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Submission to AEMO 2025 ISP Methodology Consultation

100% Renewable Energy Group (Australian National University)

Overview

The 100% Renewable Energy Group (RE100 Group) at the Australian National University (ANU) is responsible for developing and maintaining the Global Pumped Hydro Energy Storage Atlases (the "Global PHES Atlases" or "the Atlases"). This submission is made in addition to our submission to the ISP Methodology Issues Paper[1] and should be read in conjunction with that report.

1. **Pumped hydro cost is significantly overestimated**: We identify a serious problem in the GenCost2024-25ConsultDraftApxTables_20241127: a substantial overestimation of the capital cost of pumped hydro energy storage, arising from modelling lower-quality sites and ***overlooking the hundreds of premium-quality Cost Class AA sites*** near strong transmission between Brisbane and Melbourne. The GenCost model cost is substantially higher than the published cost of Snowy 2.0 and the Aurecon cost estimate of a Class AA site near Dungowan.
2. **Lack of full chronology modelling seriously distorts technology choices:** The maximum modelled storage duration is only 48 hours. This is inconsistent with Snowy 2.0 (duration of 160 hours). The 48-hour figure appears to arise from the absence of full chronological analysis of solar, wind and demand, hour by hour over decades. Sampling does not find extended periods of low solar and wind availability (as occurred in mid-2004). Instead, sampling favours short-term solutions (such as OCGT) and overlooks the lower-cost solution of long-duration (>100 hours) pumped hydro. As discussed below, 2-day and 4-week sampling **results in zero or 500 GWh** respectively of pumped hydro being deployed. Full chronology may produce even larger effects.

Sampled Chronology in SSLT

The way storage is modelled chronologically is a key issue in determining optimum storage deployment[2]. To estimate the effect this may have in the context of the NEM, the 2024 ISP Model was modified and simplified in PLEXOS to evaluate the impact of sampled chronology settings on storage and gas deployment. The following modifications were made:

- Single step optimisation from 2042-2052 with sampled chronology (tested 4 weeks per year and 2 days per month settings);
- Removed generator and battery properties related to maintenance;
- Evaluated as a point-in-time rather than capacity expansion model (i.e., max build limits constrained to be zero after 2042, modified demand trace to be equivalent to 2052 demand for every year);
- Removed all generators that are not solar PV, wind, new entrant OCGT (large), and hydro;

[1] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2026-isp-methodology/submissions/anu.pdf?la=en

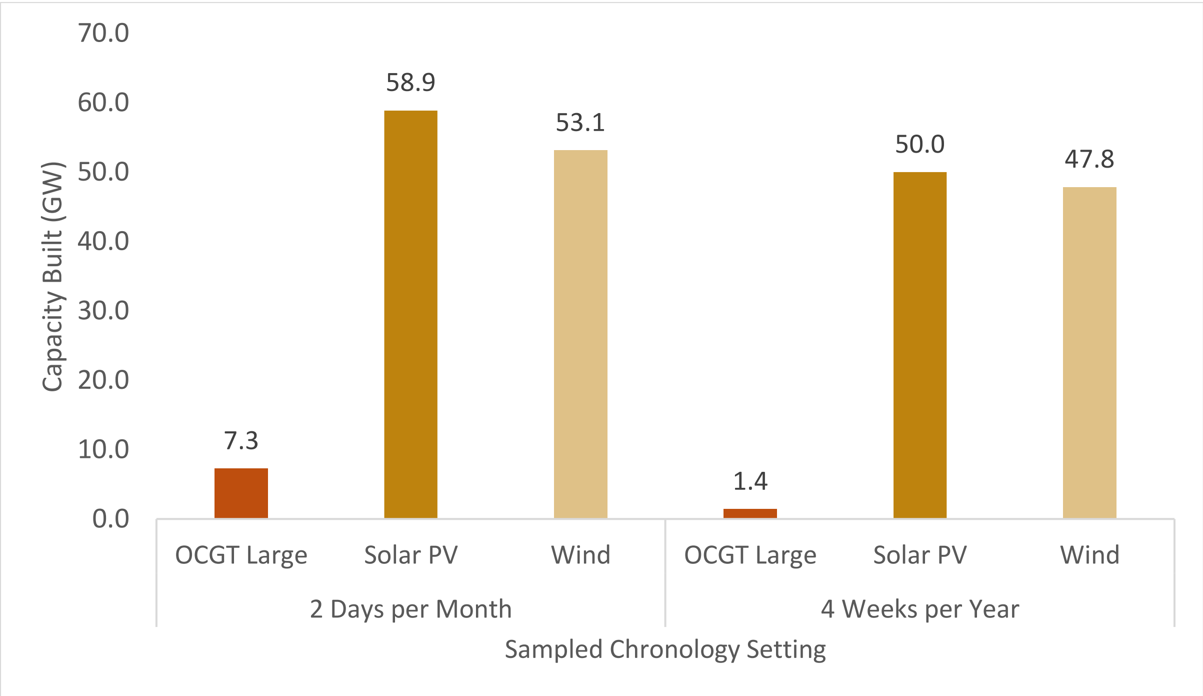
[2] Levin et al. "Energy storage solutions to decarbonize electricity through enhanced capacity expansion modelling". *Nature Energy* 8, 1199–1208 (2023). https://doi.org/10.1038/s41560-023-01340-6

- Simplified transmission min and max flow limits by only using the least-constrained 2052 limits (i.e., winter flow limits);
- Simplified pumped hydro systems to be based upon battery objects rather than storage and generator objects. Hydro max energy constraints added for modified objects;
- Set max build limit for OCGT (large) to 15,000 units (i.e., 15 GW per subregion) and batteries to 50,000 units (i.e., 50 GW per storage duration per subregion). Pumped hydro max build limits were not changed from original ISP model, though these constraints ought to be substantially increased as discussed in our submission to the ISP Methodology Issues Paper[2];
- Removed constraint objects, other than hydro max energy.

Note that this model has been simplified so that it is easier to evaluate the impact of the sampled chronology assumption, without muddying the waters through complexity introduced by other aspects of model design. As a result, the actual capacities calculated by the model are not directly comparable with the ISP results, but they do give an indication of the large effect of using a sampled chronology assumption.

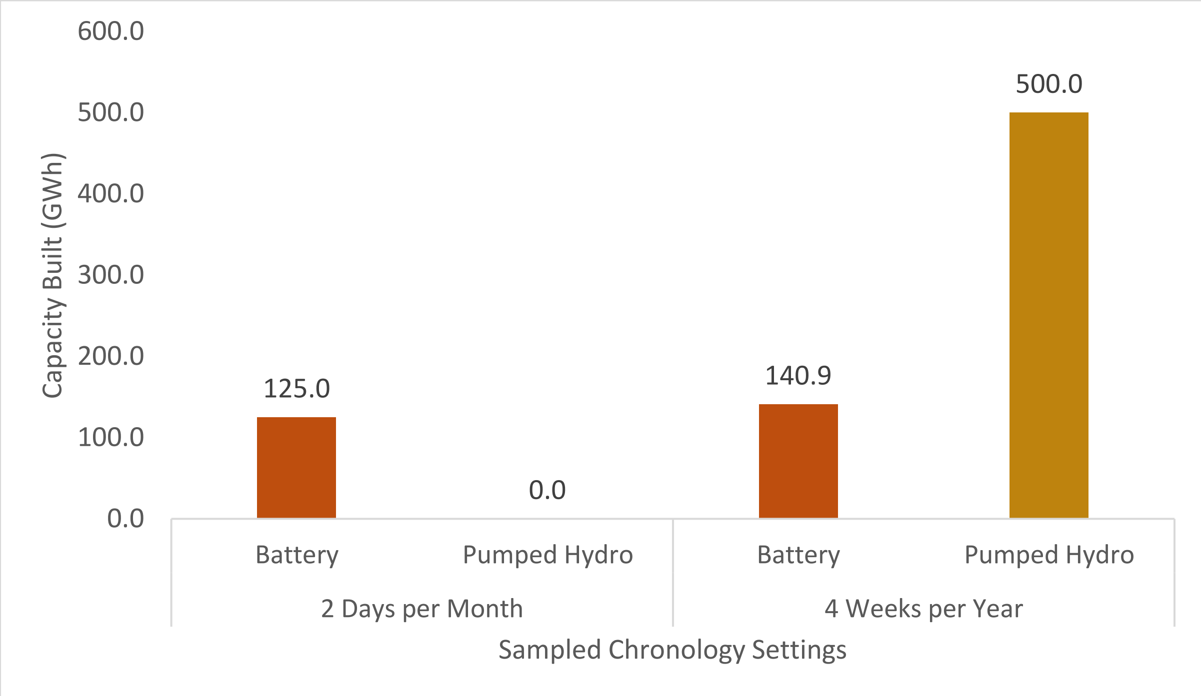
Figure 1 shows that a sampled chronology setting of "2 days per month" (the setting referenced in the Draft ISP Methodology – 2.4.2 Representation of demand and VRE profiles) results in approximately 6 GW more gas being built by the model than a setting of "4 weeks per year" (the default PLEXOS setting). Figure 2 shows that a sampled chronology setting of "2 days per month" results in no pumped hydro being built, but a setting of "4 weeks per year" produces 500 GWh of pumped hydro. This is a substantial difference using just two sampled chronology settings.

Figure 1. Generator Capacity Built with Different Sampled Chronology Settings



[2] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2026-isp-methodology/submissions/anu.pdf?la=en

Figure 2. Storage Capacity Built with Different Sampled Chronology Settings



The 4 weeks per year setting considers a longer contiguous chronological period within the optimisation than the 2 days per month setting. These results indicate that reduced chronology may provide a large, material advantage to gas within the model, and a disadvantage to long-duration storage such as pumped hydro. The results of the SSLT flow down to the DLT and time-sequential models, indicating that the sampled chronology assumption is likely a major driver of gas deployment within the ISP modelling. Improving chronological modelling within the SSLT could potentially indicate that a combination of batteries and pumped hydro could displace almost all gas in the least-cost solution.

The PLEXOS model used for this analysis can be made available upon request.

Pumped Hydro Costs

PHES comprises 95% of energy storage in the NEM. It is important to get the cost right, to avoid excess investment in higher-cost batteries and gas.

Class AA pumped hydro sites are overlooked in the GenCost Tables. Instead, lower-quality (more expensive) Class A/B sites are used in cost estimations, resulting in a capital cost of $7635/kW for 48-hour storage.

Australia has 300 class AA sites in the size range 15-500 GWh (Table 1), mostly located near high-power transmission between Brisbane and Melbourne (Figure 3). Total energy storage volume is 70 TWh, which is about 70 times larger than Australia will ever need when all energy comes from solar and wind and everything is electrified (transport, heating and industry). Australia also has 5000 sites in the cost class range A, B, C, D and E, but these are not required.

Dungowan: Conversations involving ANU, Aurecon and Saliw Cleto of AEMO were held in September-October 2024. As a result, Aurecon costed a Class AA PHES site near Dungowan (150 GWh, 3 GW, 50 hours of storage) at $15 billion which corresponds to $5,000/kW (64% of GenCost 48hr). It is puzzling that this large inconsistency is overlooked.

<u>Snowy 2.0 (Class AA site)</u>: Published cost is $12B for 350 GWh and 2.2GW of storage. This translates to $34/kWh (**<u>21%</u>** of GenCost48hr) or equivalently $5,500/kW (**<u>70%</u>** of GenCost 48hr).

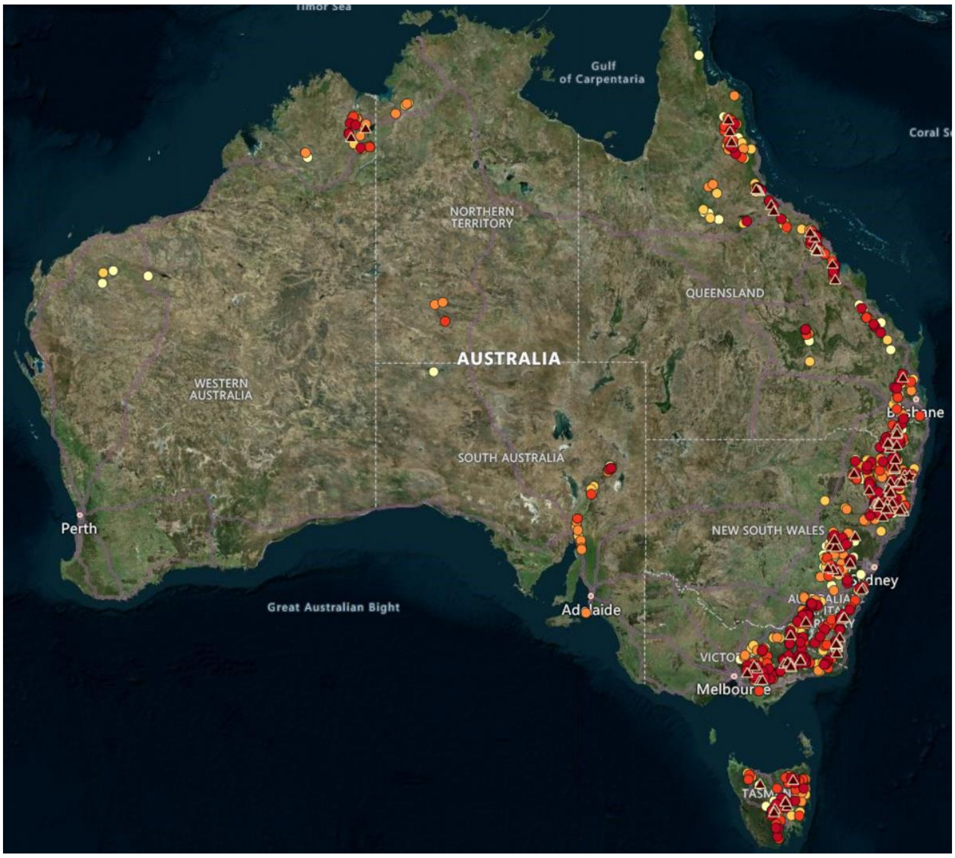
Snowy 2.0 could be transformed from a 160-hour storage to a 51-hour storage by the addition of five 1 GW, 4-hour batteries (350 GWh +20 GWh divided by 2.2 GW + 5 GW = 51 hours). The total cost would be $20.5 billion ($12 billion for Snowy 2.0 + $8.5 billion for 5*4-hour batteries). The capital cost of this **<u>hybrid system</u>** is $55/kWh (**<u>34%</u>** of GenCost 48hr) or equivalently $2800/kW (**<u>36%</u>** of GenCost 48hr).

It is difficult to understand how the GenCost estimates can overlook Snowy 2.0. Further details are included in our 24th January 2025 submission.[3]

Abundant Class AA Sites

Australia has 300 class AA sites in the size range 15-500 GWh (Table 1), mostly located near high-power transmission between Brisbane and Melbourne (Figure 3). Total energy storage volume is 70 TWh, which is about 70 times larger than Australia will ever need when all energy comes from solar and wind and everything is electrified (transport, heating and industry). Australia also has 5000 sites in the cost class range A, B, C, D and E, but these are not required.

Figure 3. Pumped hydro sites are mostly located near high power transmission between Brisbane and Melbourne (150 GWh sites are depicted)[4]



[3] https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2024/2026-isp-methodology/submissions/anu.pdf?la=en
[4] https://re100.anu.edu.au/#share=g-2cb1024a7473535f5da30a8603969a90

Table 1. Summary of Cost Class AA Sites in Australia

	15 GWh	50 GWh	150 GWh	500 GWh	TOTAL/ average	Snowy 2.0 350 GWh
Count Class AA	4	34	181	80	300	-
Average Head (m)	666	607	596	645	611	680
Average Slope (%)	12	12	6	7	7	2.5
Average W/R	20	16	15	14	15	∞

Class AA pumped hydro sites are characterised by large head (> 600 m), large average tunnel slope (>6%), large water-rock (W/R) ratio (>8), large-scale (15-500 GWh) and long duration (>50 hours). Snowy 2.0 is Class AA: it has poor average slope for the tunnel, but this is compensated for by the fact that the two reservoirs already exist.

Kind regards,

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Professor Kylie Catchpole (Co-director, ANU Centre for Energy Systems), and
Dr Cheng Cheng (Senior Research Officer)