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# ARTICLES

## Pumped storage for reduced emissions?

As part of a recent report on transitioning to a lower emissions economy (Productivity Commission, 2018), a case was made for electricity from expanded renewable sources to replace fossil fuel usage in industry, with concurrent adoption of electric vehicles (EVs).

However, as was noted by Transpower in a submission to the Report, a move toward more reliance on renewables gives increased risk of impact from future dry seasons. We would certainly look foolish if some future dry period resulted in enforced EV carless days.

The Report nonetheless is strong in its advocacy of a shift to EVs:

*A rapid and widespread transition to a very low emissions light vehicle fleet is essential for New Zealand to achieve a long-term emissions reduction target.*

It is also noted in the Report, as well as in recent television advertising, that Norway is some way ahead in terms of transitioning to EVs with renewable energy supply. However, Norway has much greater hydro storage capacity than New Zealand, including the world's largest pumped storage scheme by energy measure.

The Report sidesteps the issue of detailing specific mechanisms to offset future dry years and seems to have faith that a "voluntary market for firm energy" will provide the necessary security of future electricity supply in a low-emissions economy. Pumped storage is mentioned only to the extent of being dismissed as having high capital cost and probably being "environmentally and economically infeasible".

One alternative might be to simply permit a greater degree of drawdown of existing hydro lakes. However, power generated in this way is likely to be expensive in the electricity market and there would be a gamble on having a subsequent period of higher than average inflows to bring the lakes back to their normal operating range. Also, given the shoreline damage already present at our main hydro lakes from seasonal operation, it is concerning that the Report even raises the drawdown option as a possibility. Battery storage against dry years is not practical but one alternative might be maintaining a large stockpile of coal at Huntly. However, the present two 250 MW Rankine units there are nearing the end of their operational life and can't be relied on into the future without expensive upgrades.

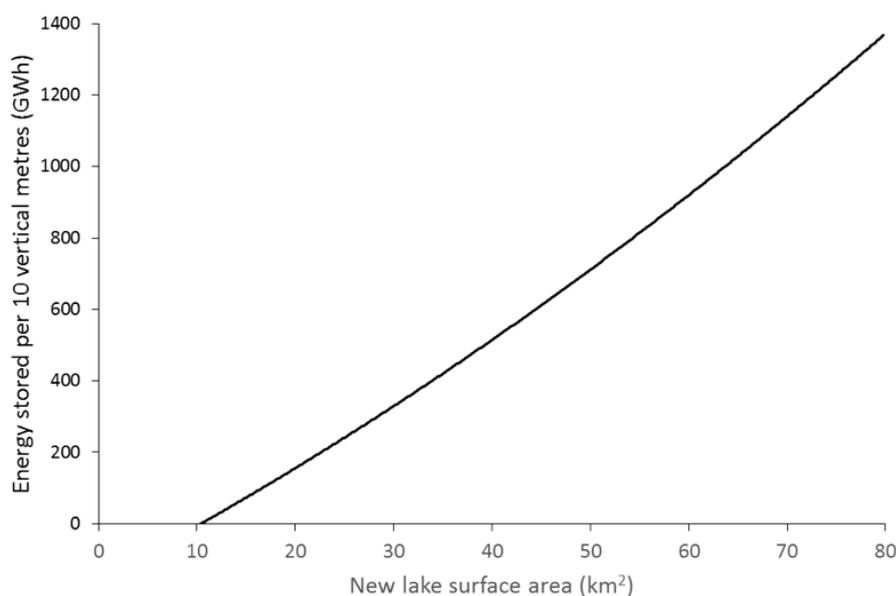


Figure 1. Energy storage from an expanded Lake Onslow as a function of lake surface area. A lake of surface area 80 km<sup>2</sup> has ≈ 1,400 GWh of gravitational potential energy over a 10-metre elevation change.

If pumped storage is to be a viable dry-year buffer in a low-emissions economy then considerable energy storage is required, implying a significant engineering scheme. Any such scheme cannot be considered in the abstract and can only be evaluated with respect to the hydrology of a specific site.

The Onslow basin in Central Otago has been noted previously as having potential for large-scale pumped storage, with Lake Roxburgh acting as the lower reservoir (Bardsley, 2005). In fact, the scheme considered in that paper was huge and would have been the world's largest by energy storage. The economics were probably never going to be viable and the large surface area of the upper reservoir might have resulted in a net water loss to evaporation.

However, smaller versions of the scheme can also be considered, each with its own energy-hydrology operating mode and economics. In each case, about 1,300 MW of installed capacity is envisaged, with a 20 km rock tunnel linking the upper and lower reservoirs (Lakes Onslow and Roxburgh, respectively). Figure 1 shows the energy storage capacity of the Onslow basin as a function of the extent to which the existing Lake Onslow is expanded beyond its present size of about 10 km<sup>2</sup>. Figure 2 shows the landscape around the southern end of the present lake.

The plotted function in Figure 1 gives the amount of energy,  $E$ , that would be released by lowering an expanded Lake Onslow by 10 metres, as a function of lake surface area,  $A$ :

$$E = 0.058 A^2 + 14.43 A - 150.1$$

where  $E$  is in GWh and  $A$  is in km<sup>2</sup>. In reality, the achievable  $E$  would be a little less because of inevitable inefficiencies in the pump storage cycle.

The increase of  $E$  with  $A$  is derived from both the increased lake surface area and the fact that a larger lake area implies a higher lake level elevation. A lake area of 50 km<sup>2</sup> corresponds to a dam height of about 50 metres at the Teviot stream outlet, while an 80 km<sup>2</sup> lake would require a dam slightly more than 100 metres.



Figure 2. Southern end of the present Lake Onslow reservoir (photo: Mohammed Majeed).

Whatever expanded lake surface area might be decided on, the most passive mode of operation is maintain it as an apparent natural lake, to be utilised only in the event of a dry season. This use is analogous to a stand-by thermal station but would have the advantage of no emissions.

A higher level of utilisation would be to operate the lake continuously to buffer short-period wind power fluctuations. Again, the expanded lake would hardly differ in appearance from a natural lake for most of the time, but would serve the useful additional purpose of allowing significant expansion of wind power without risking grid instability.

The maximum level of utilisation would be to include use of Onslow pumped storage as an active South Island seasonal hydro lake. This would also reduce the frequencies of extreme wholesale electricity prices during times of power supply issues. At the time of writing (late October 2018), average wholesale electricity prices have been in excess of \$300 per MWh because of a combination of low hydro lake inflows and gas supply issues.

An interesting variation of the seasonal theme is to maintain the Waitaki lakes (Tekapo and Pukaki) at around their mid-levels through the year, shifting their seasonal hydro storage roles to the expanded Lake Onslow. A current PhD study at the University of Waikato indicates that seasonal pumped storage operated in this way would create net positive energy output on average because of reduced spill loss from the Waitaki power scheme (Majeed, 2018). Onslow seasonal operation linked to the Waitaki scheme would have the further economic advantage of making available up to 100 m<sup>3</sup>s<sup>-1</sup> of extra Waitaki water for summer irrigation.

Evaluating whether Onslow pumped storage is “economic” is therefore a complex process which must take into account many factors, depending on scheme size and its mode of operation. Economic advantages might include including enabling expansion of wind power, reduced frequency of high electricity prices, more Waitaki summer irrigation water, and maintaining EVs and electricity-intensive industrial activity during extended dry periods.

The extent of environmental impact of Onslow pumped storage also depends on its mode of operation. As just a dry-year reserve with wind power support, for most of the time an expanded Lake Onslow would appear as a larger version of the present lake. Introducing seasonal use inevitably has environmental impact from lake level fluctuations. However, a major engineering project is the best time to carry out ecological mitigation from the outset. For example, an expanded Lake Onslow might be converted in part into an ecological tourist attraction by way of constructing an intricate maze of open channels among floating wetland islands.

Whatever its mode of operation, Onslow pumped storage construction would require a long lead time. Quite apart from consents and impact evaluations, even filling an expanded lake would have to be done in time-spaced increments. Pumped storage may or may not play a role in reducing our future emissions but detailed economic and environmental evaluations should start soon so that informed decisions can be made.

Bardsley, W.E., 2005. Note on the pumped storage potential of the Onslow-Manorburn depression, New Zealand. *Journal of Hydrology (NZ)* 44, 131-135.

Majeed, M., 2018. Evaluating the potential for a multi-use seasonal pumped storage scheme in New Zealand's South Island. PhD thesis, University of Waikato (submitted).

Productivity Commission, 2018. Low-emissions economy.