given the nature of the bilateral contracts, it is plausible that additional conditions may be included and the agreement simply needs to be attractive to both parties.

1.3 Storage benefits not captured in existing wholesale market design

In addition to the range of ancillary services currently traded in the NEM, there are a number of services which are provided to the power system but not remunerated. Typically, this is because the predominant generation technologies in today’s NEM provide these services inherently. A range of balancing services across different time scales will be required, shown in Figure 2. As synchronous generators get displaced there may be a requirement for more physical inertia. Fast frequency response (FFR), also sometimes called ‘synthetic inertia’, will provide some measure of resilience as many of the major inertia providing stations retire. Solar will need firming over several hours and wind will need firming for periods up to days.

Figure 2. Spectrum of supply-demand balancing services required across different time scales to physically firm the power system, highlighting emerging requirements

[13] Giles Parkinson 2018, *New solar “firming” contracts to boost corporate demand for big solar farms*, Renew Economy. https://reneweconomy.com.au/new-solar-firming-contracts-boost-corporate-demand-big-solar-farms-33187/

[14] Richard Wrightson 2018, *Making wind energy dispatchable energy*, AGL. https://thehub.agl.com.au/articles/2018/04/making-wind-energy-dispatchable-energy

[15] ERM Power 2019, *New Generation of Financial Products Launched to Support Renewables*. https://ermpower.com.au/media-release/new-generation-of-financial-products-launched-to-support-renewables/

1.3.1 Inertia

Inertia makes the power system more robust to sudden changes in the balance between supply and demand. Inertia suppresses and slows frequency deviations such that automatic FCAS controls can respond and return the system to balance. Until recently, most generators were synchronised to the grid and provided inertia as a by-product of energy supply. However, many new renewable energy sources, such as wind, solar photovoltaic panels and electrochemical storage, do not provide inertia to the system as they are asynchronously connected to the grid. As the penetration of asynchronous supply increases, the amount of inertia in the system is decreasing and there is the potential to fall below minimum levels required for a stable and secure power system.

AEMO has recently assessed that without Hydro Tasmania's voluntary operation of synchronous condensers, there would be a shortfall of inertia in Tasmania[16]. Steps will be taken to contract system strength and inertia services from synchronous supply options in Tasmania.

As penetration of asynchronous supply becomes more widespread through the NEM, it is possible that inertia will become a remunerated market service[17] in the future to incentivise synchronous supply.

Synchronous generators, such as conventional hydropower and fixed speed pumped hydro energy storage, provide inertia both when pumping and generating. They also inherently support grid voltage in the case of a system fault. While all generators are required to have some voltage support capability, the inherent response of synchronous generation/storage is particularly beneficial. With the right incentives, synchronous storage technologies could also be configured to operate as a synchronous condenser and thus provide inertia even when not generating.

16 AEMO, Nov 2019, *Notices of shortfalls in inertia and fault level (system strength)*. https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/System-Security-Market-Frameworks-Review/2019/Notice-of-Inertia-Fault-Level-Shortfalls-Tasmania-Nov-2019.pdf

17 A number of rule changes have already been proposed regarding this market requirement.

1.3.2 Fast frequency response (FFR)

While asynchronous technologies are decoupled from the frequency of the power system and do not supply physical inertia, they may be able to provide faster frequency response than existing technologies. However, this is not inherent and therefore will only be designed for if there is incentive to do so.

1.3.3 Price volatility suppression

Energy arbitrage will also suppress price volatility, and yet variation in price is required for arbitrage to be economic. Reduced volatility from storages will decrease financial risk in the market and therefore increase investor confidence. This can have significant benefit to the market and yet there is no mechanism to remunerate storage operators for this value that they bring. Typically, longer duration storages will be able to operate over longer periods of time and achieve higher utilisation. This will cause more price volatility suppression.

1.3.4 Transmission and distribution deferral

Storage also has the potential to be able to defer transmission and distribution upgrades, by reducing peak utilisation. The nature of this opportunity is very site specific and is expected to mainly be applicable to smaller capacity storages scaled to suit the existing transmission or distribution line; nevertheless, it is a benefit that some storage opportunities can provide that is difficult to monetise in the existing market.

1.3.5 Flexibility and dispatchability

Supply options that can rapidly respond to market opportunity – either by rapidly ramping up or down or starting up quickly and on demand – provide options to better manage the power system. While these services are not explicitly identified in Figure 2, they contribute to the ability to achieve other income streams and ensure that the power system can be securely and reliably operated. If these services are needed, then it is plausible that some kind of remuneration could be devised to incentivise suitable assets into the market to ensure resource adequacy at all times.

Five minute settlement is expected to reward faster response assets

Today, the Australian Energy Market Operator optimises and dispatches generation (and market load) on a five-minute basis. However, due to information constraints when the NEM was formed, payment is made based on the average of five-minute prices and outputs over a 30-minute period.

Presently, if the spot price spikes early during a settlement period, there is still time for a supplier to respond and be dispatched – covering some of their financial exposure. Five-minute settlement[18], which is due to be implemented in 2022, brings the payment timeframe in line with the dispatch timeframe and reduces the opportunity to respond with slower technology.

Selling cap contracts backed by technologies which have moderate start-up times (for example conventional open cycle gas turbines) will become more risky, as the likelihood of being able to respond to a high price within five minutes is much lower than the likelihood of being able to respond within 30 minutes. Generators and storage which can start within five minutes (such as conventional and pumped hydro, aero-derivative gas generators, and electrochemical batteries) are more robust to this particular risk.

18 For further discussion, see: Australian Energy Market Operator 2018, *What is 5 minute settlement?* www.aemo.com.au/-/media/Files/Electricity/NEM/5MS/Program-Information/2018/5MS-factsheet.pdf

1.4 Storage revenue opportunities under potential future wholesale market designs

The Council of Australian Governments (COAG) Energy Council's Energy Security Board (ESB) is currently developing advice on a "long-term, fit-for-purpose market framework to support reliability that could apply from the mid-2020s.[19]" The process is in early stages, but it is possible to comment on potential outcomes, particularly with reference to the drivers for the review. The fact that the request was framed as developing advice to "support reliability" indicates that the market reform will at least *consider* options to support flexibility, dispatchability and capacity beyond the existing energy-only market.

AEMO's 2018 ISP[20] identified a least-cost future energy mix where low-cost new energy (wind and solar) is complemented by a substantial increase in energy storage. While the existing market is proving sufficient to incentivise investment in wind and solar, work is still required to ensure that sufficient cost-effective dispatchable capacity investment is incentivised.

This reform is intended to support the investments required to deliver reliability in the NEM. However, while the reforms are being considered, the uncertainty associated with this process increases the risks investors must manage. Given Australia's high dependence on its fleet of aging coal assets, and the lack of recent investment in flexible dispatchable generation capacity, investments made in the next 1-5 years will be critical to maintaining electricity supply and minimising electricity costs in coming years. Lack of flexible supply options is already driving costs up and causing energy shortages in certain markets[21]. Thus options to reduce the risk of investing while the market is redesigned will be critical to ensuring the necessary investment takes place.

2. Risk asymmetry of investment

2.1 Risks to customers

The energy trilemma represents the challenge of balancing affordability, reliability and environmental sustainability to achieve the kind of modern power system that customers expect. The trilemma presents a challenging set of goals to attain and the trilemma will not be adequately addressed with short-term planning or responses. Customers are at risk of a less affordable, less reliable and less sustainable power system if the right investment signals are not provided.

In its 2018 ISP[22] AEMO forecast that up to 17 000 MW of utility-scale storage will need to be developed to achieve a least-cost transition of the electricity sector. Much of this could be needed sooner if the predicted retirement of coal-fired generation occurs faster than expected – or if Australia's energy system achieves greater electrification.

19 Council of Australian Governments Energy Council Energy Security Board 2019, *Post 2025 Market Design for the National Electricity Market (NEM)*. http://coagenergycouncil.gov.au/publications/post-2025-market-design-national-electricity-market-nem

20 Australian Energy Market Operator 2018, *Integrated System Plan for the National Electricity Market*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2018-Integrated-System-Plan

21 Hydro Tasmania 2019, *How Battery of the Nation can contribute to Victoria's energy needs and objectives*. https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/how-botn-can-contribute-to-victoria-august-2019.pdf?sfvrsn=de409a28_4

22 Australian Energy Market Operator 2018, Integrated System Plan for the National Electricity Market. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2018-Integrated-System-Plan

AEMO has also forecast a looming reliability gap for Victoria. This gap has the potential to escalate if increasing penetration of variable renewable energy continues to displace inflexible baseload generators without being supported by flexible and dispatchable supply options.

The generation mix in the NEM is heavily reliant on highly uncertain assumptions. Figure 3 illustrates the assumptions from the 2018 ISP regarding retirement dates for coal plant – predominantly based on a 50 year technical life. Updated 2019 AEMO assumptions[23], based on advice from coal plant operators, have shifted this projection. However, based on current and historic information from AEMO's generation information page[24], the average age for coal plant retirements in the NEM in the last decade is 43 years. If each station retired when its youngest unit turned 43 years old, the NEM would have almost 10 GW less coal capacity than anticipated by 2030.

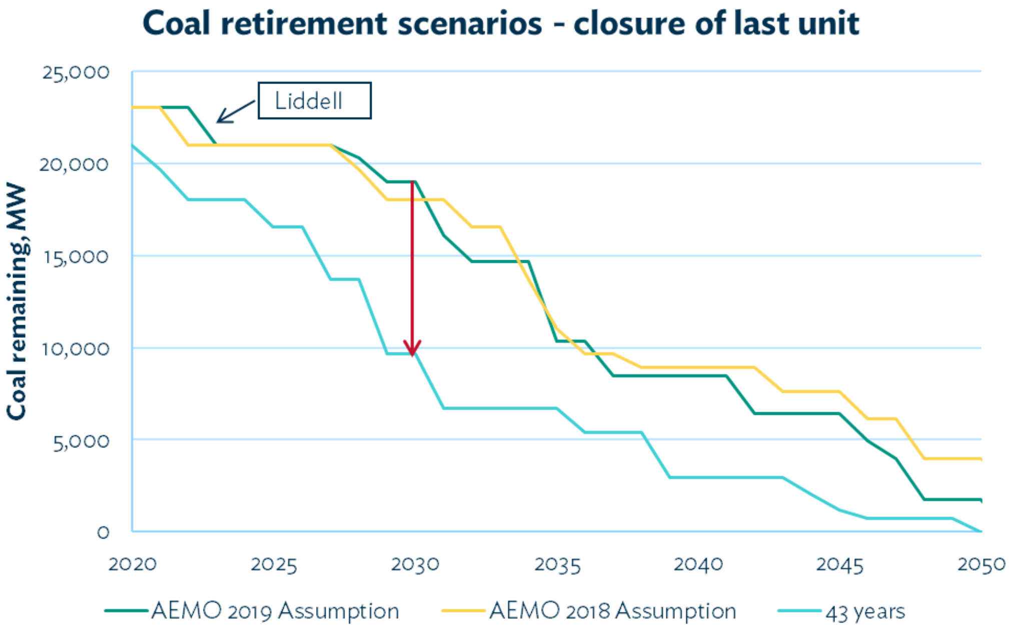


Figure 3. ISP coal retirement scenarios, compared with a scenario where stations retire when they reach the average age of recent coal retirements in the NEM

While it would be ideal to adopt a 'just in time' approach for developing energy storage and flexible generation capacity, this requires perfect foresight of changes in the power system and a perfect market to incentivise the investment. In reality, a 'just in time' approach usually becomes a 'delayed response to consistently high prices caused by scarcity' approach. This could result in higher prices, lower reliability, and potentially a less environmentally sustainable outcome too. Without proactive signals to support long-term investment planning, the responses may be prioritised by speed of commissioning rather than affordability, reliability or sustainability. Prioritising speed of commissioning, rather than long-term cost-effectiveness, could result in a structural economic inefficiency in the electricity industry. Inefficiencies in the electricity industry could degrade the performance of Australia's wider economy.

[23] Australian Energy Market Operator 2019, *2019 Input and Assumptions workbook*. Accessed October 2019 https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies

[24] Australian Energy Market Operator 2019, *Generation Information*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Generation-information,

Customers bear the brunt of these risks to the trilemma. The power system is already becoming more variable; flexible and dispatchable supply is being needed far more often. The Grattan Institute[25] found that supply constraints caused by the retirement of uncompetitive coal generators have caused a $6B increase in the annual price of electricity in the NEM since 2015. High short-term costs are driving a greater proportion of the total system cost and timely targeted investment has the opportunity to reduce prices to the customer.

2.2 Risks to developers

The primary driver of developers and investors is to make a suitable return on investment[26] – without this, the development or investment is not sustainable. When developing new projects, the costs and the revenues need to be carefully considered, as well as the impact on existing assets.

Least-cost modelling, such as AEMO's ISP modelling, shows that substantial energy storage is required to minimise the cost of replacing retiring coal-fired generation. However, while it is clear that storage would provide substantial value to the market, it is unclear how much of that value will be captured by the storage provider. Most of today's revenue opportunities are designed to efficiently optimise bulk energy supply and do not fully recognise the value of storage.

Wholesale electricity prices are at record highs, substantially driven by the lack of flexible supply[27], and yet investment in cost-effective flexible capacity (such as storage and upgrades to conventional hydropower) that can help manage these prices has been slow and difficult to commit. Much of the price signal is driven by scarcity, and is therefore inherently unpredictable over long time periods.

To invest in long-life, long-lead-time assets, there needs to be clear and reliable revenue opportunities to produce a strong business case for investment. Many of the lowest-cost prospective energy storage projects have long lead times, meaning that these business decisions must be made 5-7 years before they enter the market. These factors make it difficult to finance projects, even where a clear need for development exists.

2.2.1 Financing a project

In considering the potential funding implications of any potential storage investment, thought must be given to both the potential ownership and financing options that are available. Assuming a storage project is able to operate independently and is commercially viable, there are a wide range of ownership and financing options. The particular approach would be determined by the risk and return characteristics of both the project and the project owners.

The range of potential ownership options may include (but is not limited to):

- Tolling and offtake agreements,
- Operating leases,
- Partial equity stakes,
- Joint ventures, and
- Full equity ownership.

[25] The Grattan Institute 2019, *Mostly Working: Australia's wholesale electricity market*. https://grattan.edu.au/wp-content/uploads/2018/06/905-Mostly-working.pdf

[26] Of course, both developers and investors have a wide range of priorities that must be considered. There may be a large range of reasons that a profitable opportunity is not pursued.

[27] Hydro Tasmania 2019, *How Battery of the Nation can contribute to Victoria's energy needs and objectives*. https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/how-botn-can-contribute-to-victoria-august-2019.pdf?sfvrsn=de409a28_4

The choice between these options would be determined by a trade-off between the level of control desired and the quantum of investment size. The range of potential financing options may range from bespoke project level financing such as project financing to long term publicly listed debt such as listed bonds. The choice of financing mechanism would be determined by the trade-off of the cost of the financing against the risk position created by the financing mechanism.

2.2.2 Delayed investments

This delayed investment risks leading to constrained supply-demand balance, and associated scarcity pricing that is being passed on to customers. For example, the Grattan Institute[28] noted that the total value of electricity traded in the NEM more than doubled between 2015 and 2017, and that $6 billion (60%) of this increase was attributable to supply scarcity resulting from the retirement of Hazelwood (in Victoria) and Northern (in South Australia) coal power stations.

Incumbent supply-side market participants may be incentivised to delay investment due to the revenue benefits from scarcity pricing, particularly where a potential developer has a strong existing generation portfolio. This is an issue because those with a strong existing portfolio may be best placed to develop low-cost solutions. The market power of incumbents also increases the impact of market uncertainty on new entrants. Incumbent developers will often defer investment for as long as they are able to maintain some first-mover advantage.

Market redesign is currently underway[29], but investment must be progressed in the meantime to address existing scarcity and prevent further shortfalls. Timely investment decisions will help manage the smooth transition to the future NEM.

2.3 Timely investment decisions

High prices and reliability issues are already highlighting a need for investments in the NEM. With the degree of change being projected for the NEM, proactive investments are also needed to help manage future reliability concerns and price issues for customers. The energy industry requires mechanisms that can unlock the flexible and dispatchable capacity that Australia needs to ensure the electricity is affordable.

From a customer perspective, there will be benefits in strategically managing this transition, including managing the risks of faster, or unexpected, closure of existing (coal-fired) power stations.

For example, AEMO’s July 2019 paper ‘Building power system resilience with pumped hydro

[28] The Grattan Institute 2019, *Mostly Working: Australia’s wholesale electricity market*. https://grattan.edu.au/wp-content/uploads/2018/06/905-Mostly-working.pdf

[29] Council of Australian Governments Energy Security Board 2019, *Post 2025 Market Design Issues Paper*. http://www.coagenergycouncil.gov.au/publications/post-2025-market-design-issues-paper-%E2%80%93-september-2019

energy storage'[30] included a case study which demonstrated that the risks of late investment outweigh the savings of 'just in time' investment – even if the modelled risk of early coal closure was only 20%. Given the technical, market and political uncertainties regarding coal generator life, a 20% risk of plant closing 3 years earlier than anticipated is arguably a very modest sensitivity. For example, AEMO's 2018 ISP[31] was based on the assumption that the technical life of most coal generators is 50 years. However, the average age of coal generators which have retired recently in the NEM is just 43 years. AEMO is currently undertaking further work to understand plant retirement risk factors. Substantial electrification could have similar impacts on the supply-demand balance.

3. Options to de-risk investments

The significant uncertainty and risk in the future NEM is driving the need for market mechanisms that 'de-risk' future development investment to ensure solutions are available in advance of a market shortfall. While the spot and contract markets can deliver returns to developers of flexible supply, the consequences of undersupply make it prudent to support developers to mitigate revenue risk and ensure that critical supply options enter the market in a timely fashion.

One option to incentivise timely investment is to underwrite strategic investments to help manage reliability and prices in the market. It is preferable that this operates on the principle of a 'safety net', only providing a minimum level of revenue certainty for proposed projects, to give proponents the confidence to invest. By adopting a minimalist approach, no payments would be triggered if the future market adequately rewards the services provided. This minimises the risk of creating market distortions or any unnecessary costs to energy customers.

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30 Australian Energy Market Operator (AEMO) July 2019, *Building power system resilience with pumped hydro energy storage: An Insights paper following the 2018 Integrated System Plan for the National Electricity Market*. https://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

31 Australian Energy Market Operator 2018, *Integrated System Plan for the National Electricity Market*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2018-Integrated-System-Plan

The Australian Government's *Underwriting New Generation Investments Public Consultation Paper*[32] suggested a range of underwriting approaches, including:

- **Floor price**
  - "If the floor price is triggered, the Government would then pay the project proponent the difference when the spot price is below the floor price but the project proponent would keep the gains above the floor price."
- **Contract for difference**
  - "The parties would then have a contract for difference where the Government would pay the project proponent the difference when spot price is below the strike price and the project proponent would pay the difference to the Government when the spot price is above the strike price."
- **Cap and floor (Collar) contracts**
  - "Under this mechanism, the Government would provide an effective floor price on the sale of electricity received by a proponent and cap above which the proponent would pay the difference between spot price and the cap when the spot price exceeds this cap."
- **Government loans**
  - "Under this mechanism, the Government may provide a debt at competitive rates, and receive a rate of return to offset the costs of the program."
- **Capacity payments**
  - "Under this mechanism, the Government could support the generation projects by providing capacity payments for the availability of firm or firmed generation. These generation projects would then have a decreased exposure to spot market volatility as they would receive payment whether or not they are dispatched."

The consultation paper also welcomed stakeholder views on alternative mechanisms. The advantage of the 'safety net' approach proposed in this paper is that the underwriter would only be exposed to electricity market volatility to the minimum extent necessary to ensure that timely investments in cost-effective dispatchable capacity can be made. The underwriting should not alleviate or replace the need for normal commercial arrangements. If normal commercial arrangements are unnecessary then the underwriting could be considered to have 'over-reached' in a way that is not conducive to maintaining efficient market behaviour.

By limiting the severity of downside risk for developers of flexible supply, investment could proceed based on the identified need in the market and the likelihood that market reform would deliver the required incentives for flexible supply. Helping to manage the risk for developers would increase certainty and accelerate the investment process. Increased investment confidence would also assist in alleviating the significant risks to which energy consumers are exposed, should investors fail to invest in flexible dispatchable supply to help manage the supply-demand balance in the future NEM.

To be successful, it is important that any de-risking mechanism is implemented in a timely manner and for strategically important opportunities. This ensures the right investments are made, and the clarity of investment would create certainty for other market participants looking to invest and manage their portfolios.

[32] Australian Government Department of Environment and Energy 2018, *Underwriting New Generation Investments: Public Consultation Paper*. http://www.environment.gov.au/energy/underwritingnewgeneration

4. Cost stack analysis – a *Battery of the Nation* case study

AEMO[33] has identified that the future NEM will need a portfolio of varying energy storage durations to efficiently distribute available renewable energy and support smooth operation of less flexible existing generation. While there are a range of credible opportunities for 'shallow' storage with between 1 and 8 hours' duration, there are fewer sites in the NEM suited to the development of longer duration storage[34], or 'deep' storage[35].

4.1 The Tasmanian opportunity

Tasmania's existing hydropower system, paired with topology which is perfect for pumped hydro, provides an abundance of 'deep' pumped hydro development opportunities that can cost-effectively support the NEM's transition to a system with increased wind and solar penetration. Tasmania's existing hydropower system also presents a significant opportunity to be repurposed to better suit the needs of the future NEM.

Tasmania has a significant fleet of flexible, dispatchable and low-emissions generation assets. Hydro Tasmania is Australia's largest generator of renewable energy and there is enormous potential to increase its renewable energy generation capacity. *Battery of the Nation* presents a cohesive vision for energy investments in Tasmania, providing jobs and growth in Tasmania, and delivering secure and reliable energy to the rest of the NEM in a changing energy landscape. The *Battery of the Nation* vision includes increasing interconnection with the rest of the NEM (such as the additional 1500MW of interconnection proposed as part of Project Marinus[36]), repurposing and upgrading existing hydropower, augmenting the hydropower system with new pumped hydro energy storage, and unlocking Tasmania's world-class wind resources.

If the *Battery of the Nation* vision is fully realised, eventually there could be many thousands of megawatts of new interconnection and pumped hydro capacity to support the future NEM to adapt to increasingly important variable renewable energy. Hydro Tasmania's Future State NEM analysis released in June 2018 discusses this vision in more detail[37].

When existing hydropower is combined with cost-effective, long duration storage, high-quality wind resources and additional interconnection, an integrated solution is formed which could provide significant additional dispatchable renewable energy into the NEM.

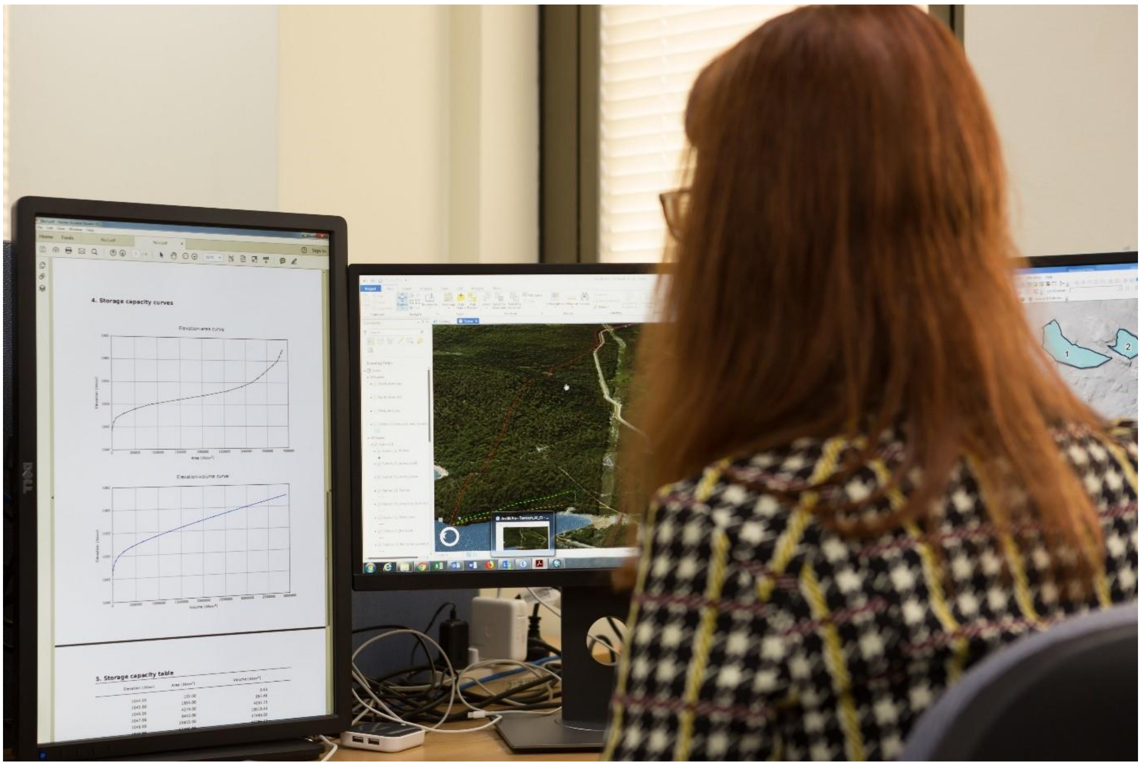
33 Australian Energy Market Operator (AEMO) July 2019, *Building power system resilience with pumped hydro energy storage: An Insights paper following the 2018 Integrated System Plan for the National Electricity Market*. https://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

34 Entura 2018, *Pumped hydro cost modelling.* https://www.aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/Inputs-Assumptions-Methodologies/2019/Report-Pumped-Hydro-Cost-Modelling.pdf

35 The Australian Energy Market Operator broadly defines "shallow" pumped hydro storages as having 6-12 hours' storage, with longer storages called "deep". Australian Energy Market Operator 2019, *Building power system resilience with pumped hydro energy storage*. https://aemo.com.au/-/media/Files/Electricity/NEM/Planning_and_Forecasting/ISP/2019/ISP-Insights---Building-power-system-resilience-with-pumped-hydro-energy-storage.pdf

36 TasNetworks 2019, *Marinus Link: Connecting Australia to low cost and reliable energy.* Accessed November 2019. https://www.marinuslink.com.au/

37 Hydro Tasmania 2018, *Battery of the Nation: Analysis of the future National Electricity Market.* https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/future-state-nem-analysis-full-report.pdf?sfvrsn=25ce928_0



4.2 Approach to the cost stack analysis

AEMO's Integrated System Plan[38] projects the need for thousands of megawatts of additional generation to be built in the NEM in coming decades. This section presents analysis that is optimised to deliver a firm supply of new energy.

In the first *Battery of the Nation* Future State NEM report[39], a comparison was developed to demonstrate the competitiveness of a variety of options for delivering a firm source of energy. The approach is based purely on cost. While price is highly variable and can be heavily influenced by financial and commercial imperatives, cost tends to be much more stable and more based on physical assets. The analysis has been performed in isolation from the other options in the energy system; so while slightly artificial, it is also a reasonable representation of a contracted load.

For this analysis, the information has been refreshed using AEMO's ISP assumptions[40], last updated in September 2019. The costs are projected for development in the late 2020s. Specific sensitivities and deviations from the assumptions are all explicitly noted.

The analysis has also been improved since the previous version as it is now optimised to deliver a shaped load rather than a flat supply. The target load profile was based on the average load profile of Victoria, scaled to be delivered by a 750 MW transmission line. This is shown in Figure 4.

38 Australian Energy Market Operator 2018, *Integrated System Plan for the National Electricity Market*. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Integrated-System-Plan/2018-Integrated-System-Plan

39 Hydro Tasmania 2018, *Battery of the Nation: Analysis of the future National Electricity Market.* https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/future-state-nem-analysis-full-report.pdf?sfvrsn=25ce928_0

40 Australian Energy Market Operator 2019, *2019 Input and Assumptions workbook*. Accessed October 2019. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies

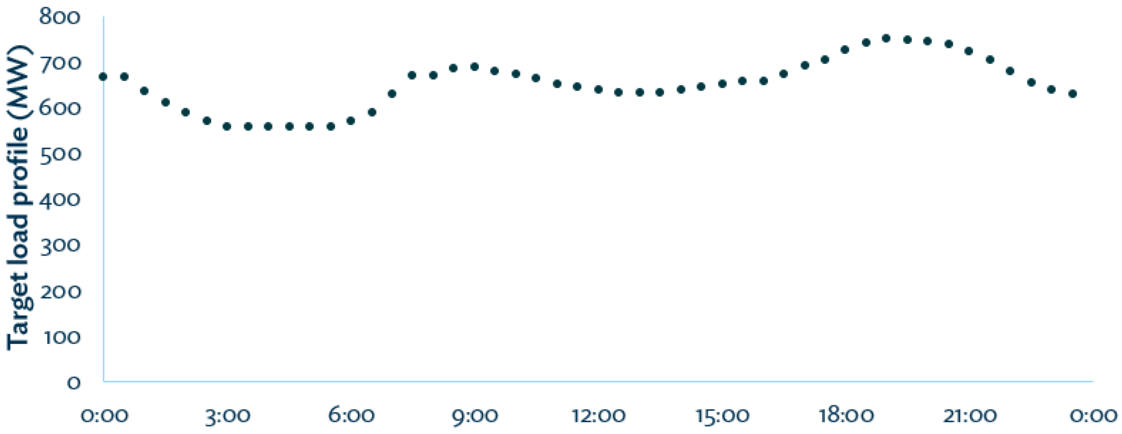


Figure 4. The targeted load shape scaled to a transmission line with a rated capacity of 750 MW

4.3 Changing assumptions change the optimal mix

The optimal generation mixes in the updated analysis had notable differences from previous analysis, due to material changes in assumptions that have changed the cost effectiveness of the energy mix.

One notable change is for the assumed battery operations. Previous assumptions included battery efficiency of 90% and the batteries operated across their full range. The 2019 AEMO assumptions book[41] assumes that the batteries only operate across 80% of their range with an efficiency of 81%. This adds a substantial impost on the cost effectiveness of battery storage from a pure energy context, particularly when their capital cost is similar to the more cost effective pumped hydro energy storage options, but the battery has to be amortised over an asset economic life of 10 years rather than 40 years.

Another significant change is that TasNetworks, which is developing the business case for further interconnection between Tasmania and Victoria through Project Marinus, is now considering the option of 2 x 750 MW cables, rather than 2 x 600 MW cables. As such, the cost stack now compares electricity provision in 750 MW blocks.

4.4 Comparison of options

The options were considered across four broad categories, all considered on a cost-only basis:

- Gas redevelopment (no new transmission costs) – but no new variable renewable energy resources,
- Combined supply options located in Victoria, including a new transmission line to access high quality wind and solar,
- Cost-optimised mix for the first cable of Marinus Link (750 MW), using surplus wind and solar to displace existing and upgraded hydro generation to be used for firming this service, and
- Cost-optimised mix for the second cable of Marinus Link (750 MW), building a 750 MW pumped hydro and optimising new wind and solar in conjunction with the assets built for the first 750 MW cable.

[41] Australian Energy Market Operator 2019, "2019 Input and Assumptions workbook". Accessed October 2019. https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM/Planning-and-forecasting/Inputs-Assumptions-and-Methodologies

These solutions are shown in Figure 5, compared against the base case cost of supply by an open cycle gas turbine. A relative comparison has been used to ensure that financial analysis is consistently applied. There is a high degree of uncertainty in the assumptions and relative values are considered more valuable than the precise costs.

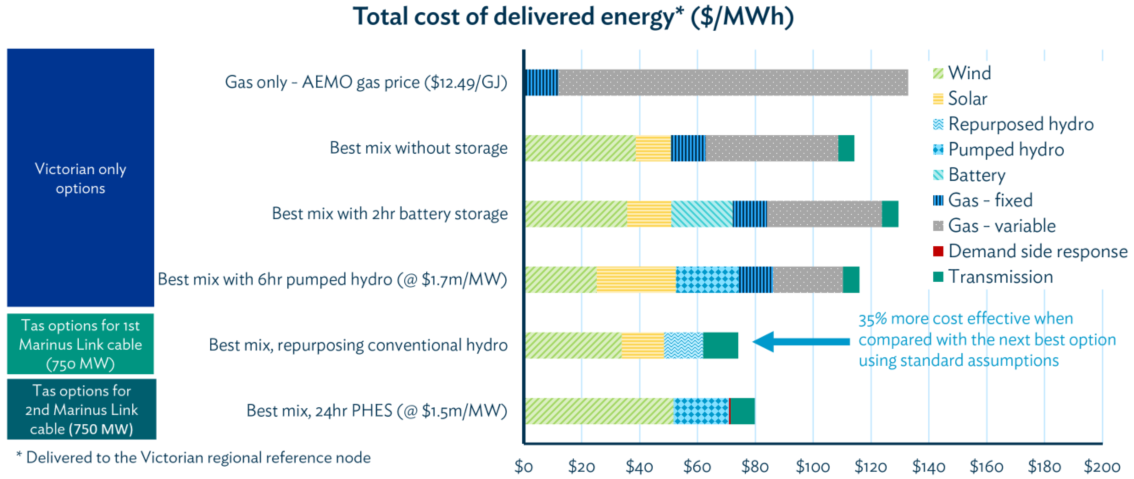


Figure 5. Comparison of credible cost options to deliver shaped 750 MW load

The gas only options is clearly expensive based on AEMO's central ISP scenario. However, this is only provided for context – it is highly unlikely that a firm contract would be sold based purely on the operations of an open cycle gas turbine.

Three Victorian combined supply options are presented, and the addition of storage was not found to be cost-competitive. Batteries attract a high cost, short amortisation and very short storage duration. Given that this is essentially an energy/reliability cost optimisation, it is unsurprising that batteries do not fare well. Their value proposition is much more localised. Batteries also derive substantial benefits from providing ancillary services and from scarcity pricing, neither of which are costed as part of this model.

Under this model, there was little to differentiate between the best mix without storage and the inclusion of Victorian pumped hydro storage. The introduction of the pumped hydro actually raised the cost very slightly, but the uncertainties outweigh the difference. Pumped hydro could also benefit from the same ancillary service market opportunities as a battery; considering ancillary services provision could be sufficient to make this cost stack competitive. It is also worth noting that the cost ($1.7m/MW) and duration (six hours) were taken from the only pumped hydro site under development in Victoria[42]. It is questionable whether there are sufficient opportunities at this price and duration to scale to 750 MW, so this is considered conservative from a Tasmanian opportunity perspective.

Tasmania's options rely on the existing and upgraded conventional hydropower stations and count the benefit of using low-cost wind and solar to displace hydro generation from low value periods which can then be used for firming the delivery of the load profile when the wind and solar energy is scarce.

The cost effectiveness of Tasmania's options are clear. Much of the opportunity comes from using Tasmania's existing hydropower assets and spending capital on repurposing assets that can be made more flexible or higher capacity.

[42] Arup 2018, *Pre-feasibility study of renewable energy pumped hydro in Bendigo*, Victorian Government Department of Environment, Land, Water and Planning, City of Bendigo. https://www.energy.vic.gov.au/__data/assets/pdf_file/0007/120130/Pre-feasibility-Study-Report-Final-for-Public-Release-.pdf

With the second cable, there are a small number of times when Tasmania's combination of pumped hydro and conventional hydro is insufficient to fully firm the wind and solar while providing the shaped load and simultaneously utilising Basslink's full export capacity. This time has been costed at $300/MWh and has been nominally identified as "demand side response". It could be customers voluntarily reducing load, it could be access to diesel supply or it could be utilisation of Tasmania's existing open cycle gas assets which have been excluded for the purpose of this analysis.

Finally, it is important to observe that transmission is a comparably small cost and has little overall impact on the total system cost. However, it is also important to realise that this is based on providing a firm supply of shaped energy, fully utilising the transmission. In reality, it is more cost efficient to share resources with other regions and be part of a supply mix. This will change the exact cost stacks somewhat. Modelling the entire system becomes a very different challenge and ends up losing some of the focus provided in this comparative analysis.

4.5 Cost sensitivities

The nature of this work is highly dependent on uncertain assumptions. Three key assumptions have been tested:

- Sensitivity 1: The cost of batteries was tested at half the projected cost in the late 2020s.
  - This is around 45% cheaper than the cheapest cost assumption for batteries in AEMO's assumptions book, even in the 2050s.
- Sensitivity 2: The Victorian pumped hydro was tested at $1.5m/MW for a six hour storage.
  - This would make the Victorian pumped hydro options' capital costs the same as Tasmania's capital cost – although the duration is still substantially different.
- Sensitivity 3: The cost of gas was tested at half the projected cost in the late 2020s.
  - This is around 33% cheaper than the AEMO assumptions book's cheapest gas price assumption.

The impact of these sensitivities are shown highlighted in Figure 6.

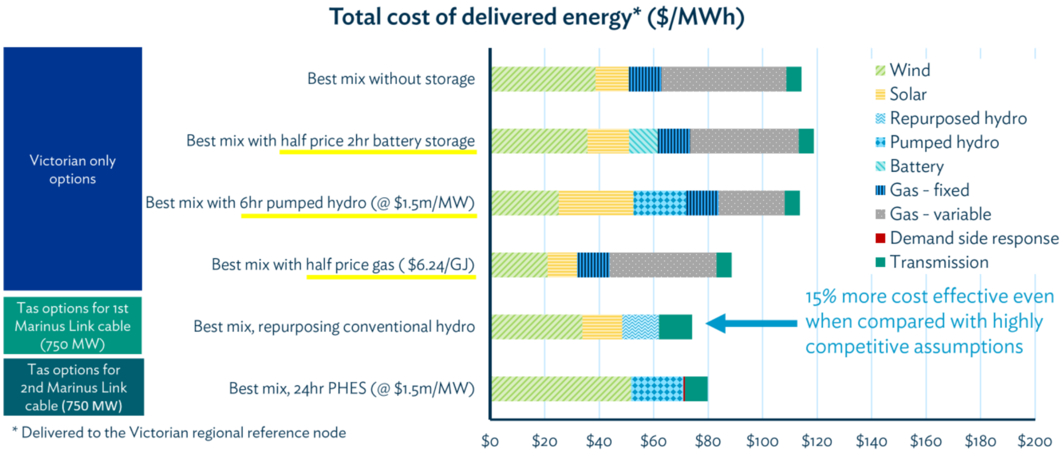


Figure 6. Testing sensitivities for the Victorian cost stacks and resulting competitiveness

With these sensitivities, it was found that batteries were still not competitive on the basis of energy[43]. Even at half cost, the battery storages were strongly impacted by the high capital cost and the short amortisation period.

43 Batteries will have a niche in the power system, but this will likely rely heavily on local congestion management and delivery of ancillary services – neither of which are calculated in this analysis.

The cheaper pumped hydro was found to be able to displace sufficient gas to justify its cost at $1.5m/MW for a six hour storage. To date, no pumped hydro project has been identified or proposed in Victoria at this cost and/or scale. Nevertheless, even with this sensitivity, there are still significant gas costs required to meet the supply profile and the combined system is more expensive than the Tasmanian options.

The sensitivity to test the impact of half-price gas made a substantial difference. Halving the cost of gas makes the cost of gas-based generation much more competitive with Tasmania's options. Under this sensitivity, the optimised cost stack achieves most of its savings by displacing Victorian wind and solar generation, particularly wind generation. The decreased price of gas results in much higher utilisation.

Tasmania's options remain competitive even against these sensitivities. The *Battery of the Nation* plan represents a highly cost-effective opportunity to deliver new firmed renewable energy to the NEM. This is strongly underpinned by the opportunity to *repurpose* Tasmania's existing hydropower system, using variable renewable energy such as wind and solar power to meet some of Tasmania's existing electricity demand to free up flexible hydropower for use when it's not as windy and sunny.

Tasmania's hydropower system already has 400 MW of latent capacity and has been shown to have 500 MW at times when it is required in Victoria[44]. Additional interconnection could unlock this latent capacity to support the rest of the NEM at times when capacity is scarce. This support could be further amplified by several cost-effective opportunities to invest in Hydro Tasmania's existing assets to repurpose them for the future energy market, for example by increasing their capacity.

4.6 Comparison with previous analysis

Some of the key input assumptions have changed significantly since the first Future State NEM Analysis report was published. The overall outcome remains the same: the Tasmanian technology stack of repurposing existing hydropower, cost-effective long duration pumped hydro energy storage and high quality wind, enabled by expanded interconnection, represents a highly cost-effective way to deliver firm new energy to the NEM. However, how much of the system value that can be captured by the storage operator is not clear and the markets need reform to incentivise the value-adding assets into the market.

[44] Hydro Tasmania 2019, *How Battery of the Nation can contribute to Victoria's energy needs and objectives*. https://www.hydro.com.au/docs/default-source/clean-energy/battery-of-the-nation/how-botn-can-contribute-to-victoria-august-2019.pdf?sfvrsn=de409a28_4

Energy storage is expected to play a central role in delivering a future NEM which is reliable, secure and cost-effective; however, the market structures need to reward and incentivise investment in valuable assets. The significant changes underway in the NEM present risks to both customers and developers.

Customers run the risk of insufficient investment in new, flexible supply, which could lead to extended periods of energy scarcity and associated high prices.

Developers run the risk of commissioning new capacity before it is needed and before there is certainty on the new market structures; therefore having insufficient return on investment in the early months or even years of their investment.

Developers could choose to delay investment to manage their risks – exacerbating the risks held by customers. It is therefore proposed that it may be appropriate to de-risk strategic developments to encourage timely investment, as a cost-effective way of mitigating the customer-side risks of late investments while the market is restructured to incentivise the right investments for the future NEM.

If appropriately targeted, support for strategic flexible supply can bring a number of advantages to the NEM including:

- Increased wholesale and retail competition
- Reduced market concentration in the NEM
- Access to cost-competitive new energy supply options
- Increased firm capacity to assist with managing inherent risks as the existing coal-fired generation fleet retire.

Tasmania's *Battery of the Nation* plan is an example of an opportunity to provide cost-effective, flexible supply to the NEM. Support, such as underwriting, could ensure that the capacity would be available when the market needs it.