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Re: 2020 Planning and Forecasting Consultation

Dear Alex,

Tesla Motors Australia, Pty Ltd (Tesla) welcomes the opportunity to provide AEMO with feedback on its latest 2020 Planning and Forecasting Consultation Paper for the National Electricity Market (NEM). The transparent nature of AEMO's consultation process continues to be appreciated. It is clear that feedback is received openly by the AEMO team and meaningfully considered – a mutually beneficial approach for industry.

Tesla notes the importance of this consultation process – recognising the inputs and assumptions underpin AEMO's Integrated System Plan (ISP) and will drive outcomes in what is an influential document that not only acts to reflect existing policies but is also being used as a credible reference for policy decision making going forward.

As such, Tesla's submission focusses on improving inputs relating to the integration of storage in the NEM, noting a significant lack of utility-scale battery storage has been included in the draft 2020 ISP modelling outcomes – a clear disconnect from the consensus view that it has a critical role to play supporting the transition to an efficient, secure and low-emission future NEM.[1]

For the 2020 planning and forecasting update, Tesla recommends:

- **Updating input costs for storage** – to reflect the latest pricing noting AEMO's 2020 capital cost forecasts are still too high for batteries. We are already observing AEMO's forecast 2030 battery storage prices for projects occurring today. AEMO appear to be relying on inputs that place battery storage at the upper bound of pricing intel (even before accounting for variances in regional siting or installation cost assumptions). Fixed operating cost assumptions for battery storage are also higher than observed costs. In contrast, pumped-hydro assumptions do not reflect the practical challenges of deployment or operational availability and need to incorporate related risk-premiums. Tesla would be happy to work with AEMO and CSIRO/Aurecon to support refinement of pricing assumptions as appropriate.

- **Incorporating market-reflective value potential** - AEMO's modelling must consider the additional capabilities and flexibilities beyond energy generation provided by both stand-alone battery storage (e.g. ancillary services, inertia contributions and system security benefits) as well as hybrid battery

[1] see Aurora analysis: http://www.auroraer.com/insight/storage_economics_in_the_nem/; Bloomberg NEF: https://about.bnef.com/blog/australia-shows-regulated-utilities-can-storage/; PWC: www.pwc.com.au/power-utilities/future-of-energy/future-of-energy.pdf; ARENA: https://arena.gov.au/renewable-energy/battery-storage/; CSIRO: www.csiro.au/en/Research/EF/Areas/Grids-and-storage/Energy-storage; ACOLA: https://acola.org/wp-content/uploads/2018/08/role-energy-storage-future-australia.pdf; Finkel Review: www.energy.gov.au/sites/default/files/independent-review-future-nem-blueprint-for-the-future-2017.pdf; ESB post 2025 work: http://www.coagenergycouncil.gov.au/; AEMC: www.aemc.gov.au/news-centre/media-releases/coordination-generation-and-transmission-investment-review-update; and AEMO's own commentary: https://aemo.com.au/news/battery-storage; EGES rule change; and REIS study

assets when paired with renewables (e.g. reduced curtailment, improved marginal loss factors, reduced causer pays liabilities). This will more accurately reflect the role and value of battery storage and better map to actual and expected market behaviour relative to other generation plant, without simply relying on oversimplified capital cost comparisons based on energy related costs ($/kW or $/kWh) - which should be used with caution for informing investment decisions (or credible system modelling).

- **Technology neutral approach -** If AEMO progresses with the existing methodology that does not accurately capture these broader market and system benefits, we recommend the ISP returns to a technology neutral approach that reflects storage characteristics (i.e. 2, 4, 6-hour duration categories) rather than technology types. New storage built will then be driven purely by commercial factors, rather than potentially influenced by a pre-determined technology outcome.
- **Adjusting technical parameter assumptions** – AEMO's assumptions for battery duration, RTE, state of charge, build lead times, and asset life can be updated to reflect the latest battery storage properties being achieved by industry today – noting these will only be improved upon for in future deployments. AEMO should also include a 6-hour battery input to remain technology neutral.
- **Clarifying updates made for the 2019 EV assumptions and better reflecting current trends** – in particular working with industry to improve the accuracy of uptake figures, charging types, charging profiles and total energy consumption forecasts for EVs being used in the modelling.

Tesla notes the additional analysis and consultant reports focused on DER uptake and supports AEMO's approach on aggregated batteries and the inclusion of VPPs as a source of general market supply akin to grid-scale storage, but this should not substitute for the entire role of grid-scale battery storage deployment.

Updating capital costs for storage

Tesla supports the approach to revise the CSIRO/GHD GenCost 2018 figures and to iterate new entrant cost curve assumptions with Aurecon to reflect latest available market data. As with any consultative process, and particularly for technologies seeing rapid innovation in manufacturing, design and deployment, these cost models must be compared against the latest pricing being seen for real-world projects being constructed around the world. ***(please refer to our confidential attachment)***

The forward outlook on price declines appears to be based on a reasonably linear curve, with over 60% capital cost reductions out to 2040. Forecasting technology costs is a complex task and typically under biased to what plays out in reality. At a minimum AEMO should update the starting figures for pricing, with additional cost reduction outlooks factored into the different scenarios. It is also unclear why the fast, high-DER and step change scenarios have higher battery storage cost assumptions than the central and slow change scenarios - when it would be more likely to have higher levels of deployment driving additional cost reductions in battery storage projects being integrated into the NEM.

Given the results of the draft 2020 ISP shows a significant lack of utility scale battery storage capacity being developed (across all scenarios and States) - inconsistent with observed market outcomes, Tesla strongly recommends AEMO re-open its inputs for sensitivity testing with updated capital cost (and technical parameter) inputs – as battery storage assets have already demonstrated their competitiveness (in real-world deployment scenarios) against other generation assets currently being substituted in AEMO's ISP modelling, most notably pumped hydro storage and peaking gas generation. Alternatively, AEMO could present storage requirements based on duration characteristics rather than technology types to ensure technology neutrality – letting the market decide based on real-world value potential. Failing to recognise the role of grid-scale batteries could undermine credibility of the broader ISP and severely damage the business case for battery storage in the NEM. This may influence government and developers in selecting particular technologies due to the perception they are lowest cost.

ISP Modelling Methodology - Incorporating the full value potential of battery storage

Battery storage has already demonstrated its ability to provide a broad range of services – both when co-located with renewables, and as a stand-alone, fast-response, flexible asset. When paired with renewable assets, battery storage can provide 'firming' of the renewable generation output and as such, by increasing flexibility and optimising connection agreements, storage will increase the amount of renewable energy that can be exported into the network and minimise the amount being curtailed. For new projects, this means direct benefits of facilitating connection in congested areas, a higher return in revenue from the renewable generator, as well as several secondary benefits such as the ability to sell the 'firmed' energy in blocks back to the market, and the ability to mitigate dispatch imbalances and associated charges (i.e. causer pays factors - regulation contribution charges that apply when dispatch limits are exceeded). AEMO's current approach to ISP modelling appears to neglect the contribution of these values, despite increasing interest in exploring market mechanisms that will recognise them in practice.

AEMO must also consider the additional capabilities and flexibilities provided by battery storage assets, such as ancillary service and system security benefits. For storage, market participation is fundamentally an opportunity cost assessment – using dispatch models and forecasting software to optimise when, in what markets, and how much to bid the limited energy capacity that is available in order to maximise returns. This is where fast-response battery storage allows for greater flexibility in market bidding strategies across both energy and ancillary service markets to maximise project revenues ('revenue stacking'). Whilst strategic bidding and commercial drivers may not be explicitly captured in AEMO's modelling, these additional revenue opportunities can at least provide an indication of the flexibility of the role battery storage can provide in the fully co-optimised NEM.

More specifically, to ensure a credible model of future generation capacity, AEMO must find a way to incorporate the full range of potential ancillary service benefits of battery storage, beyond solely energy generation. For example, an alternative approach could include reducing the upfront capital cost of battery storage deployments by a 'factor' to reflect that some portion of the asset will paid for and used by network utilities (for network services), whilst the remaining capacity can still be market facing and provide energy and frequency services.

- As acknowledged by both AEMO[2] and Aurecon[3] independent assessments, battery storage can support stable grid frequency through the provision of a 'premium' regulation frequency control ancillary service (FCAS) – offering flexible, more accurate and faster performance in following control signals to continually counteract frequency deviations during normal operating conditions.
- For future developments, it is expected that the value of the firming and system security services will only increase as more thermal generators retire and the penetration of variable renewable energy (VRE) increases. Market changes will be made to incentivise and reward all fast acting and flexible frequency, voltage and inertial responses that battery storage can offer. Over time, these non-energy services should increase their proportion of the value stack, particularly as non-traditional network support services and grid infrastructure deferrals are able to be monetised, and as regulatory reforms unlock more appropriate markets to value the services being provided.
- It is also unclear whether inertia contributions are being captured. Ancillary services should include the ability for battery storage to provide 'virtual inertia' – as currently being demonstrated to AEMO, particularly as these input assumptions ultimately support a forward-looking forecast of the NEM.

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2 https://www.aemo.com.au/-/media/Files/Media_Centre/2018/Initial-operation-of-the-Hornsdale-Power-Reserve.pdf

3 AURECON, 2018: www.aurecongroup.com/markets/energy/hornsdale-power-reserve-impact-study

Market revenue sufficiency

This broader scope of modelling methodology will be increasingly important as market reforms progress to reward faster and more accurate services likely to be of 2 to 4-hour duration (e.g. the design of primary frequency incentives being developed by AEMC following AEMO's rule change proposal, 5-min settlement in 2021). This should also be increasingly recognised by the market as AEMO's own systems evolve to keep pace with the technical capabilities of increasingly flexible and fast-response assets.

From a revenue sufficiency basis, for daily (high frequency) market participation – fast response batteries can stack multiple services and optimise dispatch. For example, Hornsdale Power Reserve's 140ms response time and 90% round trip efficiency increase revenue by enabling participation in more markets (FCAS) with lower charging costs. In contrast, for bulk (i.e. monthly or seasonal) storage beyond 5 to 6 hours in duration – pumped hydro may hold advantages, but wholesale pricing spreads still make the commercial case challenging, with return on investments forecast to take decades (initial market modelling demonstrates that there is very little marginal return in oversizing duration capacity beyond 5 hours - as investments will not be commercial).

Non-network solutions

The Draft ISP does consider non-network alternatives, however only PHES is mentioned. In practice, we are already seeing RIT-T assessment of grid-scale battery storage as non-network alternatives. For example, the recent NSW-QLD PADR[4] for upgrading QNI transfer capacity included two credible options of a virtual transmission line comprising battery systems (no pumped hydro was included). The top-ranked battery option had the greatest estimated gross benefit of all options including proposed network upgrades but was ultimately not selected based on other factors including cost allocations, commercial models and government funding commitments.

Given the work being undertaken to create an actionable system wide plan, guidance provided by the 2020 ISP will be critical in supporting future assessments by transmission networks and as noted above, should focus on storage characteristics rather than pre-determining technology types.

Scenario / Sensitivity Analysis

An alternative methodology approach for the ISP is for AEMO to consider expanding its decision-making criteria (even for a selection of scenarios) so that wider policy inclusions and storage asset deployments can be more appropriately included:

- Government policy initiatives – we note AEMO has allowed for degrees of freedom when including various government funding and policy announcements. Our recommendation is to include a wider (i.e. less conservative) range of policy mechanisms in some scenarios, even if they have not been legislated yet or policy design is undefined, as these policies will still have significant impact on new build capacity in the new term – particularly for storage. This is already being demonstrated by recent announcements in NSW and Victoria following the summer bushfires – where deployment flexibility becomes more critical in driving the generation mix and network build timeframes.

- Battery storage deployments - Tesla estimates that 240MW of grid-scale battery storage has already been commissioned in the NEM (with a strong pipeline of further MWs currently under construction, with financing decisions made, or publicly announced projects at varying levels of planning stages). In contrast, AEMO's Draft ISP models 215MW of grid-scale battery storage declining to 110MW (as assets reach end of life and are not replaced with future projects) with no growth pipeline for any scenario. Noting that satisfying AEMO's commitment criteria before being included as an 'operational asset' is less suited for battery storage than traditional thermal plant, AEMO could consider modelling some scenarios with alternative commitment thresholds for battery projects.

[4] https://www.transgrid.com.au/what-we-do/projects/current-projects/ExpandingNSWQLDTransmissionTransferCapacity

Technical Parameters

Tesla supports AEMO's transparency and commitment to continually update assumptions around battery properties to more accurately reflect the capabilities of the latest battery technologies (see Figure 3 below). However, AEMO's numbers are still conservative. We note that investment models are often based on lower bound parameters to ensure downside risk is protected, but for AEMO's purposes – i.e. modelling the future integration of battery storage from 2020 and in the decades beyond - we recommend including the latest properties being achieved – as these will undoubtedly be improved upon for any future deployments.

Taking each in turn, Tesla recommends:

- Uplifting the round trip efficiency (RTE) to up to 90% in total – i.e. accounting for both charging and discharging efficiency, and applying for both utility and aggregated assets. Tesla can provide AEMO with technical specification sheets to support updating this assumption if required.
- Extending both the economic and technical life of battery storage – to reflect the increasing length of project contracts and warranties being offered in the market. It is important to note that asset lifetimes are often based on a guaranteed energy provision warranty from manufacturers, where the market is already seeing a shift to 15-year warranties being offered as standard, and up to 20 years as an option. Moreover, beyond this lifetime, storage assets are not worthless and will still be able to provide value to the market, albeit with declining levels of energy. This should be equivalent to assumptions made around ageing coal and gas plants that are likely to see increasing levels of full/partial outage rates and expanding de-rate factors prior to retirement.
- Lowering total lead time for battery storage projects to less than 1 year – as already demonstrated by Hornsdale Power Reserve, and subsequent grid-scale projects that are seeing commissioning occur within 10 months (in contrast it is interesting to note the more optimistic timeframes presented for PHES to have a total lead time of 6 years, despite ongoing environmental and grid-connection delays evidenced by current projects that are forecasting much longer time frames).
- Expanding the state of charge range to maximise the value of stored energy (and provide a fairer comparison against pumped hydro projects that could have similar constraints at the edges of charge capacity – depending on their application).

Figure 3: AEMO battery storage assumptions vs Tesla recommendations

Property	Battery storage (2hrs)	Battery storage (4hrs)	VPP (aggregated ESS)	Tesla recommendation	Unit
Maximum power[1]	1	1	1	**1**	MW
Energy capacity	2	4	2.6	**2 / 4 / 6**	MWh
Round Trip efficiency (aggregated)[2]			85	**90**	%
Charge efficiency (utility)	90	90		**85 - 90**	%
Discharge efficiency (utility)	90	90		**100 (included in charge %)**	%
Round Trip efficiency (utility)	81	81		**85 - 90**	%
Economic life	10	10		**15**	years
Technical life	15	15		**20+**	years
Total lead time	2	2		**<1**	years
Allowable Max State of Charge	90	90	90	**100**	%
Allowable Min State of Charge	10	10	10	**0**	%

Duration capabilities

Again, turning to the results of the draft 2020 ISP, AEMO's model appears to centre on duration capacity requirements (ignoring value potential), with forecast storage capacities found to be largely 6-hour PHES (with over 6GW built in the central optimal development pathway scenario). To provide technology neutral analysis, and given the scalability of battery storage, AEMO should include a 6-hour battery storage option, which at a high level can be taken to be equivalent to 4-hour battery $/kWh system costs – making it competitive against realistic $/kW assumptions for 6-hour PHES (before controlling for viability of deployment as outlined above). Ahead of re-modelling to include system services and benefits beyond energy, AEMO could define storage as a single category based on duration only (and not split out batteries from pumped-hydro at the grid scale) - to ensure the market drives suitable investment decisions without prejudice from ISP forecasts.

Accelerating Electric Vehicle impacts

Given Tesla's leading experience in designing, manufacturing and deploying EVs globally, we would be happy to further engage with AEMO and provide supporting data that can inform NEM modelling to more accurately reflect the grid-integration of EVs in Australia.

At a minimum, it would be beneficial for AEMO to clarify what appear to be inconsistencies with the EV assumptions used previously. Comparing the latest inputs with 2018 figures – the EV assumptions appear to have changed drastically over the past year. In particular, EV uptake figures (defined as "number of EVs in use") shows the following declines in EV uptake relative to previous modelling:

Figure 4: AEMO EV assumptions 2018 vs 2019

Electric Vehicles (Uptake, Number of EV's); Central scenario; NEM-wide	2018	2019
2019-20	61,916	9,339
2024-25	438,707	100,470
2029-30	1,621,109	729,009
2034-35	3,433,820	2,237,724
2039-40	unmodelled	4,786,393
2044-45	unmodelled	6,845,056
2049-50	unmodelled	8,439,116

It would be instructive to understand what is driving this change in the NEM outlook on EV uptake, as it appears inconsistent not only with AEMO's previous forecasts, but also relative to global expectations (e.g. it is not clear whether AEMO's 2019 figures were intended to reflect number of new annual EV sales, rather than the cumulative total EV fleet).

Tesla is happy to leverage its data from on-road EVs to support AEMO's forecast assumptions around energy consumption (total GWs), charging type (e.g. the split between residential daytime vs highway vs convenience charging), as well as the charging profile data from our extensive charging network (noting these last two elements can be highly dependent on location as well as the definition of EVs and whether AEMO is also including plug-in and hybrid models). It is also not clear whether any dynamic charging profiles are introduced to reflect time-based charging or evidence the demand management capabilities of EV charging currently, let alone the decades to come.

Conclusion

Tesla looks forward to continued engagement on these items and actively participating in ongoing discussions to support AEMO in the development of its planning processes, across both battery storage and EV matters. For further information on any of the points raised please contact Dev Tayal (atayal@tesla.com) with any questions.