An analysis of the economics and greenhouse gas impact of Marinus Link and Battery of the Nation: 2021 update

A report prepared for the Bob Brown Foundation

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Executive Summary

This document updates our 2020 report "Marinus Link and Battery of the Nation: Wrong Way Go Back". The main conclusions of that report are that 1,500 MW of four-hour battery can be provided for less than half the cost of Marinus Link; that the same capacity of six-hour battery can be provided for 79% of the cost of Marinus Link and that 1,500 MW of eight-hour battery storage is still cheaper than Marinus Link.

In other words, even if Hydro Tasmania is able to provide, for no additional cost, 1,500 MW that it could export to Victoria day-in day-out for eight hours at a stretch for the foreseeable future, it will still be cheaper to build 1,500 MW of batteries in Victoria rather than to build Marinus Link. Of course the Tasmanian electrical system has no-where near the power or energy capability needed to provide 1,500 MW of supply to Victoria for 8 hours every day and so many billions will be needed to expand its storages and energy production in Tasmania in order to be able to provide the capacity that Marinus Link claims to offer.

In the year that has passed since that report was released, various things have changed. These changes reinforce our earlier conclusions:

- CSIRO's cost estimates (which we relied on for our battery cost estimates) have become even more favourable to batteries than their earlier estimates which we used.
- Several studies in other countries that point to the likely dominance of (chemical) storage in electricity decarbonisation have been published.
- Large investments in batteries have been made in Victoria and the list of highly prospective chemical battery projects has grown bigger.

Hydro Tasmania has not suggested it will be able to provide a storage service without incurring additional cost. Rather, it has suggested that the cost of Marinus and Battery of the Nation will be up to $7.1bn, which suggests that the cost of establishing the storage capacity (i.e. "Battery of the Nation") will be about $3.6bn – about the same as the capital cost of the Marinus Link cable needed to make that storage available to the main land.

But if Marinus alone is more expensive than eight-hour battery[1], how can it be the case that building Marinus plus spending a similar out to build storage capacity in Tasmania, can be preferable to building 1500 MW of batteries in Victoria?

A possible reason that Marinus and Battery of the National could be valuable is that long duration storage (i.e. longer than eight hours) is valuable. In its Project Assessment Conclusions Report, TasNetworks asserts that long duration storage is needed. However this is just assertion, TasNetworks provides no analysis or evidence to substantiate this. For example, TasNetwork has not analysed the Residual Demand from AEMO's Integrated System Plan data traces. Instead, TasNetworks "encouraged" us to extend our analysis of Residual Demand (in our 2020 report) to AEMO's Step Change scenario, from our analysis of the Central scenario in our previous report. Presumably, the intention was that by such "encouragement" we would come to a different conclusion than we had in our initial report.,

We have responded to TasNetwork's encouragement in this report and we comes to the same conclusion for the Step Change scenario as we came to for the Central scenario: there is no reason to believe that long duration storage will be valuable based on AEMO's projection of demand and production from variable renewable generation up to the end of the period it forecasts (i.e. to 2042). Furthermore, it is not even clear that either Hydro Tasmania or Marinus Link will be able to provide long duration storage (however they might define it). In absence of any evidence that there is a demand for long duration storage, or that Marinus Link and Battery of the Nation can supply it (whatever it might be), and in view of the compelling evidence that eight-hour battery is cheaper than Marinus alone, how can it be plausible to claim (as TasNetworks does) that Marinus will deliver benefits that exceed its costs?

As we set out in this update, our updated analysis and our original analysis of residual demand is consistent with the conclusions of major studies elsewhere. In particular, in this report we cite studies published in the last few months by the National Renewable

[1] TasNetworks has not disputed our analysis of this, though they chose to say that our analysis found that Marinus was more expensive than four-hour battery (which indeed it is, but it is also more expensive than eight hour battery).

Energy Laboratory and the United States Government's Department of Energy (DoE). Neither envisage that pumped hydro will have a big role to play in the decarbonisation of electricity supply in the United States. DoE in particular forecast that a fully decarbonised electricity system in the United States will involve the expansion of 2, 4, 6, 8 and 10 hour (chemical) battery capacity from their current capacities of 2, 1, 0, 0 GW in 2021 to 117, 393, 618, 212 and 336 GW by 2050 in the scenario that involves complete decarbonisation of electricity supply and also deep electrification of the United States economy. By comparison, pumped hydro capacity remains unchanged from its 2020 level of 23 GW in all scenarios except the complete electricity sector decarbonisation plus deep electrification scenario where it stays at 23 GW until the 2040s, and then expands to 26 GW by 2050.

Finally, contemporary developments in Victoria since our last report provide confidence that battery storage capacity will be built and operational in Victoria long before Marinus Link and the "Battery of the Nation" developments in Tasmania are close to operational. For example, in the 12 months since our report was published, the Victoria Big Battery (300 MW/450 MWh) was announced and will be commission soon. Another 300 MW/1400 MWh battery in Victoria has been announced for commissioning at Jeeralang by 2026. In addition to these, since our report was released there are now four more grid-scale batteries with aggregate capacity of 1,150 MW/3500 MWh that are not yet under construction but seem likely to proceed. Three of the five (80% of total capacity) are co-located with generation.

With the evidence that has come to light in the year since our previous report, we now feel able to conclude that not only does Marinus Link have no chance of competing with battery alternatives but that if Hydro Tasmania develops pumped hydro capacity in Tasmania it is very likely that, like Snowy 2.0, it will not be viable not least because it will be rarely used. This does not show in AEMO's modelling because that modelling assumes that Tasmanian pumped hydro capacity (and Snowy 2.0) will crowd-out battery development. But we have already seen investor response in the development of batteries, as cited above. It seems to be increasingly likely that necessary storage capacity in the form of chemical batteries will be operational long before pumped hydro capacity in either Tasmania or from Snowy 2.0 is operational. Considering the much higher

efficiency and responsiveness of chemical batteries than pumped hydro, if pumped hydro is developed in Tasmania it is surely likely that it, not batteries, will sit idle.

1 Introduction

This document presents an update to our 2020 report "Marinus Link and Battery of the Nation: Wrong Way Go Back". The main conclusion of that report was that 1,500 MW of four-hour battery can be provided for less than half the cost of Marinus Link. The same capacity of six-hour battery can be provided for 79% of the cost of Marinus Link and 1,500 MW of eight-hour battery storage is still cheaper than Marinus Link. In other words, even if Hydro Tasmania could provide, for no additional cost, 1,500 MW that it could export to Victoria day-in-day-out for eight hours at a stretch, it will still be cheaper to build 1,500 MW of batteries in Victoria rather than to build Marinus Link.

In the year that has passed since that report was released, various things have changed. These changes reinforce our earlier conclusions. This report draws on the evidence of these changes in responding to the arguments and claims that TasNetworks had made in its Project Assessment Conclusions Report, on our initial report. The next section sets out our response and a concluding section summarises the main points.

2 Response

2.1 Claim 1: VEPC concluded that four-hour storage is sufficient for the NEM

TasNetworks claimed that we concluded that four-hour storage is sufficient for the NEM. This is not correct. We did compare the present cost of Marinus with four- and eight-hour batteries and concluded that both were cheaper than Marinus alone. In other words, even if four- or eight-hour storage could be provided in Tasmania for no cost, it would still be more economical to build four or eight hour batteries in Victoria than it would be to build Marinus and comparable storage capacity (i.e., 1,500 MW capable of exporting continuously to Victoria for up to 4 or 8 hours).

2.2 Claim 2: A landmark study in California reinforces the findings in the PACR that Project Marinus has an important role to play given the future needs of a low carbon NEM

In the Project Assessment Conclusions Report (PACR), TasNetworks likens the pace of the energy transition in the NEM to that in California and draws attention to a "landmark" study that it says found "*an unequivocal and urgent need for significant deployment of long duration energy storage*", and that these findings "*reinforce the findings in this PACR that Project Marinus has an important role to play given the future needs of a low carbon NEM*".

Response

We examined the report[2] that TasNetworks referred to. It was prepared by a consultancy (Strategen) for an industry association, the California Energy Storage Alliance. We make the following comments on the outputs of this study:

- First, it does not seem to be reasonable to liken the pace of the energy transition in the NEM to that in California. The emission reduction target in California is GHG emissions from electricity production of just 33 mtpa CO_2-e by 2030 in the California Independent System Operator's area. This is in a power system that is around 50% larger than the NEM. A comparable emission target in the NEM would be around 15 mtpa by 2030 (about a 90% reduction from current levels). None of the jurisdictional governments or the Commonwealth is contemplating an emission reduction target in the NEM that is anywhere near this level.
- Second, it is not appropriate to liken long duration energy storage (LDES) to pumped hydro (as TasNetworks do). In fact, in the Strategen report, LDES is modelled using assumed capital and energy costs for 5, 10 and 100 hour storage "solutions". None of these are based on estimates of the costs of pumped hydro

[2] https://www.storagealliance.org/longduration#:~:text=California%20needs%2045%2D55%20gigawatts,45%2D55%20GW%20by%202045

storage (PHS). What the report classifies as "long duration" is therefore well within the range of commercially deployed chemical batteries.

- Third, the report found (base case) that only 1.9 GW of storage needed to be added to meet the 2030 target. Furthermore, almost exactly the same storage capacity needed to be added even if no LDES, i.e., 5 hour plus storage solutions were available. In other words, despite a far faster and deeper decarbonisation in California than in Victoria, the Strategen report does not conclude that LDES (as they have defined it) is needed.
- Fourth, in the period from 2030 to 2045 (by the end of which the target is net zero emissions), the Strategen report does show much more LDES. But in the Base Case, all of this is 10-hour storage and none of this is 100-hour storage. And, if they assumed that no LDES was available, their modelling predicts that by 2045, the total storage capacity to be added would be less than if LDES was available. They do conclude that total costs would be a little lower if LDES was available, but the gap is not big, and furthermore it is important to be clear that this reflects Strategen's LDES cost assumptions, none of which can be referenced to the costs of available technologies.

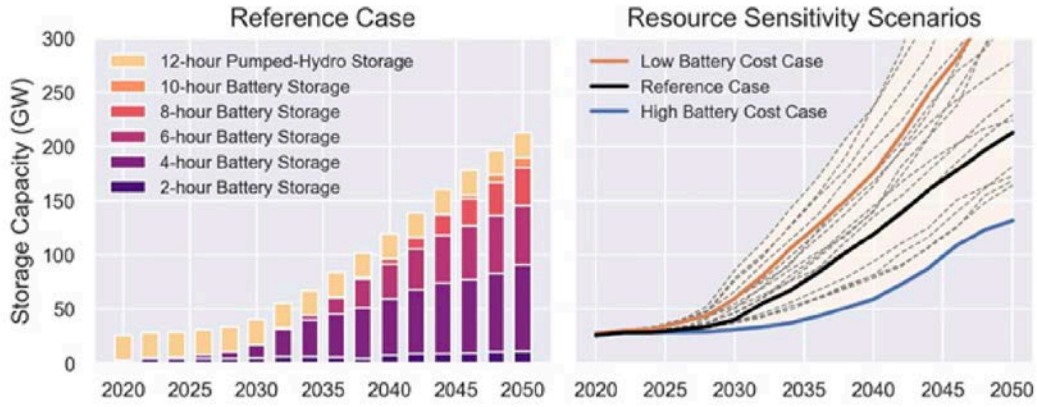
For these reasons, we do not think it is plausible to conclude, as TasNetworks has, that the Strategen report reinforce(s) the findings in the PACR that "*Project Marinus has an important role to play given the future needs of a low carbon NEM*".

Storage development has been studied extensively in California, what do these other studies find? The California Public Utility Commission sets the Reference System Portfolio which is to be used by all retailers that are required to file integrated resource plans. The Reference System Portfolio uses the California-wide GHG reduction target of 46 mtpa $CO_{2\text{-}e}$ by 2030. In their individual integrated resource plans, the retailers are required to show how their procurement to date, and planned procurement in the future, of electricity resources will help the state collectively meet this optimal portfolio and GHG target. The Reference System Portfolio is therefore the regulator's guide on what it considers to be the optimal resource development plan. Their base case projects that to meet the 46 mtpa target, 11.4 GW of battery storage will need to be added. This rises to 15.8 GW if the GHG target is 38 mtpa and to 19 GW if the target is 30 mtpa. No scenario projects that any more pumped hydro will be needed, except the 30 mtpa scenario, where

just 85 MW (i.e. 0.4% of the total storage demand) of pumped hydro storage is envisaged[3]. Evidently California's utility commission expects that battery storage will dominate storage development for their foreseeable future. To reiterate an earlier observation, in a comparison with the NEM the California GHG target by 2030 is comparable to a circa 90% reduction in GHG emissions in the NEM from their current levels.

Is the Californian projections of storage unusual in comparison to the rest of the United States? The National Renewable Energy Laboratory is publishing reports as part of its Storage Futures Study, a multiyear research project that explores the role and impact of energy storage in the evolution and operation of the U.S. power sector. Their recent study focussed on the economic potential of diurnal storage in the U.S. power sector (the vast bulk of the storage market is diurnal)[4]. The main results are shown in Figure 1 below. In this chart, we see not only that no pumped hydro is expected to be competitive in providing sub-12-hour storage, but some of the pumped hydro that currently exists will close.

Figure 1. United States storage capacity in the reference case by storage duration (left) and across all durations (right)



Source: Frazier, A. Will, Wesley Cole, Paul Denholm, Scott Machen, Nathaniel Gates, and Nate Blair. Storage Futures Study: Economic Potential of Diurnal Storage in the U.S. Power Sector. Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-77449. https://www.nrel.gov/docs/fy21osti/77449.pdf. Page vi.

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[3] California Public Utilities Commission, 2020. "Rulemaking 16-02-007 2019-2020 ELECTRIC RESOURCE PORTFOLIOS TO INFORM INTEGRATED RESOURCE PLANS AND TRANSMISSION PLANNING". Page 21.

[4] https://www.nrel.gov/docs/fy21osti/77449.pdf

For the Reference Case, the average storage duration is 6.2 hours. NREL also produce 18 sensitivity studies for various combinations of gas price, solar, wind, storage and transmission cost assumptions. None of these scenarios predict pumped hydro development and the average storage duration across all the scenarios ranges from a high of 6.9 hours to a low of 4.5 hours.

The United States Department of Energy also publishes projections of storage development. Specifically, the recently published "Solar Futures Study"[5] forecasts generation and storage to 2050 in the United States. It projects[6] that 2, 4, 6, 8 and 10 hour battery capacity will expand from 2, 1, 0, 0 GW in 2021 to 117, 393, 618, 212 and 336 GW by 2050 in the scenario that involves complete decarbonisation of electricity supply and extensive electrification of the economy. By comparison, pumped hydro capacity remains unchanged from its 2020 level of 23 GW in all scenarios except the complete decarbonisation plus deep electrification scenario where it stays at 23 GW until the 2040s and then expands to 26 GW by 2050.

Does the United States Energy Information Administration (EIA) have a view on storage? In its battery trends report[7], the EIA noted that battery costs have reduced by 72% over the five years to 2019, during which period capacity tripled. It projects battery capacity will grow by a factor of 20 between 2019 and 2023 and by a factor of 50 by 2050 in its Reference Case. It does not forecast any expansion in pumped hydro capacity.

Conclusions on Claim 2

We do not think it is plausible to conclude, as the PACR does, "*that the Strategen report reinforces the findings in the PACR that Project Marinus has an important role to play given the future needs of a low carbon NEM*". To the contrary neither the Strategen Report nor the National Renewable Energy Laboratory nor the U.S. Department of Energy nor the

[5] https://www.energy.gov/sites/default/files/2021-09/Solar%20Futures%20Study.pdf
[6] Ibid, page 214.
[7] https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf

Energy Information Administration provide reason to suggest that long duration energy storage through pumped hydro will be valuable. To the contrary, these organisations forecast that almost all additional storage capacity in the United States assuming full decarbonisation and deep economy-wide electrification by 2050 (i.e. 4,771 GW out of 4,774 GW) will be provided by chemical batteries of 10 hour duration or less, and two thirds of this will be provided by batteries with storage duration of 8 hours or less. In the full decarbonisation of electricity supply scenario, no expansion of pumped hydro (or other similarly long duration storage) is predicted. This is consistent with our analysis of the situation in Australia based on the demand and renewable energy traces from AEMO's ISP modelling set out in our initial report and extended in our response to Claim 3.

2.3 Claim 3: VEPC's analysis of Residual Demand is flawed

TasNetworks critiqued our analysis of the distribution of the 4, 12 and 24 hour moving average Residual Demands and the comparison of this to dispatchable capacity in Victoria in 2040. They had two main points:

(a) For the Central Scenario they said our analysis showed that diesel and open cycle gas turbines that have a typical capacity of factor of 5% "*are expected to perform the role of a dispatchable generator that is continuously generating for at least 24 hours*".

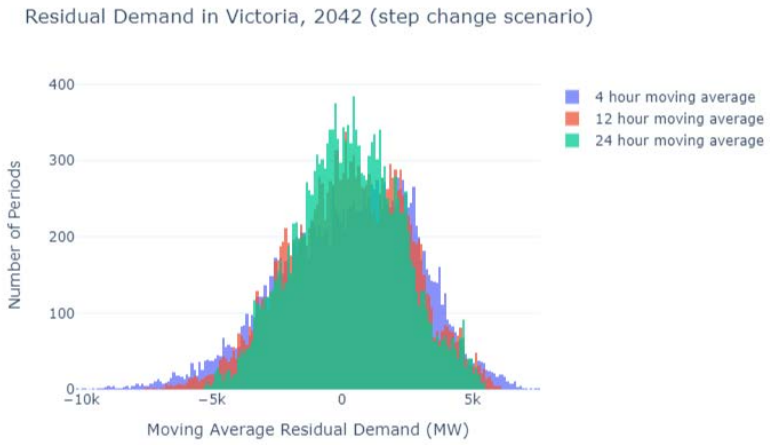
(b) That we should have analysed the Step Change scenario instead of the Central Scenario as we had done in our report.

Response

On (a), TasNetworks has misunderstood our analysis. There are only about 300 half-hours in the year in which the 24 rolling average Residual Demand is more than the expected capacity of coal and hydro generation in 2040. Meeting such Residual Demand is easily within the operating range of the open cycle gas turbine and thermal gas generation capacity in Victoria, and does not imply operating regimes for such capacity that are any different from what such plant is designed to do (and historically has done).

On (b), we have analysed the Residual Demand rolling averages under AEMO's Step Change scenario and using Development Path 2 (the only Development Path under which neither Marinus 1 nor Marinus 2 are developed). The result of this analysis is shown in the histogram in Figure 2 below.

Figure 2. Analysis of rolling average Residual Demand in Step Change scenario



Source: Data from AEMO ISP Step Change data traces, VEPC analysis.

Figure 2 shows a similar distribution of the 4, 12 and 24 hour rolling average Residual Demands in 2042. It is a similar distribution as we observe for the Central Scenario, but using the Step Change scenario and assuming Development Path 2 (the one Development Path that does not include Marinus Link). When we overlay the total amount of the dispatchable generation and storage in Victoria in the Step Change (Development Path 2) i.e. 9,976 MW, based on AEMO's ISP projections we see that there is even less chance of the Residual Demand not being met than there is in the Central Scenario.

This should not be a surprise. All that happens in the Step Change scenario with the Development Path in which Marinus is assumed to not be built (i.e. DP2), storage capacity and dispatchable generation is built in Victoria rather than in Tasmania.

Conclusions on Claim 3

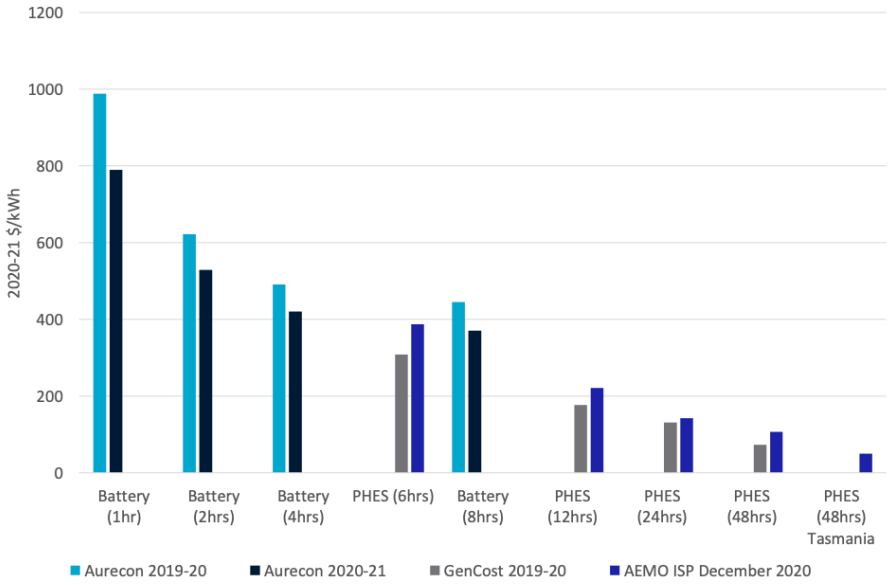
TasNetwork's critique of our Residual Demand analysis is not correct. They have misunderstood the histograms. In addition, their suggestion that use of AEMO's Step

Change scenario would result in a different conclusion to the conclusion of the Central Scenario is not correct, and their claim of the dispatchable capacity in the ISP is not correct. The conclusions in our initial report seem to be strengthened if we assume that electricity developments in Australia follow the Step Change scenario assumptions (and Marinus 1 and 2 are not built i.e. AEMO's Development Path 2).

2.4 Claim 4: CSIRO says that long-duration storage in Tasmania is at least 2 to 4 times more cost-effective than equivalent long-duration storage provided by batteries

TasNetworks cites a chart (reproduced below) from CSIRO's Gencost 2021 report[8] to support this claim.

Figure 3. CSIRO Gencost 2021 storage capital costs, stated per kWh of duration



Source: CSIRO, Gencost 2021.

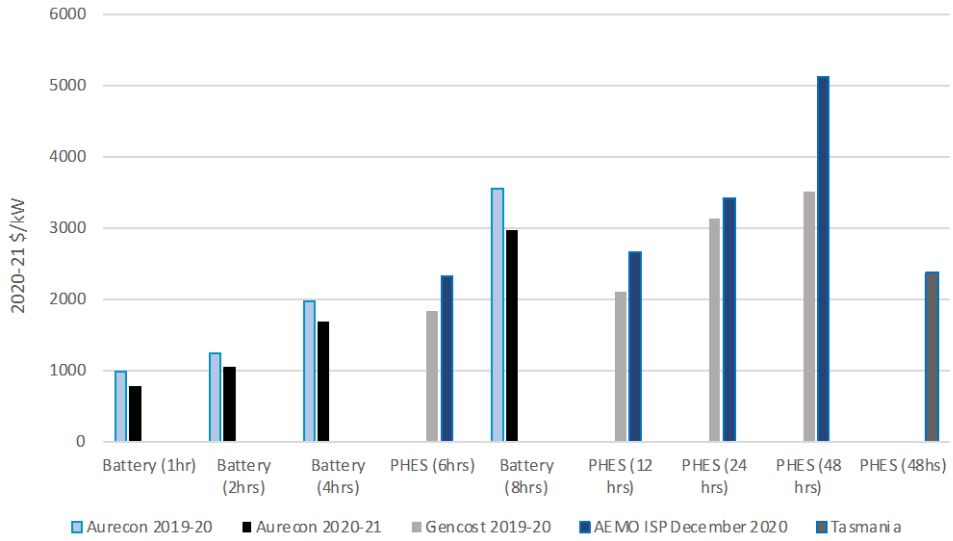
Response

TasNetworks seems to have misunderstood the information in CSIRO's chart. This chart simply expresses capital costs ($ per kWh of storage) as a function of the duration of each

8 https://www.google.com/search?q=csiro+gencost+2021&oq=csiro+&aqs=chrome.0.69i59j0i433i512j46i512j69i57j0i512j46i512j46i175i199i512j0i512l3.2255j0j4&sourceid=chrome&ie=UTF-8

storage type (i.e. how long the storage is capable of discharging at its rated capacity). The chart can be re-stated in $/kW simply by multiplying the capital cost per kW by the storage duration. Indeed, CSIRO did the reverse of this to generate their chart. The (original) chart is shown in Figure 3 below.

Figure 4.CSIRO Gencost capital cost stated per kW of storage capacity



Source: CSIRO Gencost 2021, VEPC analysis.

Using TasNet's logic, the chart presented in this way would suggest the opposite of their conclusion – i.e. that short duration storage is more "cost effective" than long duration storage. But this would be wrong the conclusion to draw from this, for the same reason that TasNetwork's conclusion on the transformed chart is wrong. It is impossible to draw any conclusion on cost-effectiveness from an analysis of capital costs alone. Rather "cost effectiveness" is a function of the unit cost of production for the market in which the technology competes. Its measurement requires information on capital costs, operating costs, asset life, residual value and utilisation. Conclusions on "cost effectiveness", as TasNetworks has drawn conclusions that are based on just one of these five variables.

In addition, we urge caution in the reliance on capital cost estimates for PHES in CSIRO's report. While battery costs can be reliably estimated – lots are being developed and their costs can be observed – pumped hydro is highly diverse. The existing PHES in the NEM (Tumut 3, Shoalhaven and Wivenhoe) differ greatly in their costs and capability. The one mainland PHES under development (Kidston) is likewise completely different to Snowy

2.0 or whatever PHES might ultimately ever be brought forward in Tasmania. A single PHES cost estimate can not plausibly be used as the basis for a general conclusion on the economics of PHES relative to its competitors.

2.5 Claim 5: AEMO say that Project Marinus is needed to meet customer needs at the lowest cost

TasNetworks claims that in its ISP, AEMO identified 'actionable ISP projects', and that projects are required to address an identified need which forms part of AEMO's optimal development path, or as TasNetworks says: "*projects (that) are needed to deliver the lowest cost solution that meets customers' electricity needs*". TasNetworks then note that AEMO said that: "*Marinus Link is a multi-staged actionable ISP project ... with early works recommended to start as soon as possible, and with further stages to proceed if their respective decision rules are satisfied.*"

The "decision rules" include either the Tasmanian Government legislating its renewable energy target ("TRET") or AEMO's "Step Change" or "Fast Change" scenario unfolding.

Response

It is not reasonable for TasNetworks to claim that AEMO says that Marinus is "needed to deliver the lowest cost solution that meets customers' electricity needs". AEMO does not say this. Neither is it correct to suggest that AEMO conducts any analysis that is able to lead to a conclusion on their part as to whether Marinus Link is "least cost" or that it is needed to meet customers' electricity needs.

3 Summary of the main points

This update to our 2020 report has reviewed various claims that TasNetworks makes in its PACR that:

(a) VEPC concluded that four-hour storage duration is sufficient for the NEM;
(b) Californian studies of long duration storage support a conclusion that Project Marinus has an important role to play in a low carbon NEM;
(c) VEPC's analysis of Residual Demand is flawed;
(d) CSIRO's estimates of storage capital costs support a conclusion that pumped hydro is two to four times more cost effective than batteries; and
(e) That AEMO says that Project Marinus is needed to meet customer needs at least cost.

None of these claims can be sustained:

(a) We did not suggest that four-hour storage duration is sufficient in the NEM.
(b) The Californian study TasNetworks quotes does not provide evidence helpful to Marinus Link. To the contrary, the Californian and American studies all seem to support a conclusion that chemical batteries will completely dominate storage supply in California and the rest of the United States.
(c) Extending our Residual Demand analysis to AEMO's Step Change scenario reinforces our conclusions that Marinus is not needed. TasNetwork's critique suggests that they have not understood the Residual Demand analysis or the calculation of dispatchable generation in the ISP.
(d) CSIRO's storage capital cost estimates can not, of themselves, be used to reach a conclusion on "cost effectiveness".
(e) AEMO did not say that Project Marinus is needed to meet customer needs at least cost.

Our 2020 report sought to evaluate the merits of Marinus by comparing it to the alternatives – open cycle gas generation or chemical batteries built in Victoria. We found it was not necessary to evaluate the cost of providing storage in Tasmania because

Marinus alone was more expensive than the alternatives, i.e., batteries in Victoria. TasNetworks has not challenged that fundamental conclusion.

In the year that has passed since our report, the official projections of battery costs have come down, Marinus' cost has gone up and pumped hydro cost estimates have gone up. Since our report was published, the Victoria Big Battery (300 MW/450 MWh) was announced and construction will be completed soon. Another 300 MW/1400 MWh battery in Victoria has been announced for commissioning at Jeeralang by 2026. In addition to these, since our report was released, there are now four more grid-scale batteries with aggregate capacity of 1,150 MW/3500 MWh that are not yet under construction but that seem likely to proceed. Three of the five (80% of total capacity) are co-located with generation.

Considering the now well-established trend of transmission, pumped hydro and battery costs and the evidence of investor response in the development of batteries, we suggest that the gap between Project Marinus and its competitors will continue to widen in future.

Our initial report focussed mainly on the economics of Marinus Link and this update confirms that Marinus Link continues to have no prospect of competing against battery alternatives in Victoria. More than that, with the information we analysed in the development of this update, we now feel able to conclude that if Hydro Tasmania develops pumped hydro capacity in Tasmania it is very likely that, like Snowy 2.0, it will not be economically viable. This does not show in AEMO's modelling because that modelling assumes that Tasmanian pumped hydro capacity and Snowy 2.0 will crowd-out battery development (if the Tasmanian Government and Australian Government force their development). However, contrary to this assumption, we have already seen private investor response in the development of batteries in Victoria and New South Wales. It seems to be increasingly likely that large amounts of storage capacity in the form of batteries will be operational long before pumped hydro capacity in either Tasmania or from Snowy 2.0 is operational. Considering the much higher round-trip efficiency and responsiveness of chemical batteries than pumped hydro, if pumped hydro is developed in Tasmania it seems to be quite likely that it will sit idle.