Low-emissions economy

Thank you for the opportunity to input into the Low-emissions economy – Draft report, provided by the Productivity Commission

This submission on the Draft Report (DR) is with respect to reduction of carbon dioxide emissions. CO_2 is relevant because it is a long-lasting GHG and would be the most visible of our GHG reduction activities via a transition to electric vehicles (EVs).

Emphasis here is on the probable need for significant increase in energy storage capacity as a prerequisite to meaningful reduction in CO_2 emissions, and how this might be achieved economically in New Zealand by incorporating pumped storage. Pumped storage is given only brief mention in DR as "high capital cost and is probably environmentally and economically infeasible", while no reference to pumped storage was made in the in the Royal Society (2016) *Transition* report.

Pumped storage involves major engineering and is not amenable to evaluation in an abstract way. Rather, it must be judged at a specific site and linked to economic and environmental multi-use. Some aspects of present hydro storage operations are mentioned first in this submission, followed by a concept of how seasonal pumped storage could lead to CO_2 emissions reduction and EV uptake, coupled with better water and energy management and improved lake and river environments.

Current hydro storage and CO_2 emissions

As is well known, there is association between New Zealand hydro lake levels and CO_2 emissions through the electricity wholesale price. Low hydro lake levels coupled with low lake inflows result in reduced hydro power output and price increases in the electricity market, so power generation from thermal plants becomes economic or is required to meet contract obligations (Fig. 1). This sometimes is seen as an inverse relation between hydro power and thermal power station output (Fig. 2).

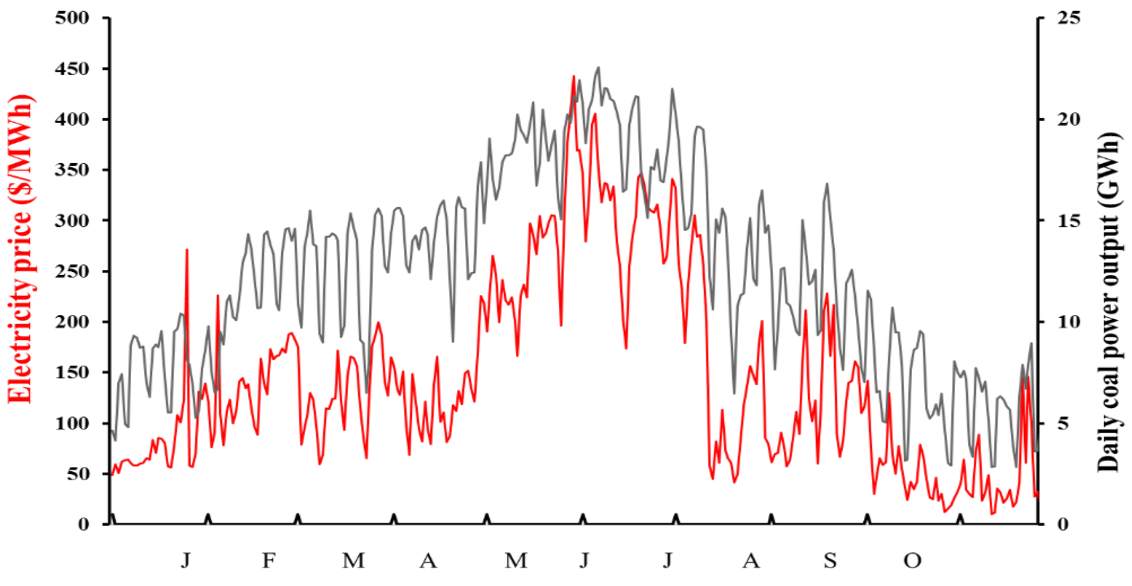

Figure 1. Linkage in 2008 between electricity price and coal-fired power generation (mean daily Haywards price shown).

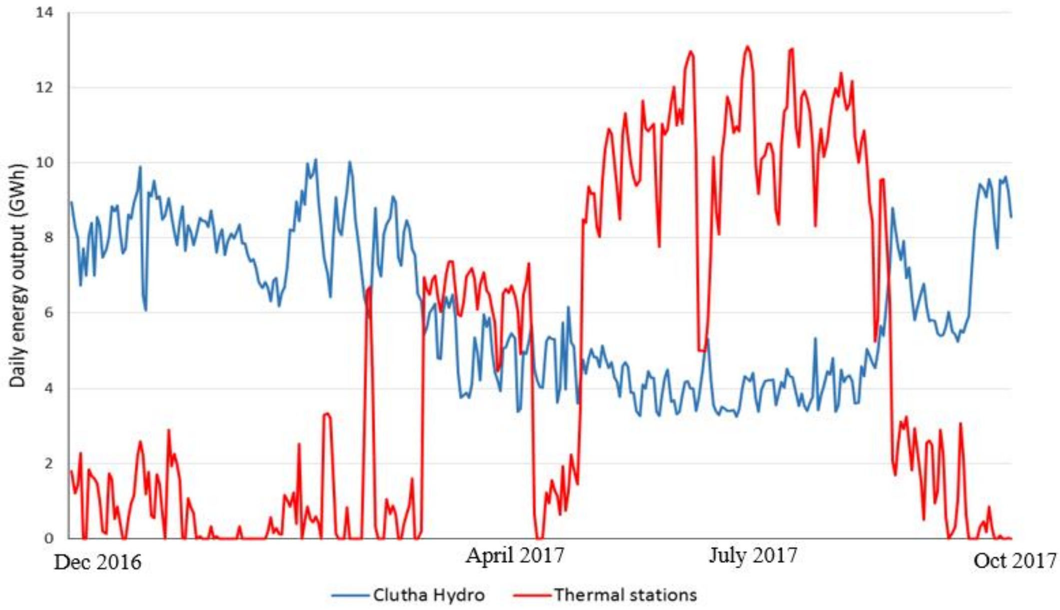

Figure 2. Contact Energy daily thermal station and hydro power output (Dec. 2016 - Oct. 2017).

Figs. 1 and 2 reflect influence of periods of extended low inflows to the South Island hydro lakes. This linkage of CO_2 emissions to low inflows in turn derives from insufficient national hydro storage capacity to buffer over multiple years and dry periods.

With limited hydro storage capacity in a market environment, even a *belief* in coming low inflows can be sufficient to result in CO_2 generation from thermal stations. An example is the history of hydro lake operations through December of 2010. At the start of the month national hydro storage was above average but trending down and NIWA issued its 3-month summer climate outlook as "hotter and drier than usual, with driest conditions in the West Coast, Southland, and Fiordland". As a precaution, water release was restricted in some South Island hydro lakes and the reduced hydro power output resulted in electricity price rises sufficient for thermal power station generation. This situation remained until later in December when heavy rains started to fall in the same localities which had been forecast to be driest. Because water had been held back in some hydro lakes, there was greater spill from hydro power stations than would otherwise have been the case. With the rapid late-December increase in hydro power generation, the electricity price fell and coal-fired thermal stations largely ceased operation (Fig. 3).

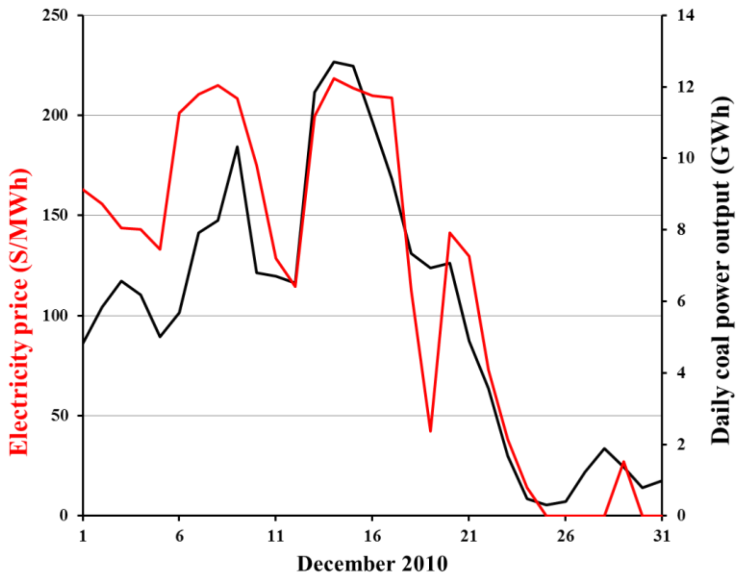

Figure 3. Electricity price and coal power electricity output, December, 2010.

The net consequence of the South Island hydro lake operations through December 2010 was (i) needless emission of a significant amount of CO_2, (ii) needlessly high electricity prices, (iii) lost hydro generation opportunity through greater spill volumes than would otherwise have been the case.

There is no implication of blame involved for the December events. NIWA would have been using its best estimates available at the time and the hydro lake operators were responsibly seeking to conserve water against a possible summer drought. However, if there had been a large available national hydro storage capacity then concerns about a coming dry season would not have resulted in significant emissions.

Hydro storage and the environment

As noted in the DR, there is a considerable (and necessary) seasonal load shifting by way of seasonal storage in the major hydro lakes to anticipate higher winter power demands. This results in enhanced seasonal fluctuations of hydro lake levels compared to pre-hydro times, quite apart from lake level raising (Fig. 4). The main hydro lakes have soft sediment shorelines susceptible to erosion when wind waves coincide with sustained high lake levels during times of maximum storage (Figs. 5 - 7). As hydro lake levels recede during the seasonal cycle, the eroded sediment is transported down to lower shoreline levels. The net effect of the seasonal cycle can be shoreline retreat and damage along lake shores. At the other extreme of levels, drawdowns of South Island hydro lakes during dry years are not consistent with our tourist image of scenic lakes (Fig 8).

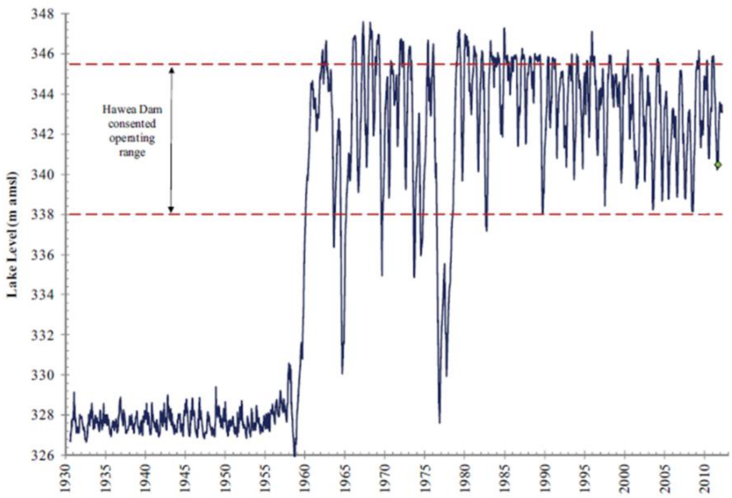

Figure 4. Lake Hawea water levels, contrasting natural water level fluctuation with enhanced fluctuation subsequent to conversion to a hydro lake in 1958.

Figure 5. Lake Hawea shoreline erosion.

Figure 6. Shoreline retreat at Lake Pukaki.

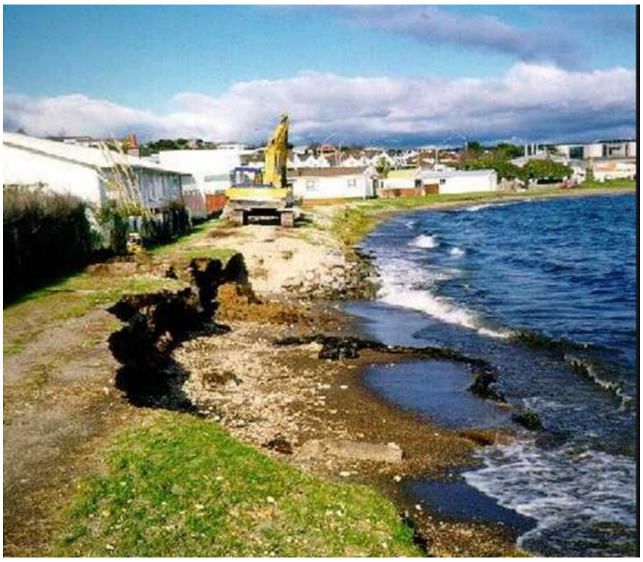

Figure 7. Shoreline erosion from high lake levels, Lake Taupo.

Figure 8. Low water level at Lake Tekapo.

There are also down-river effects from the current mode of operation of seasonal hydro storage. If lake inflows flood into already high lake levels from increased hydro storage then downstream floods will be worse than they otherwise would have been from operating hydro lakes in permanent flood control mode (Figure 9).

Figure 9. Waikato River flood, 1998.

One example of downstream environmental impact from hydro lake operation is the changed seasonal flow regime of the lower Waitaki River (Fig. 10). Like most of the main South Island rivers, the natural Waitaki flow regime is for high flows in spring and summer, while headwater winter precipitation as snow gives low winter flows. This is opposite to the seasonal cycle of electricity demand, so the necessary holding back of spring and summer water in Lakes Pukaki and Tekapo results in much reduced spring/summer downstream flows.

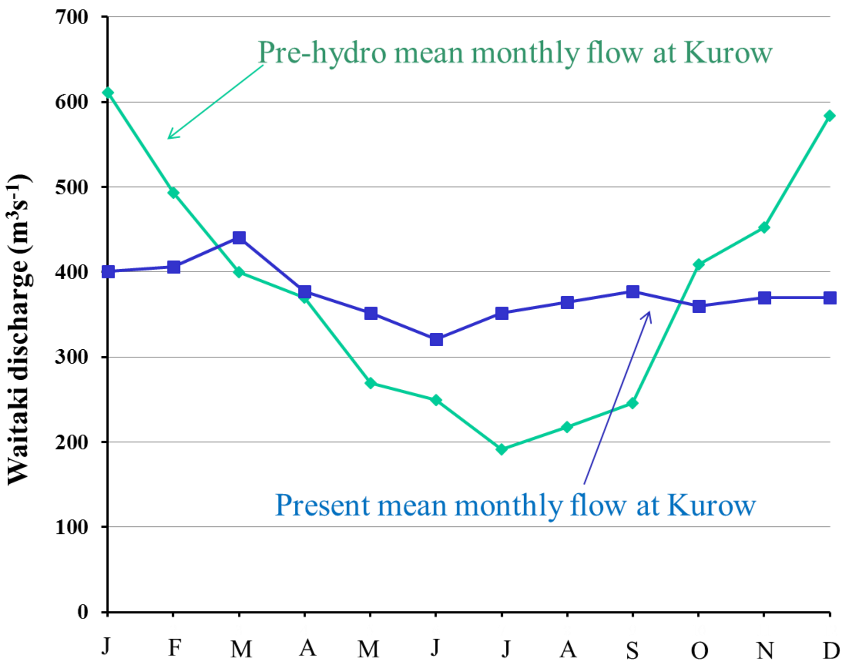

Figure 10. The changed flow pattern in the lower Waitaki River from seasonal hydro lake storage.

Emissions and dry year options in the Draft Report

It is evident that that the current seasonal operation of New Zealand seasonal hydro storage leaves much to be desired from both an emissions and water management viewpoint. Any transition toward a low CO_2 nation cannot simply expand an already flawed system.

The DR seeks a goal of transition toward EVs, noting that the Commission's modelling indicates a rapid uptake of EVs will likely be critical for achieving a low-emissions economy. Also, two trends are noted in the DR: (i) CO_2 emissions from transport is increasing as the population increases and the economy grows, and (ii) the cost of wind generating plant is decreasing. Accordingly, the increment of renewable energy to enable a future transition to EV's is seen as being derived significantly from wind energy, with perhaps some geothermal contribution.

However, it is also noted in the DR that as the proportion of electricity generated from intermittent renewable sources rises, ensuring that supply meets demand at all times may be more challenging. This applies in particular with respect to the issue of dry years.

With an uncertain climatic future, the past record is not necessarily helpful. While the DR makes reference to the current 4,000 GWh of national hydro storage being an adequate buffer for "average years", dry years by definition are outside of the average. Nor is there any guarantee that average years in the past will be the same as average years in the future. With reference to future extremes, it is possible that a long sequence of anticyclonic conditions would lead to both reduced wind speeds and reduced rainfall in hydro catchments. Incentives for transition to EVs may come to be regarded in hindsight as something of a trap if EV carless days are required because there is not always enough power to charge their batteries. It is surprising, therefore, that uncertainty of EV power supply through dry years was not listed as one of the negative factors when seeking to phase out fossil fuel vehicles (DR, Table 11.1).

Given the critical importance of maintaining (largely) renewable power through dry years in transitioning to an EV fleet, the DR seems vague as to how security of supply might be achieved. Similarly, the National Energy Research Institute (2017) report simply notes that a New Zealand energy research priority should be toward finding low-cost clean options for dry year support.

The DR cites Stevenson et al. (2018) as raising the possibility of some form of stand-by plant that does nothing except in dry years, with the owners significantly compensated for all the periods of non-operation. However, this would seem an expensive insurance policy just to maintain plant that remains mostly idle. The DR also makes reference to a developing a firm energy market as a means to work through dry years. However, this appears to have economic implications (temporary closure of portions of the Tiwai point aluminium smelter) and emission implications (increased use of thermal stations).

The DR also suggests that one way around the dry year issue might be low-cost wind energy generation installed at a high level of redundancy. This raises the issue again of plant which does nothing for much of the time, presumably requiring compensatory payment. It is also unclear how the extra wind-generated energy would be stored. Hydrogen from wind power is mentioned as a possibility but it is unrealistic to think that stored hydrogen could offset a dry year.

The DR raises the possibility of further storage at Lake Pukaki. It is disappointing that a report advocating bold policy changes should propose at the same time that a bad environmental situation should be made even worse. There is enough visual impact already from low levels of Lake Pukaki during dry years without allowing minimum water levels to be lowered still further.

Finally, the DR cites Mason et al. (2013) as advocating working through dry years by incorporating switching geothermal stations on and off. However, it is probably better economically to maintain geothermal stations always at constant rates for aiding baseload. Also, as noted in the DR, geothermal stations are associated with some degree of GHG emission.

Seasonal pumped storage: moving toward EV's with better national hydro management with cheaper power

Norway is a good model for New Zealand, having a dominant energy component of hydro power generation and a policy in place for all new cars to be low emissions (battery EV, plug-in hybrid EV or hydrogen by 2025). However, Norway differs from New Zealand in possessing a much larger amount of hydro storage capacity, with a significant contribution from seasonal pumped storage. The DR makes the point:

The biggest challenge for New Zealand in moving to a very-low emissions electricity system is providing for resource adequacy, particularly in dry years.

In fact, even moving toward just a "low" emissions situation (including transition to EV's) there still needs to be a significant increases in energy storage capacity because renewables are intermittent over all time scales.

There are many possible energy storage technologies at the small or medium scale. However, for the large amounts of energy needed for dry year security there is no technology likely to be available other than hydro storage. This poses a problem for New Zealand because permitting still greater fluctuation of existing hydro lake levels is not an option from an environmental viewpoint. It is suggested therefore that the New Zealand government move toward constructing seasonal pumped storage, being the only dry year security option outside of stand-by thermal generation with its associated high power costs and emissions.

This call will raise philosophical issues. For example, the Meridian Energy (2017) submission on the Commission's *Issues* paper states that government ownership of generation solely for security of supply was not considered to be a success, noting that the Whirinaki power station was eventually sold to the private sector. However, the extent of our present security of supply against dry years is actually due solely to past government construction and ownership of energy storage. For example, at Lakes Hawea, Pukaki, Tekapo, and Taupo. This includes Meridian's own main storage at Lake Pukaki.

The Meridian submission also considers that New Zealand's current market-based regulatory arrangements for the supply of electricity have (to date) proved more than adequate to the challenges posed by dry years. Even setting aside the unknown nature of future climate change, the number of years of operation of the regulations are not adequate to provide a sample of the full range of variability of rainfall over the country. New Zealand was only saved from a 2017 electricity supply situation by the fortuitous intervention of tropical cyclones drifting far enough south to recharge hydro lakes.

Meridian Energy also appears to put some faith in the nature of future climate change being more toward westerly wind conditions, with increases in both summer and winter precipitation. This may well happen, but if we are unable to forecast a season ahead then forecasting decadal averages into the future is problematic. A more prudent policy is to plan for worse conditions than at present.

In light of the future uncertainties, the Commission might consider the specific question:

Is it possible for New Zealand to economically transition to EVs in the absence of seasonal pumped storage ?

There is some urgency here because pumped storage schemes have significant lead times and planning needs to be initiated soon if the transition to EVs is to move as quickly as desired by the Commission.

The remainder of this submission is on the basis that dry year offset with pumped storage is a requirement for an EV transition. A case is made that a seasonal pumped storage scheme, while expensive, need not be environmentally and economically infeasible.

The most important point about a seasonal pumped storage scheme in New Zealand is that it can serve multiple purposes. So while stand-by plant against dry years remains idle most years, a seasonal pumped storage scheme can (i) provide emission-free cheap power in dry years, (ii) play a dominant role in national seasonal power management, (iii) provide buffering of wind energy to allow for wind speed fluctuations at small time scales.

Therefore, in addition to contributing to low-emission dry year insurance, a seasonal pumped storage scheme can also be part of day to day renewable energy operations. A recently-completed PhD thesis at the University of Waikato (Majeed, 2018) simulated the operation of a seasonal pumped storage at Lake Onslow, a small artificial lake located in a high basin near Roxburgh, Central Otago (Fig. 11).

Figure 11. View of Lake Onslow.

The essence of the proposed scheme is that water would be pumped up a 20-kilometre rock tunnel from existing Lake Roxburgh to an expanded Lake Onslow, with water being released back down when power was needed. The modelled scheme has a storage capacity of 7,000 GWh and 1,300 MW of pumping/generating capacity. The large storage capacity is a particular feature and can be compared with similar magnitudes of pumped storage in Norway. In comparison, the present total storage capacity of New Zealand's hydro lakes is about 4,000 GWh.

The Onslow scheme was simulated as functioning in the national grid over 1998-2012, with an environmental strategy of shifting seasonal hydro storage away from the hydro lakes. That is, the existing hydro lakes are simulated with recorded water inflows, but with an aim to stabilise lake levels within narrow ranges around the mid-point of their present more extended range. For example, the Lake Hawea water level fluctuations became more like the pre-1958 situation. The only exception in the simulations was permitting brief periods of higher lake levels as flood control.

This simulated seasonal operation of New Zealand's hydro lakes is quite different to the present hydro lake management. Subject only to avoiding downstream floods and hydro spills, the simulations release water from the hydro lakes at the same rate as water enters from the inflowing rivers, so lake levels remain largely unchanged except for variation within a narrow operating range. This means that at times of high lake inflows there is surplus power generated from downstream power stations, then used to pump water up to Lake Onslow. During winter there are low inflows to the South Island hydro lakes and lake water releases are correspondingly low to maintain constant lake levels. The recorded winter power demand is met to a large extent by water released from Onslow. Lake Onslow is thus simulated with seasonal storage as the "battery of the nation", in much the same way as is currently proposed for Tasmania with respect to Australia.

A sense of the simulations can be seen in Fig. 12, illustrating how Lake Taupo water levels could be stabilised with Onslow pumped storage. This significant change to current lake management would need refinement of the electricity market to recognise multi-use aspects of hydro lakes. For example, whenever Lake Taupo rose above its narrow operating range, Mighty River Power would be given dispatch priority in recognition of maintaining mid-range levels as permanent insurance against future floods. This might result in excess hydro power in the South Island because stable lake levels would be maintained there also, initiating a period of pumping to Onslow. Fig. 13 illustrates how operating Lake Taupo always toward a constant medium water level would have almost eliminated the impact of the 1998 Waikato River flood. As it happened, the 1998 Waikato flood cost (Munro, 1998) was in the order of $25 million in 2018 dollars.

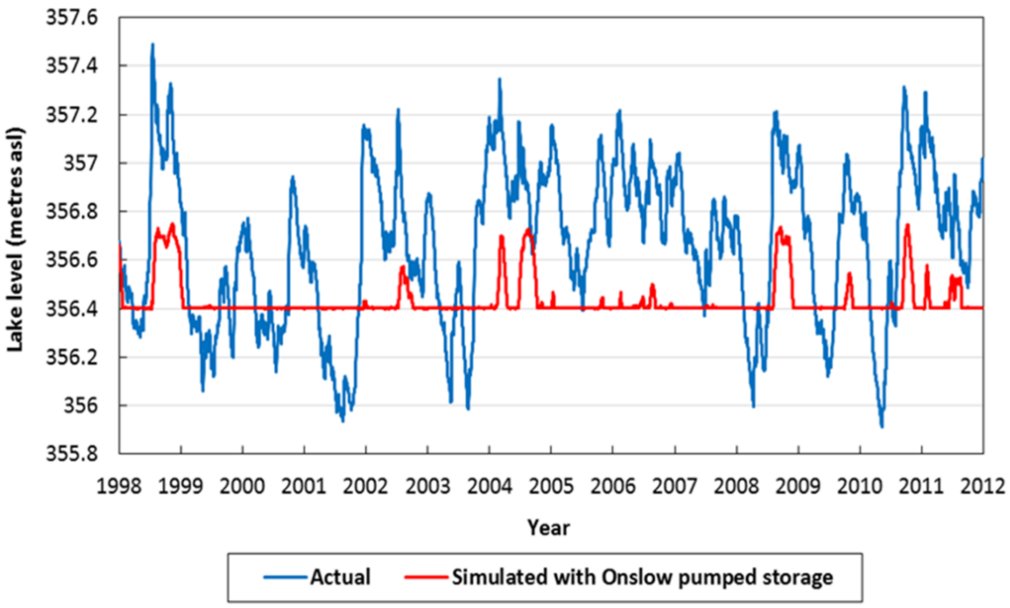

Figure 12. Lake Taupo water levels, 1998-2012. Actual and as simulated in conjunction with the operation of Onslow pumped storage.

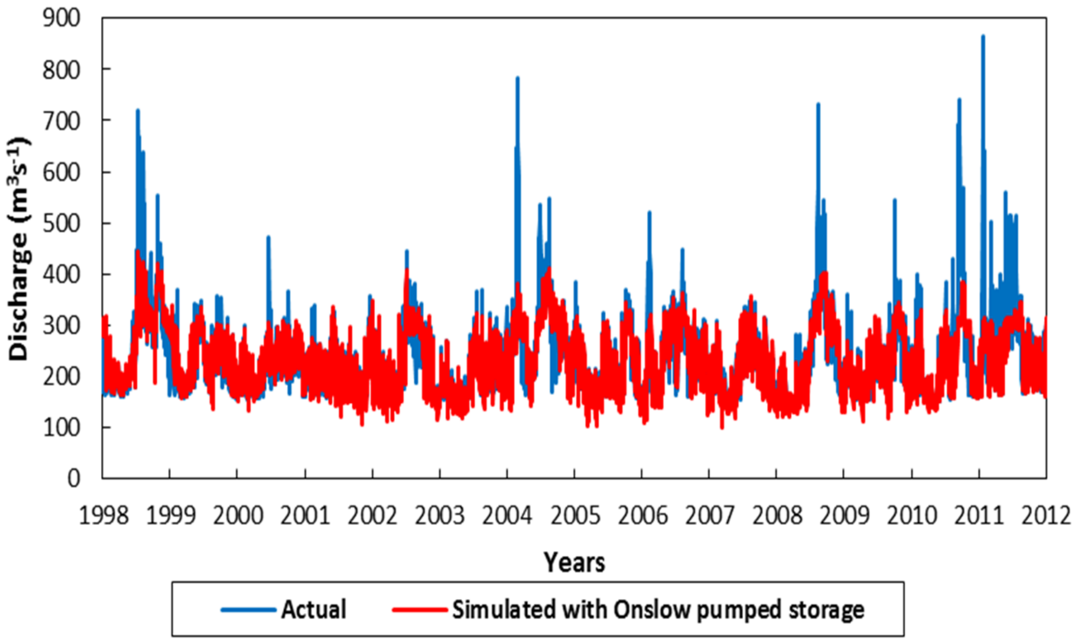

Figure 13. Waikato River discharge at Cambridge, 1998-2012. Actual and as simulated in conjunction with the operation of Onslow pumped storage.

The emission reduction contribution of seasonal pumped storage has already been mentioned. That is, there would be reduced requirement for thermal power station operation in winter and in dry years. In extreme dry years there remains the possibility of drawing down the former hydro lakes but this would probably not be needed because a significant wind power increment for EVs would help maintain Onslow water levels.

Simulation of lake level stabilisation for all the main hydro lakes together suggests that the Onslow scheme operation in this mode would result in a net power gain as a consequence of total reduced spill loss at hydro power stations (Majeed, 2018). If confirmed, this would mean that Onslow pumped storage would add an increment of power to the national grid, as if introducing a new hydro power station. This net positive effect is a long-term average because spill events are rare but, like flood damages, are significant when they happen.

A further economic gain would be achieved indirectly from the large 7,000 GWh increment of Onslow energy storage capacity. Given the tendency for the inverse relation between hydro storage volume and electricity price, the long-term effect of the additional storage can be anticipated to both lower and stabilise electricity wholesale prices, of value to the major energy users in particular. Having both cheaper and reliable power should also aid uptake of EVs. There could also be economic gain in a less obvious way from seasonal pumped storage through avoidance of dry year and electricity crises, which in the past have delivered bad publicity and probably deterred some overseas investment.

Finally, there is economic gain to be had at the regional level because shifting the Waitaki river flow back toward its original seasonal flow regime means a significant increase in summer river flow would enable irrigation expansion while at the same time still having higher summer mean discharges for recreation.

In summary, there is an economic case to be made that the cost of constructing Onslow seasonal pumped storage in New Zealand will be offset by: (i) reducing thermal power station CO_2 emissions, (ii) creating cheaper and more secure power for economic development and transition to EVs, (iii) providing grid stability for a significant increment of wind power, (iv) reduction of flood risk, particularly for the Waikato and Waitaki Rivers, (v) significant extension of irrigated lands in the lower Waitaki valley without reducing summer river flows. An economic overview of these various aspects is given by Majeed (2018), where the evaluated pumped storage scheme is a smaller and more economic version of a larger scheme originally proposed by Bardsley (2005).

From the environmental viewpoint there are inevitably both gains and losses. The main environmental gains are stabilising water levels of Lake Taupo and the South Island scenic hydro lakes, reducing flood risk, and increasing the availability of summer recreation water in the Waitaki River. Further into the future there could even be possibility of stabilising the levels of natural lakes for both reduction of extreme levels and improved downstream hydro power operation. For example, stabilising Wanaka levels (given a slight change in the Lake Wanaka preservation Act) would produce no evident change in the lake other than reduced frequency of shoreline flooding events.

The negative environmental aspect is at the Onslow site because the large increment of energy storage as simulated is achieved at the expense of a particularly large separation of maximum and minimum water levels – some 60 metres. However, the simulations indicate that the water level varies slowly while still being fully operational through dry years, without large within-year seasonal fluctuations.

Choosing to focus the national hydro energy storage environmental impact at a single location is actually desirable because Lake Onslow is located in a rock basin, which will be much more robust against wave erosion and water level fluctuations than the soft sediments around the present hydro lakes. Also, any modern civil engineering project will plan for environmental mitigation as part of the construction design. For example, much of the surface of the extended lake Onslow might be covered by a constructed floating wetland, offsetting to a degree the considerable loss of wetland habitat over much of New Zealand.

Details of possible engineering configurations and geotechnical considerations at Onslow are beyond the scope of this submission. However, it would be possible to construct the scheme in increments. A first stage might be simply a limited extension of the current Lake Onslow, using pumped storage for the single purpose of maintaining grid stability in support of wind power development. A comparable relatively small (by energy storage) scheme was suggested by Mason et al. (2013), though no site was specified.

Subject to the net economic and environmental worth of a seasonal pumped storage scheme being confirmed, there is still a need to formulate a system enabling its construction. In this regard, he DR makes reference to the “tragedy of the commons” with respect to GHG accumulation in our collective atmosphere being impacted by disconnected human activities not motivated by global considerations. The same might be said about New Zealand’s multiple-ownership hydro resources with competing entities, noted also Mason et al. (2013).

However, as previously mentioned, the current competitive market structure could still be maintained with pumped storage, combined with regulating hydro lake levels to be within narrow ranges and refining the electricity market to reflect multi-use aspects of hydro lakes and rivers. Energy ownership might then operate with seasonal pumped storage acting as a multi-user energy bank, rather than the existing partitioning of different lake storages between competing entities.

Conclusion

As noted throughout the DR, a scenario towards emission reduction cannot be just about emission reduction. There must be concurrent shifts in many different components, with an aim to plan toward a net better future outcome. Seasonal pumped storage with concurrent change in national water and energy management has the potential to play a role toward achieving the end goals. There are long lead times involved but, if demonstrated economical, initiation of pumped storage construction would indicate that New Zealand was taking emission reduction responsibly.

References

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 (under review).

Mason, I. G., Page, S. C., & Williamson, A. G., 2013. Security of supply, energy spillage control and peaking options within a 100% renewable electricity system for New Zealand. *Energy Policy*, 60, 324-333.

Meridian Energy, 2017. Submission on Issues paper: Low-emissions economy (Sustainability Commission)

Munro, A.J., 1998. The Waikato Regional Flood Event of 9-20 July 1998. *The Australasian Journal of Disaster and Trauma Studies* Volume : 1998-2.

National Energy Research Institute, 2017. *Energy Research Strategy for New Zealand: The Key Issues*.

New Zealand Productivity Commission. 2018. *Low-emissions economy: Draft report*. Available from www.productivity.govt.nz/inquiry-content/low-emissions-draft-report

Royal Society, 2016. *Transition to a low-carbon economy for New Zealand*.

Stevenson, T., Batstone, S., Reeve, D., Poynton, M., & Comendant, C. (2018). *Transition to zero net emissions by 2050: Moving to a very low-emissions electricity system in New Zealand*. Wellington: New Zealand Productivity Commission. Available at http://www.productivitycommission.govt.nz/low-emissions/draftreport

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