Battery of the Nation

Analysis of the future National Electricity Market

Exploring a vision where Tasmania plays a significantly expanded role in the NEM

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Prepared by

Hydro Tasmania

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Foreword

Stage 1 analysis of the future energy investment opportunities identified by the *Battery of the Nation* concept shows Tasmania can make a significant contribution to the transformation of the National Electricity Market (NEM) over the next two decades.

The national market has the opportunity to invest in a combination of more interconnection, wind development and new hydropower assets in Tasmania, offering a future energy solution that is clean, reliable and affordable. The opportunity offers economies of scale, diversity and high quality new renewable energy resources combined with large scale storage that is able to be built with economic and timing optionality.

Key findings from the Stage 1 analysis

Significant hydropower potential at competitive cost

- Existing Tasmanian hydropower assets can be repurposed to provide more valuable services in the future market; targeted investment in pumped hydro energy storage in the system strengthens this proposition. When the obligation of Tasmanian energy security is shared with wind generation, the hydropower system can provide new system support services at very low cost to construct and operate. Adding pumped hydro capability to existing hydropower schemes would also increase the value of existing schemes through increased controllability.
- The cost to develop Tasmania's pumped hydro opportunities is very competitive, with over 4800 MW and 140 GWh of opportunity at a cost to construct from $1.05-$1.5m/MW.

Significant wind potential

- Tasmania's undeveloped wind resource is high quality and diverse. This is due to a high quality natural resource and lower correlation with wind resources on mainland Australia. Further development of this resource could bring substantial and valuable diversity to the NEM over the next 10 years.

A cost competitive coordinated solution

- The coordinated development opportunity of Tasmanian pumped hydro, wind and interconnection is cost competitive against all other realistic options for the future energy system.

National planning alignment

- The opportunity aligns with AEMO's current integrated system planning (ISP) and delivers on all identified benefits required of a renewable energy zone (REZ) in that plan. In particular, it introduces more generation diversity (by location) and market investment optionality.
- As significant investment will be required across the whole NEM, Tasmanian development can be adapted to work within nationally coordinated market planning to manage the risk of asset stranding.
- Investment decisions on new interconnection can be timed to align with retirement of coal-fired generation, which in turn will trigger further Tasmanian wind and hydropower investment.

Addressing the energy trilemma

- The concept strongly supports all three requirements of the energy trilemma - sustainability, security and equity (affordability) - in one coordinated system solution. It can bring new generation firming services to the market and put downward pressure on Tasmanian and mainland prices.
- Initial modelling shows these opportunities can reduce national reliance on open cycle gas generation (OCGT) for capacity. This is because flexible hydropower can be used more for system capacity support. This could translate to a 20% reduction in energy costs and an additional reduction of up to nine million tonnes of greenhouse gas emissions per year.

Through these attributes, *Battery of the Nation* has shown that Tasmanian development options can deliver reliable and secure energy supply at least cost to consumers both in Tasmania and the mainland states.

The formal assessment for the second Bass Strait interconnector has already commenced: a critical step on this journey. Hydro Tasmania will continue to support this effort.

This report is only the first stage of this investigation. We welcome feedback on its content.

We will continue to further investigate the longer term market opportunity to better understand the opportunities and challenges to the concept.

Stephen Davy
Chief Executive Officer, Hydro Tasmania

Battery of the Nation offers a future energy solution that is clean, reliable and affordable.

1.0 Executive Summary

The national challenge

Australia's energy fleet is ageing. Approximately 65% of Australia's energy fleet is already at or beyond the mid-point of its technical life. It is forecast that from 2028 to 2037 about 35% of Australia's existing generation capacity will retire simply due to age-related deterioration. This represents the loss of around 15 000 MW over a 10-year period.

This scale of retirement of major infrastructure is significant. Replacing this infrastructure will require a substantial response on a national scale.

Figure 1 shows a conservative retirement schedule for generation assets in Australia based *purely* on age – primarily retirement of coal-fired generation. As older plant retires, new plant will need to be built. The late 2020s is forecast to be the precipice of a rapid change.

The retirement of the Hazelwood coal-fired plant in 2017 increased energy security risks and caused a substantial rise in energy prices. This highlighted the thin reserve margins in the NEM and indicates a need for significant proactive investment in new generation infrastructure.

The scale of the challenge facing the NEM is an order of magnitude larger and will require a combined response from a variety of technologies and proponents across the NEM.

Replacement generation sources are likely to be variable – notably wind and solar. The interactions of these variable energy sources will change the nature of the power system and power system planning and modelling.

Energy services that help manage the reliability and security of the system will become critical to the market. New services that can store large quantities of energy during times of energy surplus and supply back to the grid during times of relative energy scarcity will be part of a solution to produce the lowest cost supply for customers.

Changes in the physical power system are prompting reconsideration of market design. A market design based on dependable floor prices underpinned by short run marginal cost of energy may not support the transformation of the electricity sector away from fossil fuel-based technologies. The new system services that work alongside variable energy sources to provide a steady output to meet demand will need to be properly assessed and valued. Any change to the market design will need to solve the energy trilemma of energy equity (affordability), security and sustainability.

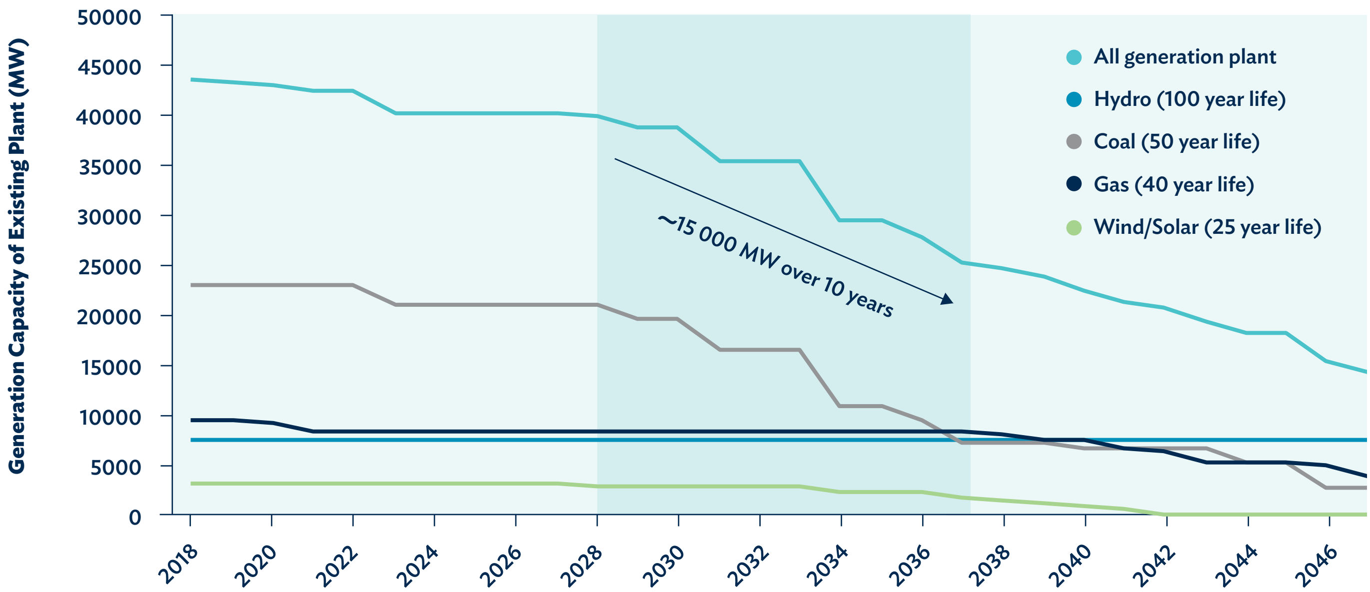


Figure 1. Expected retirement profile of existing generation assets in the NEM (based on life expectancy)

Key challenges

Australia's energy fleet is ageing. The late 2020s will see the start of an unprecedented rapid and sustained retirement schedule.

No single solution will be able to meet the size of the challenge. A coordinated response is needed. There will be no 'business as usual'.

Wind and solar are likely to be cost competitive energy sources of the future and the power system will need new services to support their variability and integration.

Can Tasmania deliver on this opportunity?

Tasmania has a strong opportunity to contribute competitive large scale energy storage and high quality wind resources to the future energy mix of the NEM.

Tasmania's existing valuable and flexible hydropower assets can play a system balancing role, maximising the value of new variable renewable energy developments while providing a new supply of secure and firm energy to mainland Australia. This value could be amplified by targeted investment in pumped hydro technology increasing system controllability – a critical asset in a national market with substantial variable wind and solar generation.

Tasmania's wind resource is relatively untapped, plentiful, high quality and could bring substantial diversity to the national market.

With further interconnection and a sound development plan, Tasmania could produce significantly more renewable energy for the nation and fully realise the value of its current hydropower system.

With further interconnection and a sound development plan, Tasmania could produce significantly more renewable energy for the nation and fully realise the value of its current hydropower system.

The full report presents the findings of the first stage of analysis. The Executive Summary presents key outcomes. The supporting evidence underpinning the views, assertions and outcomes in the Executive Summary is contained in the full report.

The Tasmanian perspective

Critical to the success of this proposal is active engagement and participation from the broader Tasmanian community. This vision for their energy future must deliver the best possible outcomes for Tasmanians. This opportunity could:

1. **Ensure the lowest possible power prices for Tasmanians**

   The modelling so far supports this view. In simple terms, Tasmania will need to have comparably low prices to be able to export its excess energy.

2. **Ensure long term energy supply security for Tasmania**

   Thousands of MWs of new wind generation on island and more interconnection to the mainland would mean secure long term energy supply for Tasmania. It would diversify Tasmania's energy options and reduce direct exposure to climate change variability, particularly relating to rainfall.

3. **Provide a long term economic stimulus to regional areas of Tasmania**

   The investment in pumped hydro, wind generation and the transmission system will be incremental over decades and is focussed on areas of the state outside major city centres. This will generate significant, ongoing economic stimulus in regional areas of Tasmania.

At this stage, the identified social and environmental impacts are also relatively low. It is possible to create and sustain broad community support for this opportunity.

The national perspective

The *Battery of the Nation* opportunity offers economies of scale, diversity and high quality new renewable energy resources combined with large scale storage that is able to be built with economic and timing optionality. This will bring national benefits including:

1. **Ensure the lowest possible power prices for the NEM**

   The modelling so far supports this view. Compared with credible alternatives, the developments modelled under *Battery of the Nation* would reduce cost across the NEM.

2. **Provide stable, secure and reliable energy supply**

   The ability to leverage existing assets and storages will enable Tasmania to provide critical system balancing and firming services to ensure reliable energy provision in the NEM.

3. **Meet Australia's energy sustainability targets**

   Investing in Tasmania's world class and nationally diverse wind resources will deliver towards Australia's energy sustainability targets and international carbon abatement commitments.

Approach to the analysis

To understand the opportunity presented by *Battery of the Nation*, a consistent and plausible view was formed for the future NEM. Stage 1 of the project has:

1. Assessed **technologies** that make up the Tasmanian opportunity against other known credible future technology options.
2. Assessed the specific **application** of these technologies in the Tasmanian context and compared them against other known credible future application across the NEM.
3. Constructed an integrated 'system solution' cost model for the Tasmanian option, and
4. Tested this model for competitiveness against credible future NEM **scenarios.**

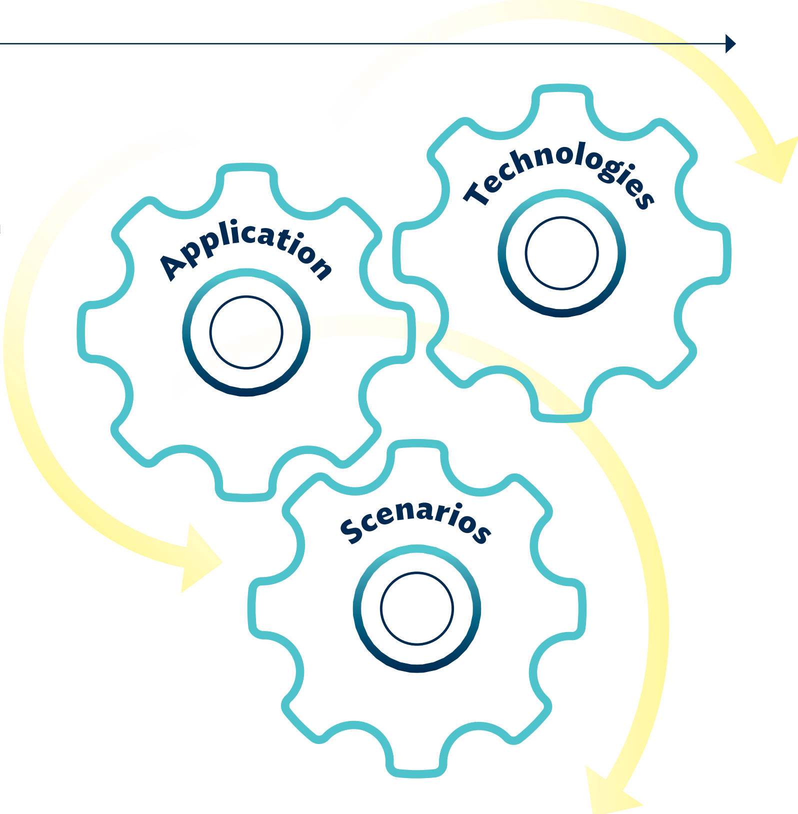
In this process, third party system modelling consultants have been utilised for the modelling (EY) and review (Oakley Greenwood).

A 'systems thinking' approach was taken for the scenario modelling to account for the fact that in the future, time-variable renewable energy sources will begin to dominate the energy mix. This also allows for synergy of new assets. A conventional resource allocation approach was considered inadequate. The chosen approach led to a range of planned 'build out scenarios' that considered the complementary development of wind farms and pumped hydro projects in Tasmania.

Dispatch modelling of the NEM was undertaken for four scaled scenarios, six sensitivities and a 'NoTasDev' situation (no further energy developments in Tasmania beyond Cattle Hill and Granville Harbour wind farms). These scenarios translated to modelling scenarios with three to five interconnectors, 2000 MW to 6500 MW of wind generation, and 1500 MW to 3500 MW of pumped hydro. Figure 2 shows the range of modelled scenarios. Figure 3 shows the scenario with five interconnectors and strong wind development.

The *Battery of the Nation* concept is not intended to meet all the future needs of the NEM. The largest scenario explored shown in Figure 3 only meets 20% of the total need for dispatchable capacity through to 2040.

The first phase of analysis explored substantial change in the broader market in response to retirement of coal-fired generation and typically chose conservative market assumptions. This resulted in the modelling showing substantial utilisation of open cycle gas generation (OCGT) to provide the marginal capacity required to fill, potentially extended, periods of scarcity.



This results in a conservative position for the *Battery of the Nation* concept; a high level of gas generation decreases the requirement for (and value of) long term storage. This is consistent with the initial findings of AEMO's Integrated System Plan [ISP 2017] and also with any more aggressive carbon abatement targets for the electricity sector.

A key hypothesis for this analysis is that storage of 12 – 24 hours will be required to support the system for (southern) states where the variability is driven primarily by wind energy. This is supported by the analysis; across the entire NEM, there will be a two day period of low wind generation every fortnight on average, see Section 5.2.2 in the full report for more detail.

Chemical batteries are not considered economic for storages beyond four hours duration, even by 2050, see Section 5.2.5.2 in the full report for more detail. Flexible generation will be required to help manage generation variability. OCGT has traditionally provided this service to the market. Due to the cost competitive nature of Tasmanian pumped hydro options (see section 5.2.5 in the full report for more detail), it will outcompete other options for dispatchable energy supply.

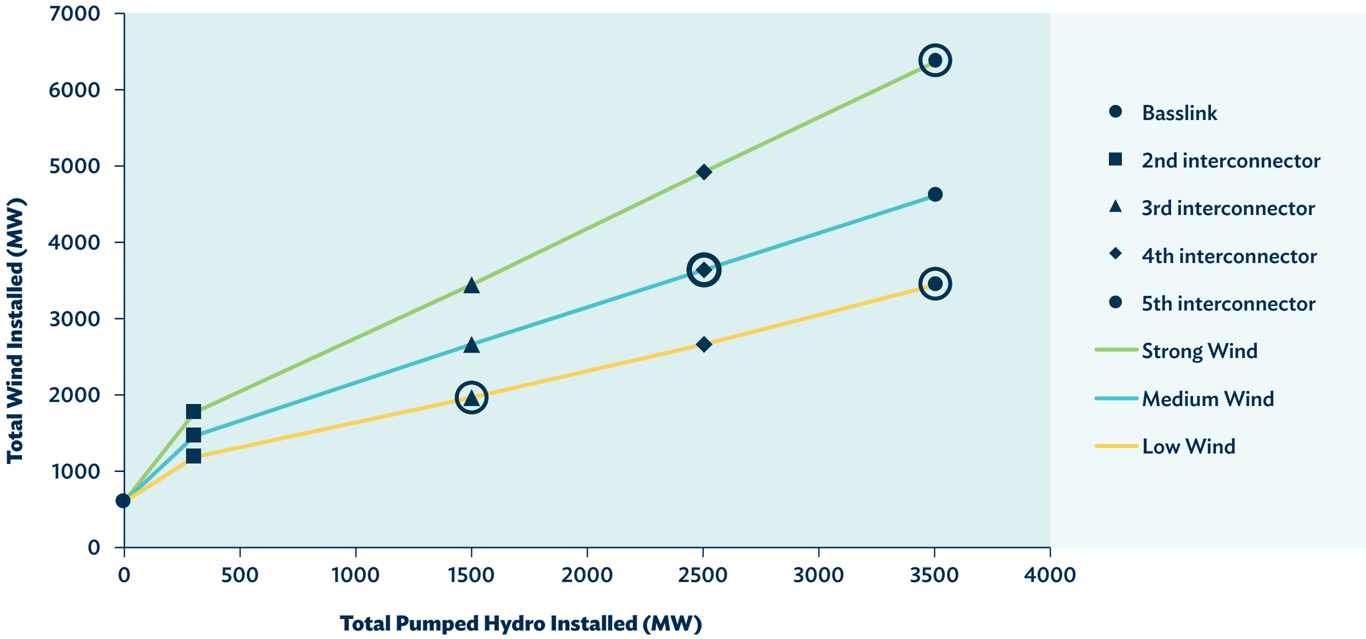


Figure 2. Range of modelled scenarios

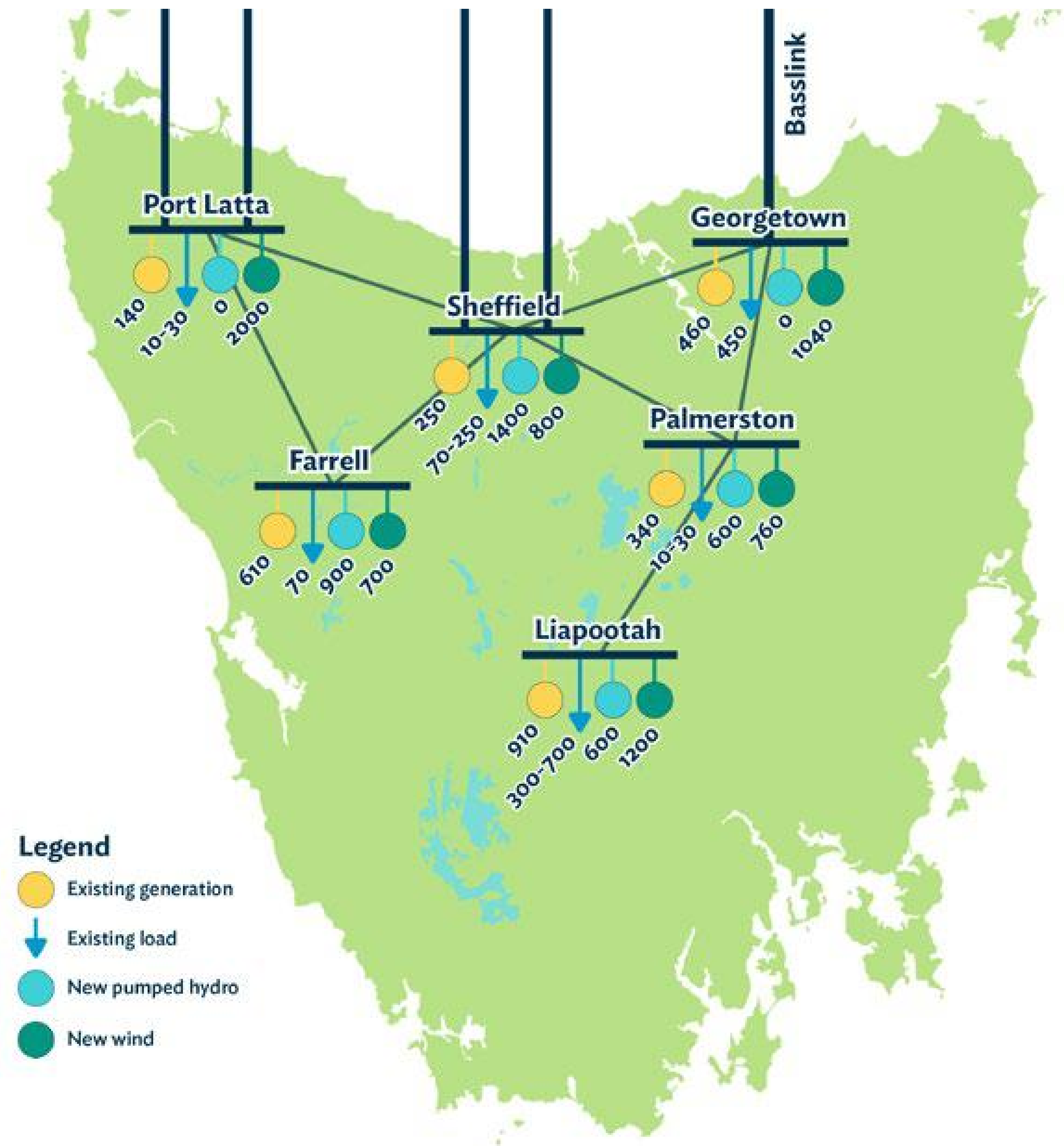


Figure 3. Five interconnector, strong development scenario

Key *Battery of the Nation* findings

Key finding – significant hydropower potential

Existing Tasmanian hydropower assets can be repurposed to provide more valuable services in the future market; targeted pumped hydro investment in the system strengthens this proposition.

When the obligation of Tasmanian energy security is shared with wind generation and more substantial interconnection, the hydropower system can provide new system support services at very low cost to construct and operate. Adding pumped hydro capability to existing hydropower schemes would also increase the value of existing schemes through increased controllability.

Tasmania's extensive and established hydropower system is well-placed to contribute to the challenges facing the energy system with proven, reliable, dispatchable renewable energy backed by Hydro Tasmania's extensive experience developed over 100 years.

Tasmania's hydropower assets are currently primarily focussed on long term energy security for the state and most plant are optimised to provide baseload power to Tasmania. However, with the right investment Tasmania can repurpose existing elements of the hydropower system to store energy when sun and wind energy are abundant, and draw on this storage to deliver power to the nation when weather conditions limit wind and solar generation, demonstrated in Figure 4.

Increasing the flexibility of a greater proportion of hydropower assets in Tasmania would result in more cost-effective energy dispatch and lower prices for consumers.

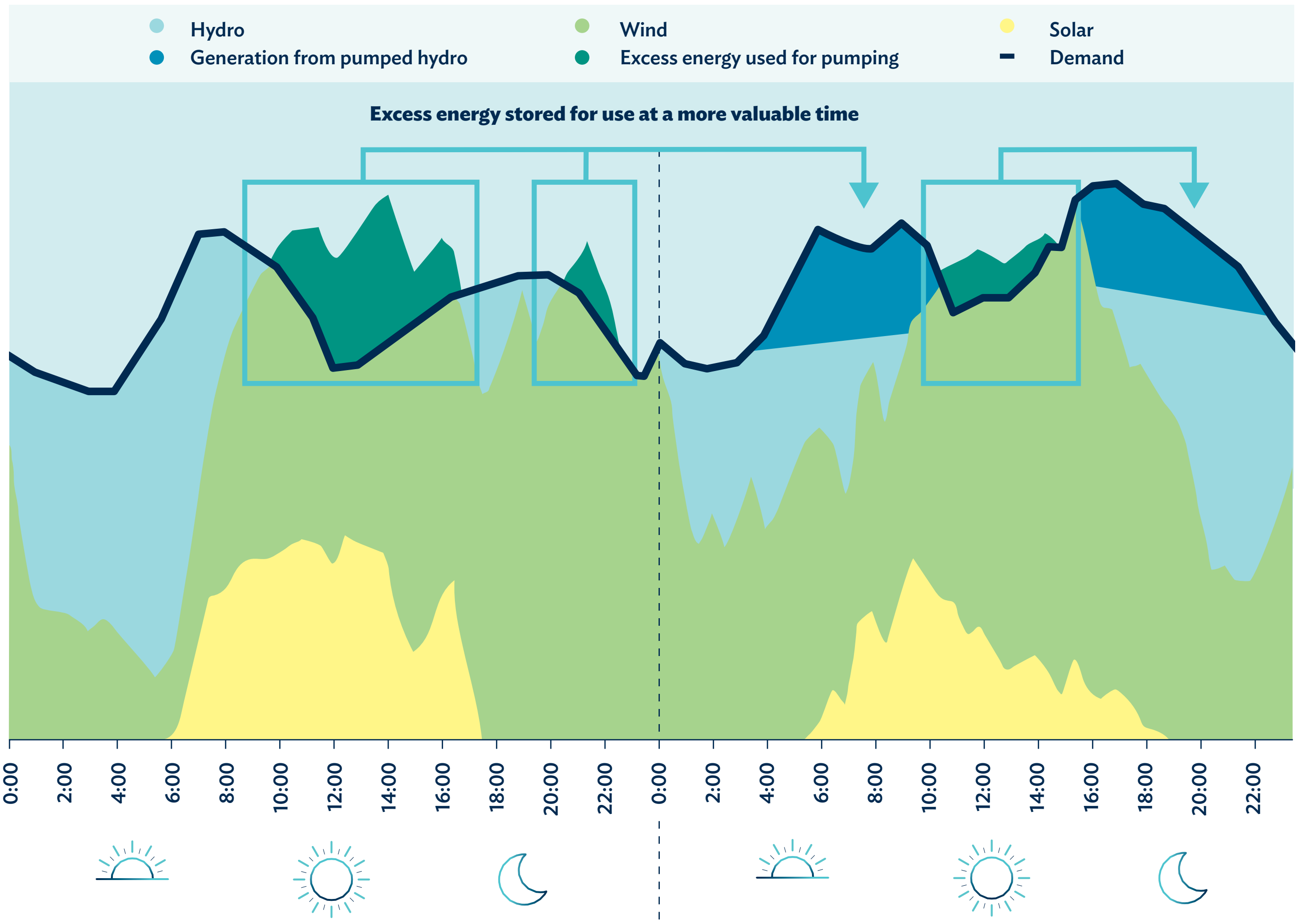


Figure 4. The role of energy storage

Tasmania has strategic advantages which should make pumped hydro investment a national priority.

The suite of pumped hydro energy storage projects under *Battery of the Nation* is large, mostly being able to support 24 hours of continuous supply, and cost-effective with construction costs that range from $1.05 to $1.5 million per MW. Note the actual energy storage for each pumped hydro station is largely dictated by geography and has little correlation to construction costs, resulting in economically scalable duration of supply.

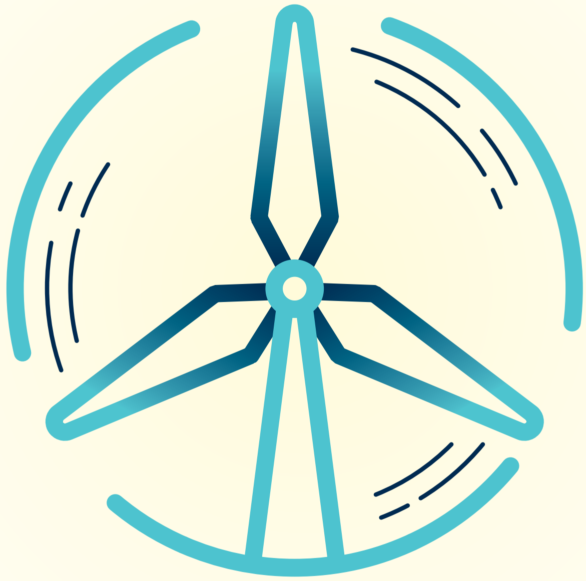
Modelling of existing hydropower in Tasmania has shown that under a likely future energy mix the schemes with more storage (which are more flexible and controllable) are substantially more valuable than those that have smaller storages. The value of existing run-of-river hydropower assets could increase by as much as 25% with selective development of pumped hydro energy storage.

A major advantage for the suite of projects being considered in Tasmania is that a pumped hydro installation towards the top of a series of cascaded hydropower stations amplifies the contribution of the pumped hydro asset as released water from the station can pass through all downstream power stations.

Tasmania has natural topographical advantages and existing infrastructure that position the state as a very attractive location to develop large-scale pumped hydro necessary to meet all elements of the energy trilemma (security, affordability and sustainability).

Investment in pumped hydro will help ensure Tasmania can deliver valuable system security services to the market when they are most needed.

Key finding – significant wind potential



Tasmania's wind resource is high quality and diverse. This is due to a high quality natural resource and lower correlation with wind resources on mainland Australia. Further development of this resource could bring substantial diversity to the NEM over the next ten years.

This diversity will become more and more valuable as the penetration of variable renewables increases and is a key benefit of the nationally planned renewable energy zones. Tasmania's typical diurnal cycle has also been found to have a low correlation with mainland wind energy and also a notably different daily pattern of generation, see Figure 5. This difference in wind patterns provides diversity benefit to the NEM. It is also coupled with the highest capacity factor for wind energy generation in the NEM.

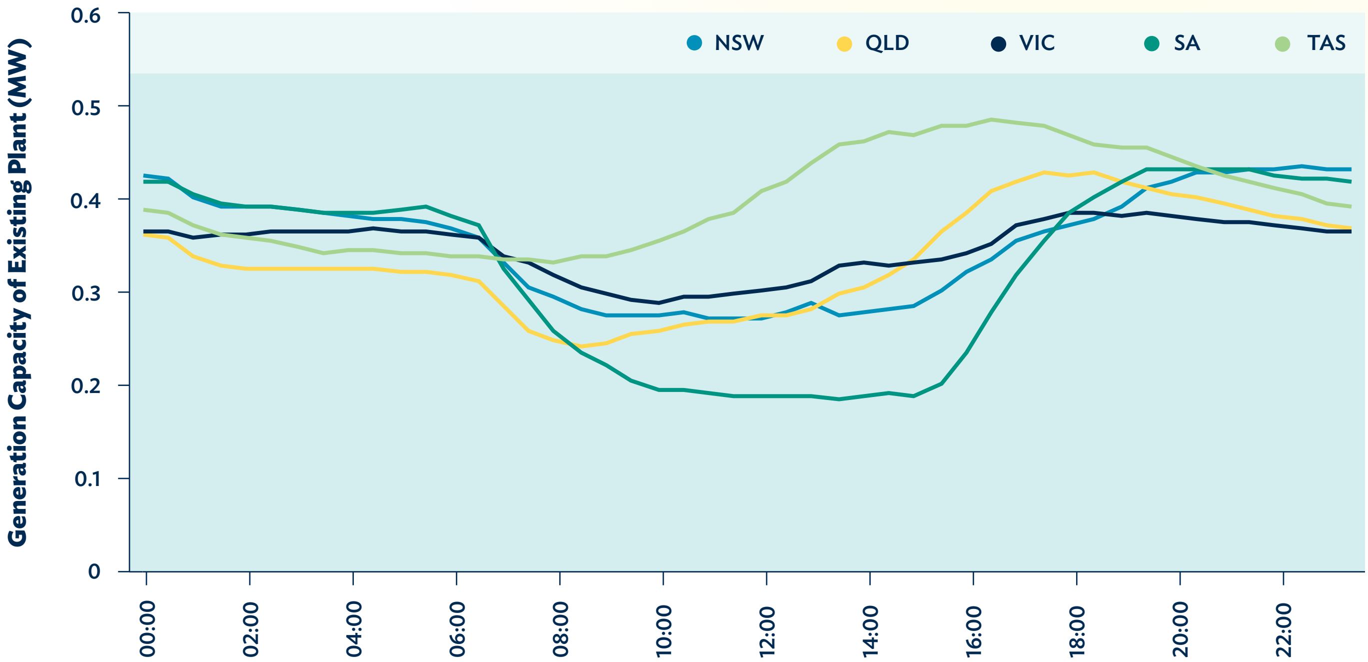


Figure 5. State wide wind energy diurnal capacity factor comparison based on modelled data in 2050

The benefit of Tasmania's wind energy diversity can be visually demonstrated to change the NEM-wide characteristics of wind energy production, see Figure 6. The figure shows that with substantial contribution from Tasmania, the national wind profile spends far more time in the most useful range and less time generating low amounts of energy. The need for storage will be reduced nationally by careful expansion of diverse variable renewable energy opportunities. This characteristic increases the value of Tasmanian renewable energy development to the entire system.

The proximity of strong wind resources in Tasmania to long term storage options, shown in Figure 7, increases the relative value of both resources. This is further amplified when combined with existing transmission corridors and reservoirs to reduce cost and minimise environmental impact. Preliminary investigations have shown that these developments are economically attractive and have relatively low social and environmental challenges (to be confirmed in the future with more detailed site specific assessments).

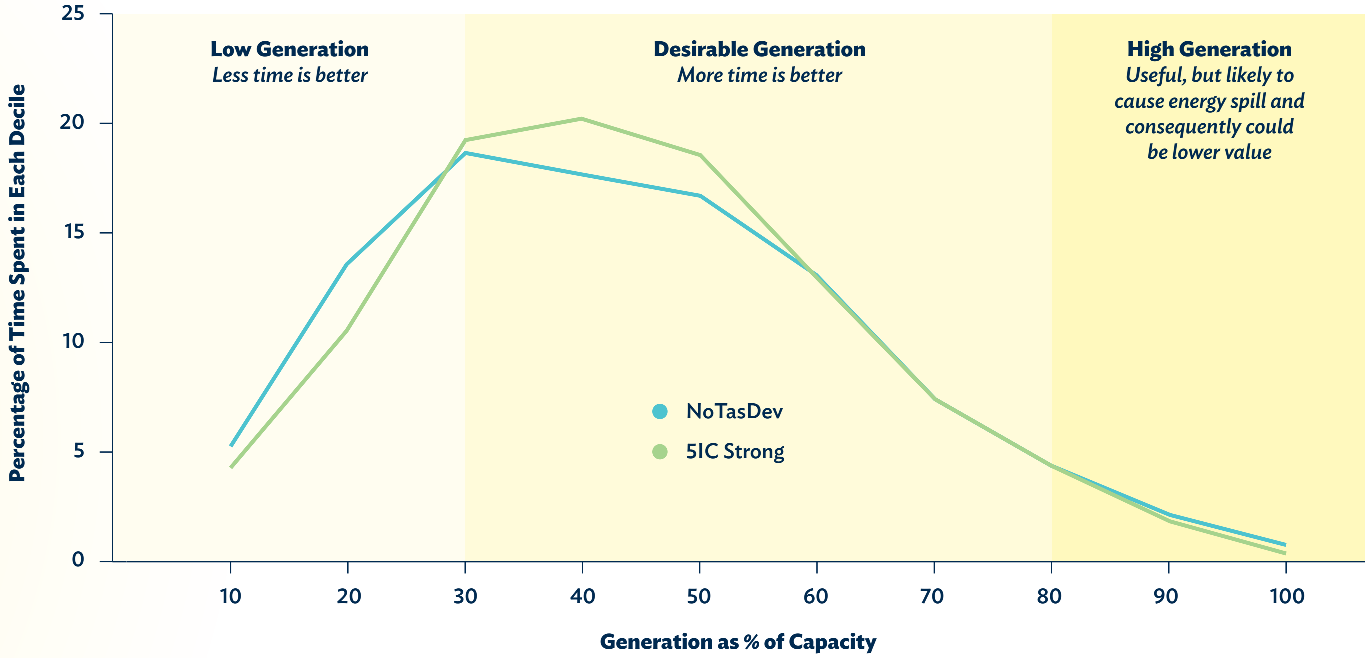


Figure 6. National wind generation profile – with and without Tasmanian development

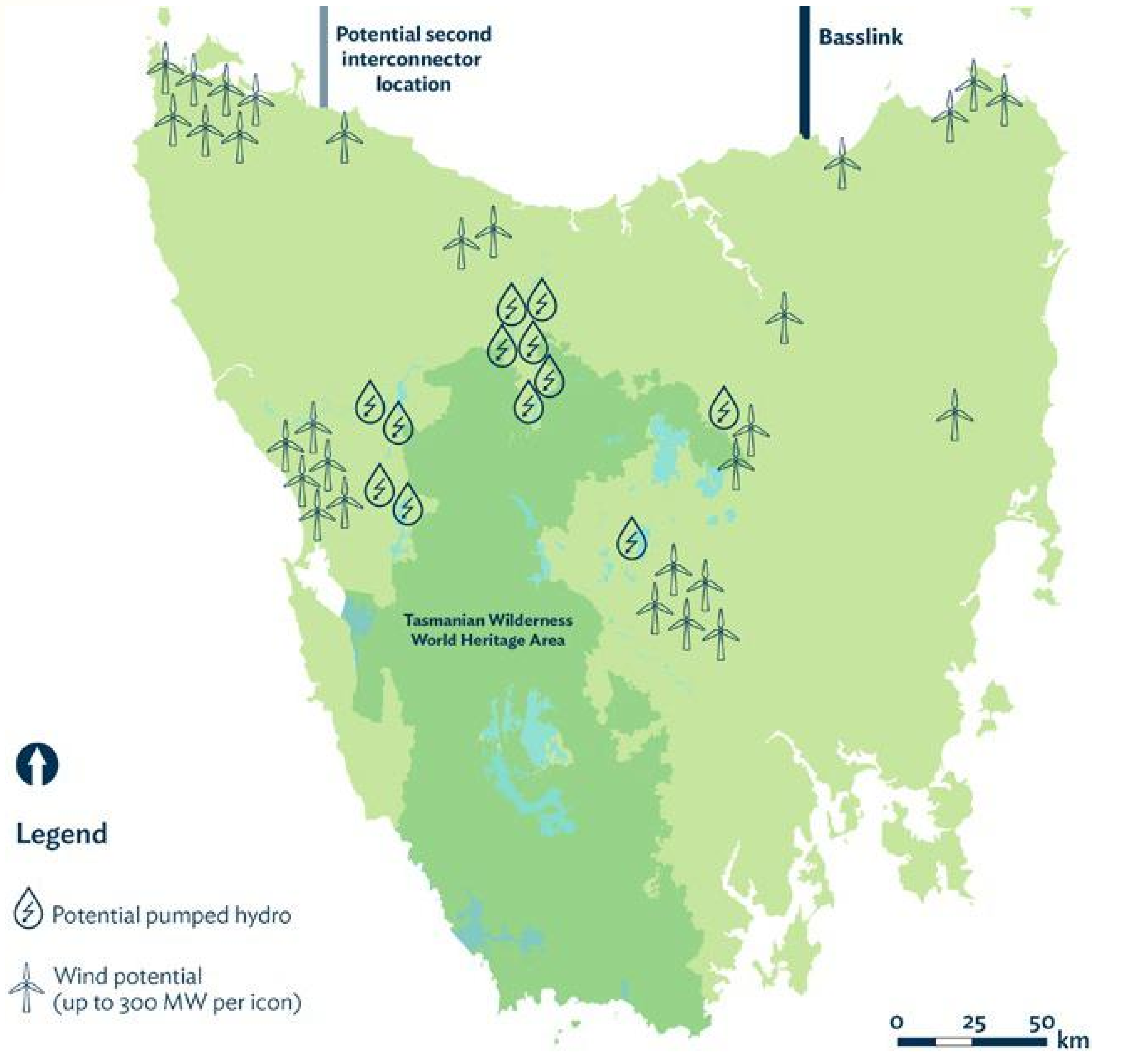


Figure 7. Wind and pumped hydro opportunities in Tasmania

Key finding – cost competitive coordinated solution

The coordinated development opportunity of Tasmanian pumped hydro, wind and interconnection is cost competitive against all other realistic options for the future energy system.

Figure 8 and Figure 9 show the cost stack of the coordinated development opportunity in Tasmania compared to other credible options for delivering a large amount of new, reliable energy to the market. For the purposes of this comparison the stream of energy was scaled to deliver 600 MW to Victoria's load centre, representing a possible size for the second interconnector. In the future, this assessment will need to be regularly validated as other credible options are developed in the market.

In Figure 9, the "gas only" option is the reference case. The size of the missing pieces in each pie chart reflect the relative competitiveness – the bigger the missing piece, the better the option. The two major cost contributors are variable gas costs (fuel) and the wind energy. This analysis shows the transmission and interconnection costs are only a minor contributor to the overall investment required.

Battery of the Nation also presents a staged infrastructure development pathway that can be a key component in meeting the future NEM requirements through scalable large scale and long duration (12+ hours) storage and high quality, regionally-diverse wind energy.

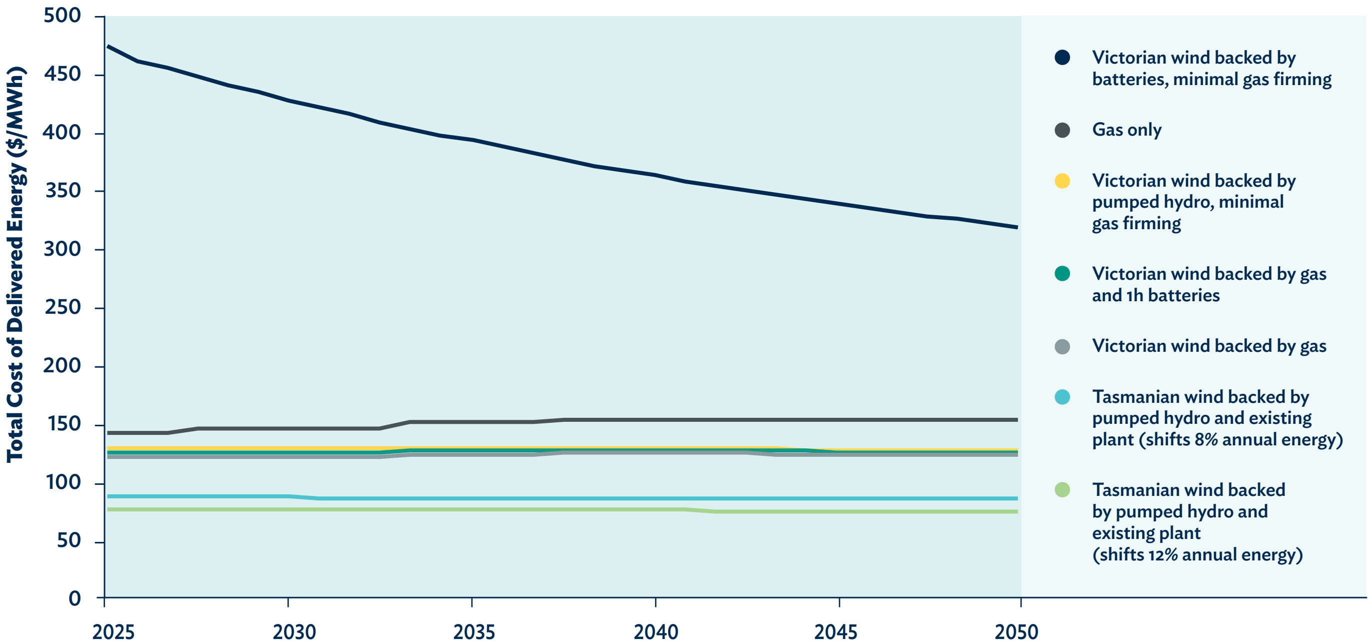


Figure 8. Comparison of options to deliver 600 MW from a new energy zone to the Victorian load centre

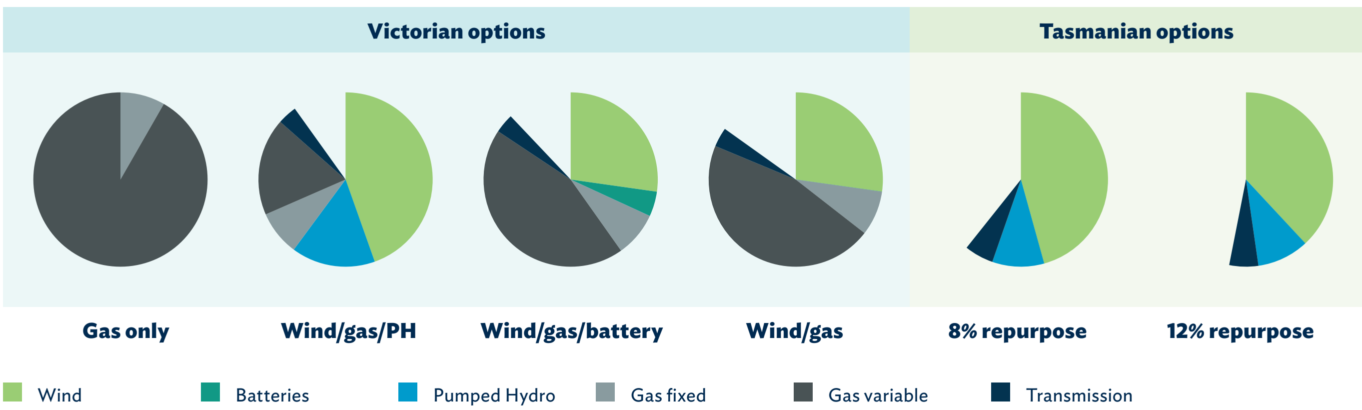


Figure 9. Comparison of options based on cost stack

There is optionality in both scalability and timing for pumped hydro, wind development and interconnection options that could occur in Tasmania. This makes Tasmanian infrastructure choices robust to a range of potential futures, bringing benefits to both Tasmanian and mainland customers.

Tasmania can further leverage existing hydropower assets by investing in a number of new pumped hydro storages to optimise the Tasmanian hydropower system to provide critical system balancing services to the NEM. The discrete nature of these opportunities, shown in Figure 10, also means that the program can be structured to provide substantial optionality around timing and scale of construction.

Development of pumped hydro and wind farms in Tasmania could be strategically sequenced to align with development of additional interconnection; yet, given the scale of the vision, the actual 'building blocks' allow careful management of investment risk.

As significant investment will be required across the whole NEM, Tasmanian development can be adapted to work within nationally coordinated market planning to manage the risk of asset stranding. Investment decisions on new interconnection can be timed to align with retirement of coal-fired generation, which in turn will trigger further Tasmanian wind and hydropower investment.

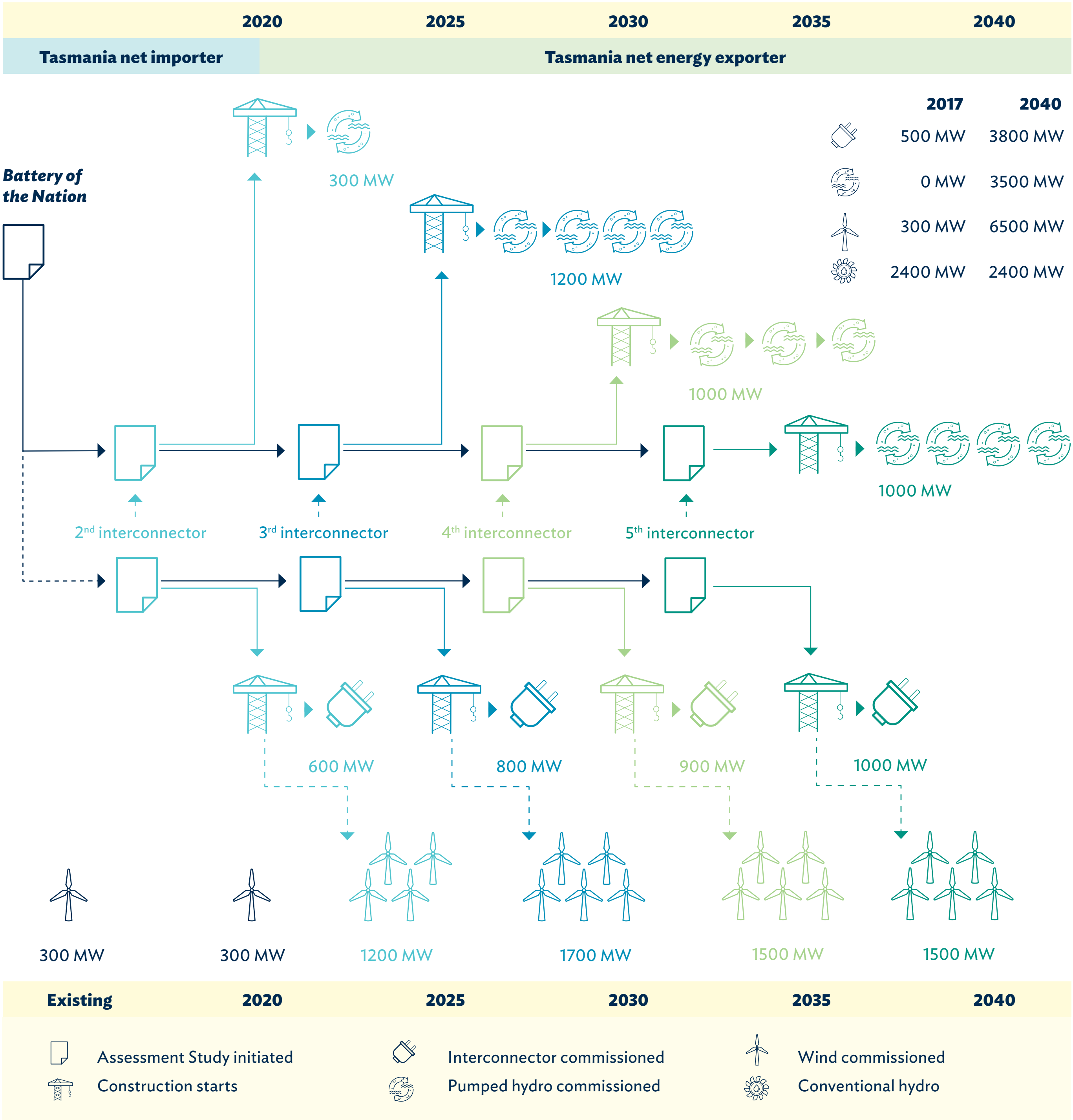


Figure 10. Demonstrative timeline of the optionality of future Tasmanian energy system investment

Key finding – national planning alignment

The opportunity aligns with AEMO's current integrated system planning (ISP) and delivers on all identified benefits of a renewable energy zone (REZ) in that plan.

The Tasmanian power system has the potential to unlock greater value from existing hydropower assets to deliver a new source of low-cost reliable energy supply to the NEM. During the course of this Future State NEM analysis, the concepts of renewable energy zones and AEMO's Integrated System Plan have emerged. It is possible that the analysis in this report could act as the first step in identifying Tasmania as an opportunity to develop a significant REZ.

The Tasmanian development opportunity strongly supports all three requirements of the energy trilemma in one coordinated system solution. The mix of technologies is environmentally sustainable and has substantial flexibility that will work towards meeting system security needs.

Developments proposed by *Battery of the Nation* deliver on all identified benefits of a REZ:

- Achievement of reliable and secure energy supply at least cost to consumers by:
  - Leveraging economies of scale for generation, storage and efficient use of both new and existing transmission using synergistic technologies.
  - Improving the national diversity of variable renewable energy through the addition of Tasmanian wind energy, reducing the need for storage.
  - Delivering substantial access to the highest quality wind resource in the NEM.
- An opportunity that is modular in nature and can be scaled to the size of the economic opportunity enabling progressive investment.
- The ability to adapt timing and build outs to work within nationally coordinated planning to manage the risk of asset stranding through flexible optionality.

To extract the potential value from Tasmania's natural advantages, substantial and timely interconnection to mainland Australia will be required. The Australian Renewable Energy Agency (ARENA) and the Tasmanian Government announced support for a business case study of a second interconnector in late 2017, a critical milestone for *Battery of the Nation*.

The CSIRO Low Emissions Technology Roadmap [CSIRO 2017a] found that electricity sector emissions may need to reduce by 52–70% by 2030 and 90% by 2050 to meet the national target of 26–28% by 2030 and 70% by 2050. In the recent Integrated System Plan produced by AEMO a 'fast change' scenario is proposed based on the low end of these targets. While this analysis has not modelled a fast change scenario, *Battery of the Nation* would be consistent with achieving more ambitious reduction targets.

Tasmania has scalable options which provide optionality to fit a range of scenarios based on different levels of interconnection.

Tasmania has scalable options which provide optionality to fit a range of scenarios based on different levels of interconnection.

Key finding – addressing the energy trilemma

The modelling is showing positive impacts on the sustainability and equity (affordability) elements of the energy trilemma.

The modelling is based on comparison of multiple scenarios using consistent assumptions to explore the value of the Tasmanian development options. The 'NoTasDev' (no further energy developments in Tasmania beyond Cattle Hill and Granville Harbour wind farms) situation provides a basis for comparison in which substantial variable renewable energy is largely firmed and balanced by open cycle gas turbines generation.

The largest scale scenario for *Battery of the Nation* was compared against 'NoTasDev' and found to substantially reduce the reliance on open cycle gas turbine generation. This resulted in potential reductions to generation weighted NEM-wide resource cost of energy (analogous to spot price) by 20%, Victorian resource costs by 30% and Tasmanian resource costs by 50%, see Figure 11. Concurrent with the savings, CO_2-equivalent emissions reduced by up to nine million tonnes per year during the later stages of the development.

More diverse generation combined with system balancing solutions, such as those offered by *Battery of the Nation*, will also continue to add value beyond the end of the period modelled.

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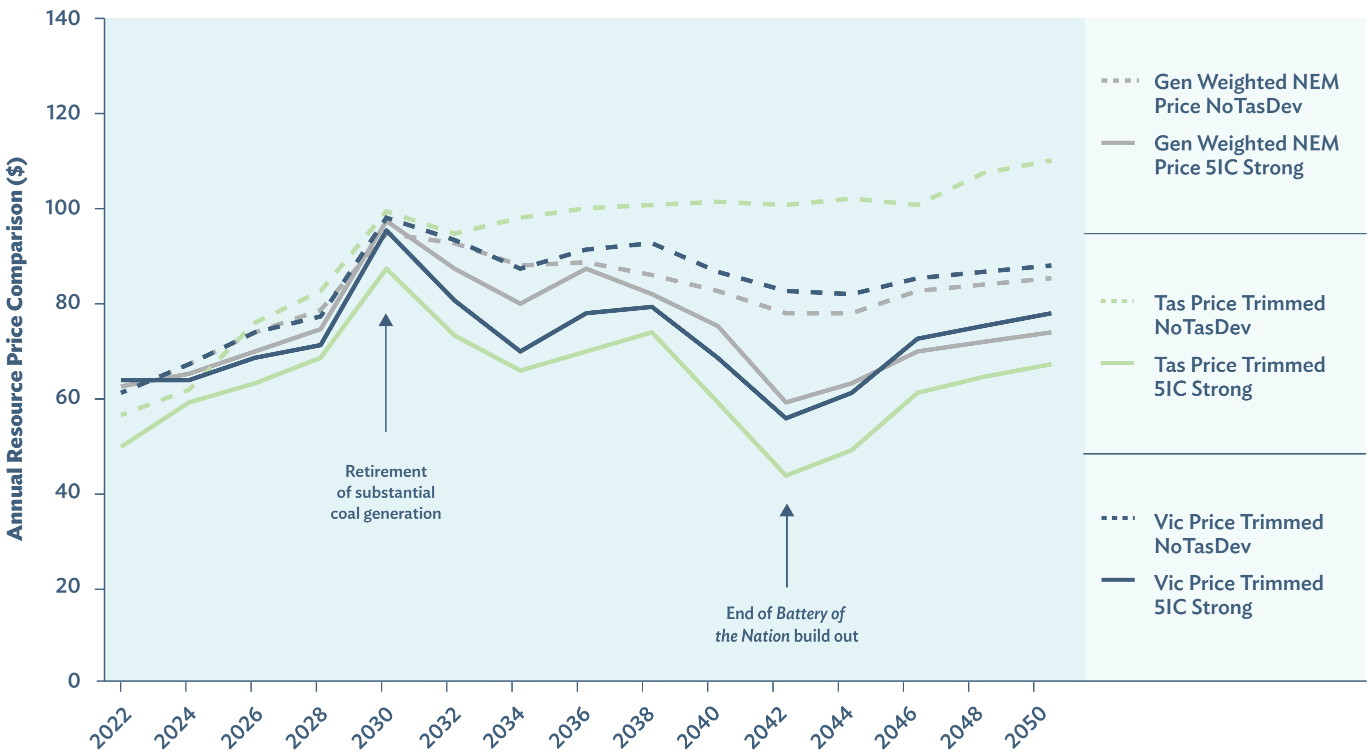

Figure 11. Comparison of NEM annual resource costs translated to market price

A future market design will need to value a variety of system services that will recognise the value of inertia, flexibility and ability to rapidly change output, alongside the existing energy and ancillary services.

Broader market findings

In the future NEM, the definition of 'peak' and 'off-peak' will change.

The modelling shows that the familiar peak versus off-peak paradigm will shift, and even invert, on a national scale. The new 'peak value' and 'off-peak value' times will be defined by generation scarcity or abundance (rather than the level of demand).

The modelling shows that by 2035 there may be sufficient residential solar that the daily average minimum net national demand will occur at midday (and this will be even more pronounced in certain regions). Wind energy will also have a substantial impact on the system resulting in extended periods of surplus or scarce energy generation. This will likely erode the relevance of baseload generation as responsiveness becomes valued more than efficiency.

The modelling is underpinned by the operation of the existing market (based on the concept of short run marginal cost) and what would be considered feasible within that paradigm. The future market will need to provide market signals for new system management services, such as storage and rapid response generation, to make best use of the available energy and manage a system that has redefined concepts of peak and off-peak.

Realising the full value of energy storage is difficult in the context of the current NEM.

A study by the Rocky Mountain Institute [RMI 2015] collated a series of results from earlier studies showing up to 13 different value streams. Attempts to assign direct value to storage in Australia typically only recognise energy arbitrage value (since frequency control ancillary services (FCAS) markets are not presently considered bankable).

The Future State NEM analysis modelling has found that storage reduces the cost of energy in the NEM and is qualitatively understood to provide critical system reliability services.

A future market design will need to value a variety of system services that will recognise the value of inertia, flexibility and the ability to rapidly change output, alongside the existing energy and ancillary services.

Storage is not simply a generator that buys its 'fuel' from the same market it sells into; acknowledging the value of its other services, including dispatchable load to help manage excess generation, will better optimise the potential benefits of this technology for the broader operations of the NEM.

Storage provides a variety of services, all of which have value, and should not be simply seen as a 'generator' within the system. This oversimplifies the value proposition of storage, which should be treated as a provider of system services.

The future market will need to provide market signals for new system management services, such as storage and rapid response generation, to make best use of the available energy and manage a system that has redefined concepts of peak and off-peak.

Not all storage is equal.

Storage is typically priced on a $/kWh or $/MWh basis, with the implicit assumption of one-hour duration. Figure 12 shows a cost comparison of the two main storage technologies being considered in the Australian market, over a lifespan of 40 years based on Electricity Generation Technology Cost Projections [CSIRO 2017b], the same source that AEMO is using for the Integrated System Plan.

The figure shows that batteries are already cost competitive for single-hour storage, and will be roughly competitive for four-hour storage by 2050. Longer duration batteries are not cost competitive against identified pumped hydro energy storage opportunities. For longer storage requirements, pumped hydro will be the main viable option.

It is important to note that the cost and storage size of the pumped hydro opportunities are influenced more by geography and hydrology than electrical or mechanical plant costs.

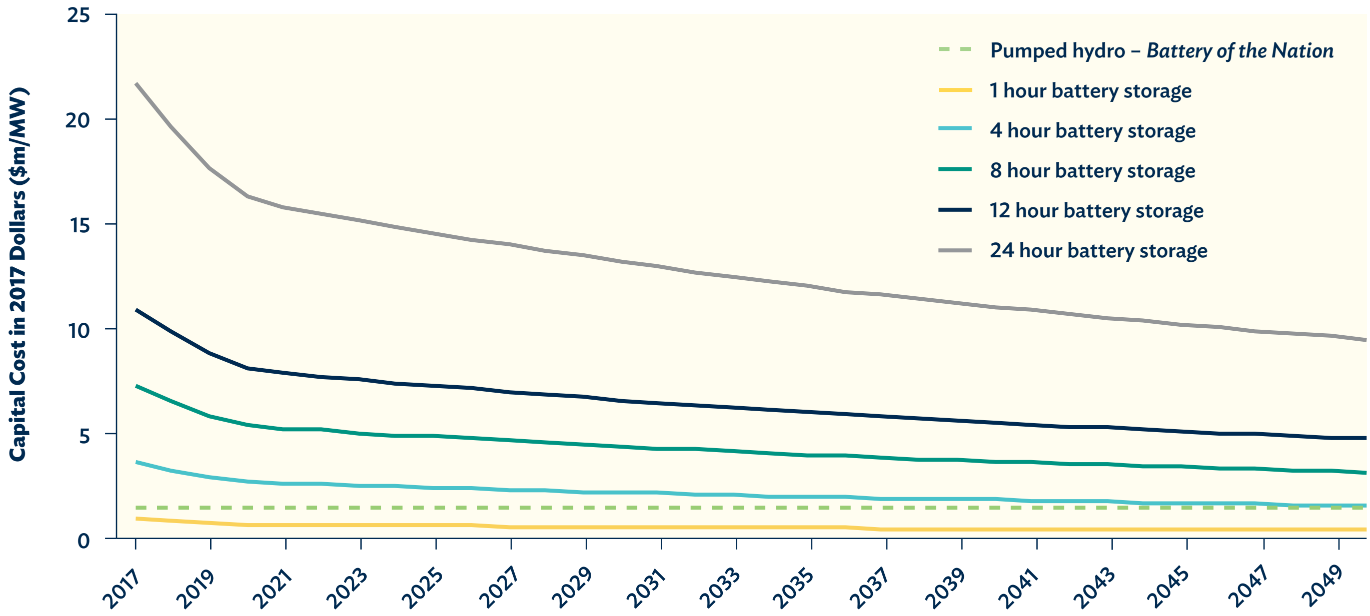

Figure 12. Capital costs for 40-year storage assets (future expenditure recognised, discounted at 7.5%)

The modelling showed that longer duration storages will be effective for system reliability. Even the largest storages were found to be fully operated and have value in the extremes of their operating range. Figure 13 shows a snapshot of the modelled operations for storages of different sizes. Each storage contributes to system reliability across different timescales.

Figure 13 highlights that solar-dominant states are likely to be well-served by storages that can capture energy over a six-to-eight hour period: storing energy during the daylight hours, and supplying energy during the night hours. States with substantial wind penetration (such as Tasmania, Victoria and South Australia) will need storage capable of storing days of excess generation and supplying energy to support the system during days of relatively low wind generation. The larger storages can (and do) store for longer and supply for longer – showing very different operational characteristics.

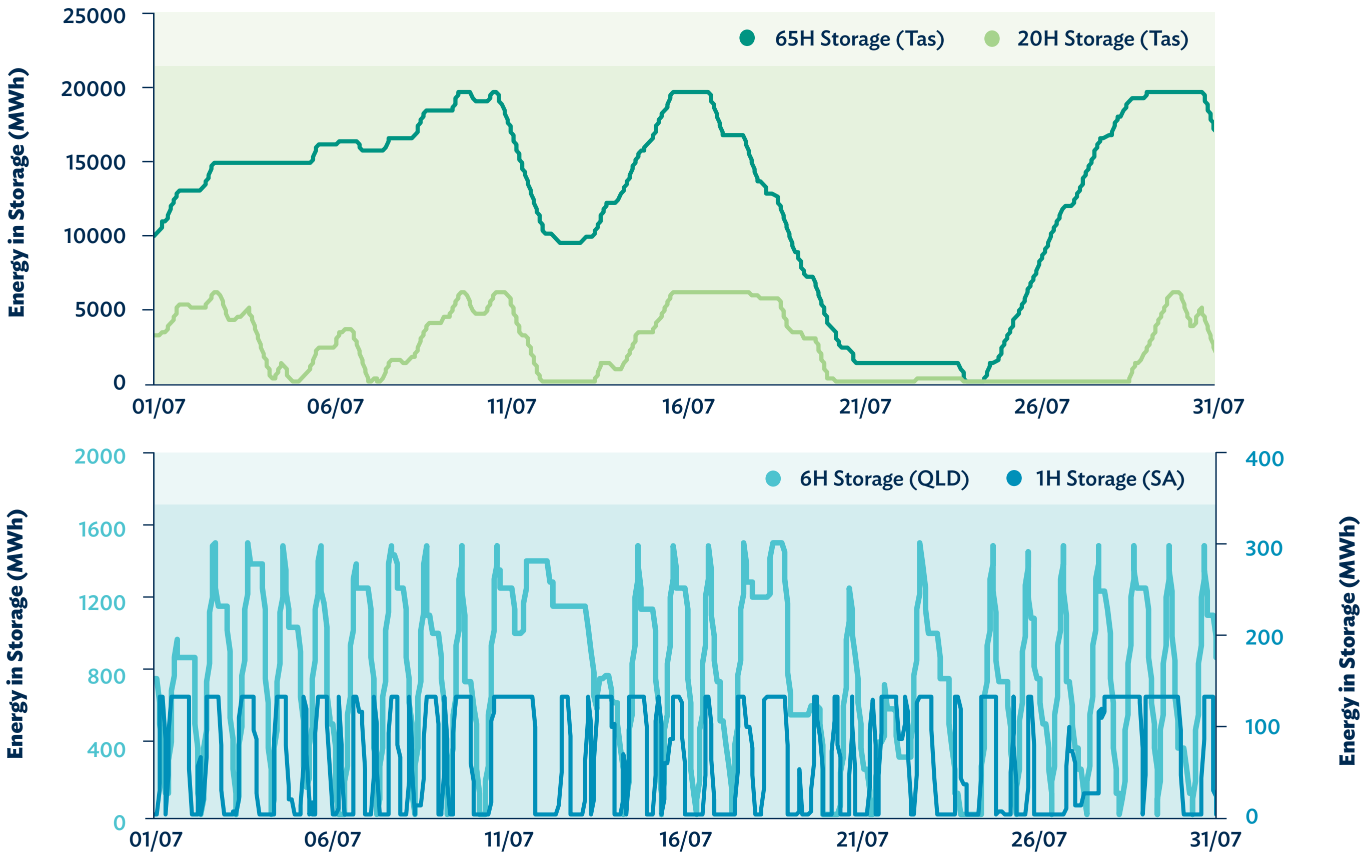

Figure 13. Sample month showing the contrast between storages of different duration


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Next steps

Timing is critical.

The *Battery of the Nation* development options provide a clear pathway to better system security, improved affordability and increased sustainability. While Tasmania has a number of substantial advantages, this opportunity is bound by time due to the long term nature of the investment planning and construction cycle. Retiring coal generation will need to be replaced over the next two decades and without careful and proactive planning, it will become difficult to displace operators and technologies that opportunistically fill the gap at greater long term cost to the market.

No single solution can meet the scale of the challenge facing the NEM.

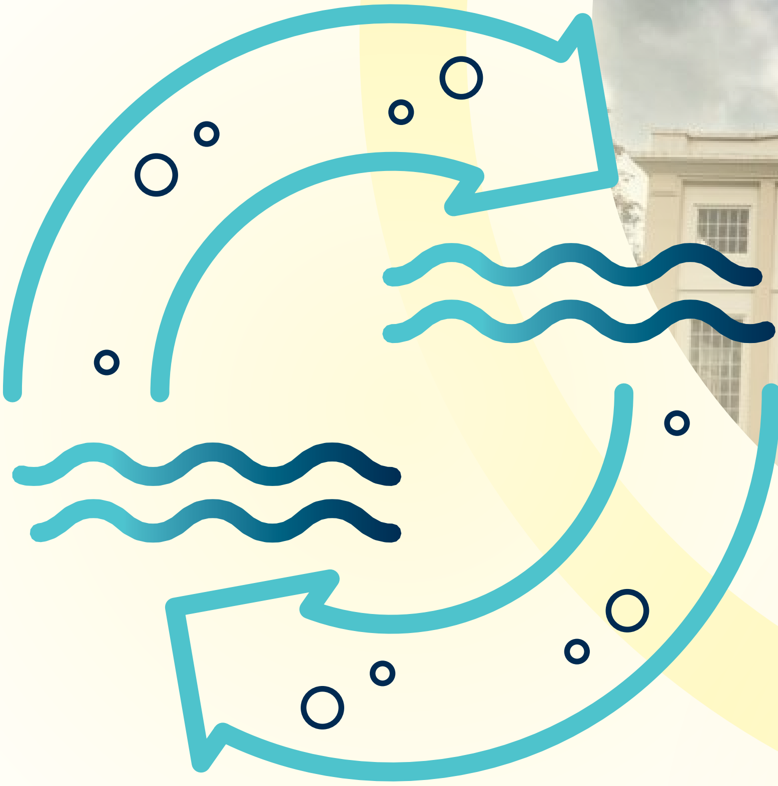
A range of technologies have a variety of strengths, and, if judiciously planned and incentivised, these strengths can be coordinated to best solve the energy trilemma in the national interest. The use of a combination of options is likely to result in an efficient outcome, with the ability to ramp-up investment in a strategically managed transition.

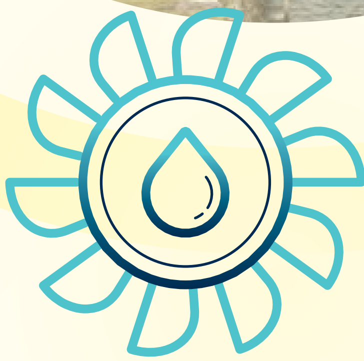
Reacting only to short term investment triggers will likely lead to suboptimal solutions driven by first-mover advantage. This could result in missed system opportunities and ultimately mean that Australia's energy economy is uncompetitive.

Similarly, investment without both economic and timing optionality can be ineffective as well. The ability to plan, bundle and fast-track efficient options for long term outcomes will better optimise Australia's national electricity system.

Energy security is a national issue built on a legacy of state-based assets and jurisdictions.

The accountability for energy security at a jurisdictional level is a strong influence in decision making. Controlling individual accountabilities is understandable, yet this will reduce the cross-regional optimisation from leveraging Australia's national resources and diversity of energy sources. All state jurisdictions have a major role to play to drive the new required development – collaboration and cooperation will be key to national success.





Next stage of the analysis

This report is the first stage of this investigation. During this first phase, a number of simplifications and assumptions were made due to the complex nature of the work. Further work is required to refine this analysis and understand the interplay between the Tasmanian development opportunities and likely mainland developments. Additional modelling will be required to further test sensitivities and assumptions and to improve optimisation against future market constructs. This will include supporting further assessment of the Tasmanian pumped hydro and existing hydropower opportunities.

The following themes will be further examined as part of the second phase of the Future State NEM analysis. Some elements may be undertaken as part of a coordinated national effort.

- ***Requirements for storage***

  In the modelling to date, the size of storage required is not yet optimised. Two characteristics need to be balanced in terms of storage – capacity and duration. Capacity is frequently discussed and understood in order to make storage work like generation – but duration is critical for system reliability and reserves. Industry reports suggest an extremely wide variety of answers to these questions, highlighting the uncertainty of the optimisation.

  To date, *Battery of the Nation* has established that its cost-effective pumped hydro energy storage will be competitive as part of a value-stacked renewable energy zone, but the national need for storage (and even the best size for individual projects) needs further analysis.

- ***Impacts on individual hydropower storages***

  The first stage of this analysis undertook high-level investigations of the impacts to Hydro Tasmania's existing hydropower schemes. Further study will be required by Hydro Tasmania to better understand site-specific interactions.

- ***Greater understanding of the required services and markets in the future electricity system***

  Better understanding of the physical services that the market requires, and the markets that will support the delivery of those services, is necessary. The interdependency of the underlying time series (demand, price, wind, solar, water/rain, storage etc.) makes this a complex issue to address. The services must support the physical operations of the system and the markets must allow for both price signals and risk management/hedging. The introduction of five minute settlements may further affect the services or the availability of those services.

- ***Management of an energy system with a high proportion of generation with $0 fuel costs***
  As the penetration increases of technologies with near-zero 'fuel' costs, new challenges arise in terms of capital investment planning since the 'floor-setting' short run marginal cost is essentially $0.

- ***Imperfect foresight***
  Most power system market models assume participants have perfect foresight over a certain time period. This assumption allows optimisation of the use of plant – storing energy at the lowest possible prices and supplying energy at the highest possible prices to maximise system value. However, with imperfect foresight, longer duration storages will have additional value, demonstrated in Figure 14. This element needs further examination.

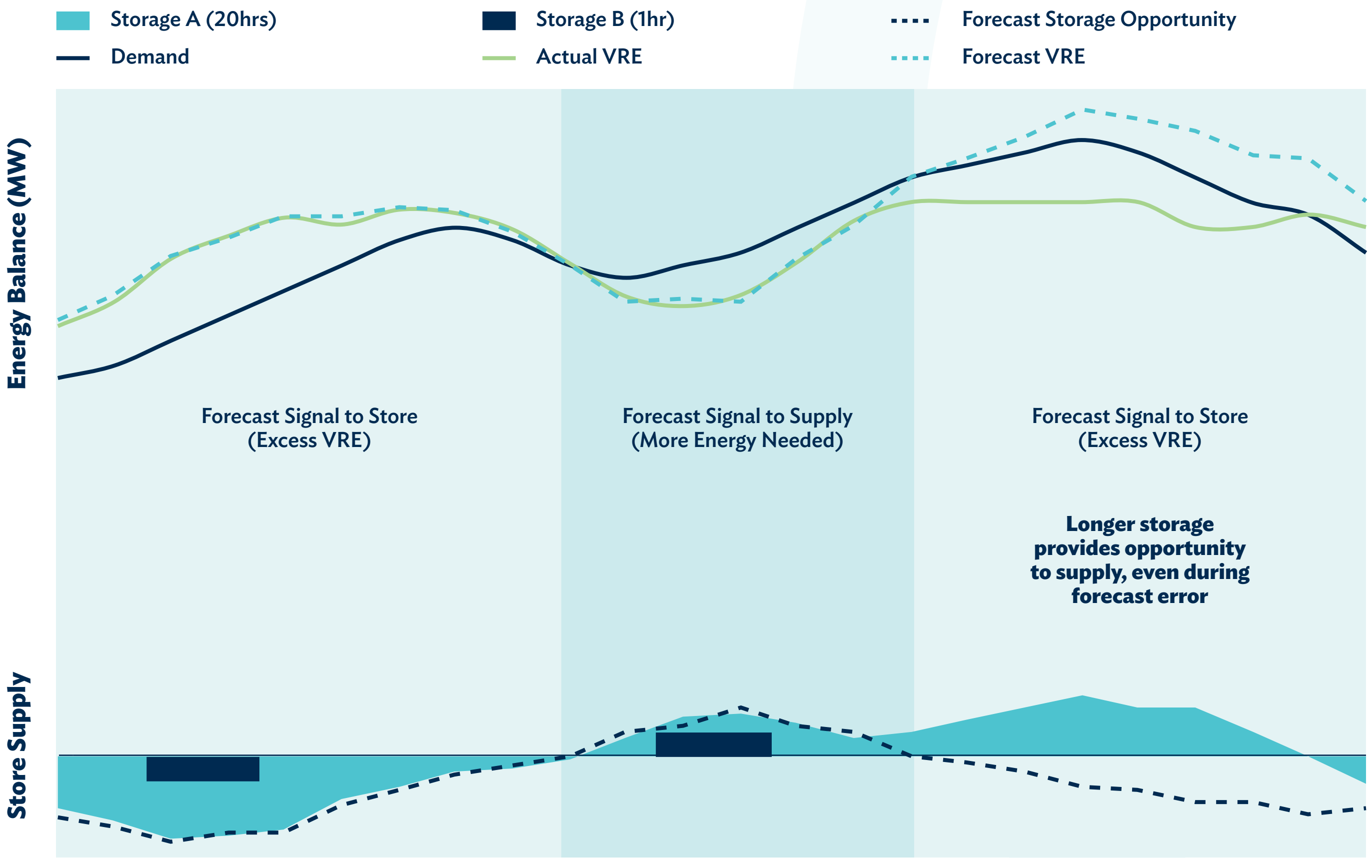


Figure 14. The impact of imperfect forecasts on storages of different size

- ***Valuation of the full set of services from High Voltage Direct Current (HVDC)***
  The full capabilities of latest HVDC transmission technology needs to be understood in the context of the services it can enable in the future market. This will impact the cost benefit analysis for studies of further interconnection between Victoria and Tasmania.

This report is only the first stage of the investigation. To better understand the case for a larger Tasmanian role in a future NEM, the analysis will continue to be developed from stage 1 (model, assumptions and scenarios) to define a clear case for Tasmania as a high priority renewable energy zone.

The formal assessment for the second Bass Strait interconnector has already commenced, which is a critical step on this journey and one that will continue to be supported by Hydro Tasmania.

Hydro Tasmania will continue to collaborate with the industry in working through some of the challenges that face the industry more broadly in this market transformation.

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