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Evaluating the Potential of Pumped Hydro Energy Storage to Mitigate Dry-Year Hydroelectric Shortfalls in New Zealand

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ABSTRACT

New Zealand's electric system relies heavily on hydroelectric generation; thus, the system is vulnerable during dry years due to the shortage of precipitation. Pumped hydro energy storage (PHES) is a proposed option to store surplus electricity in a reservoir and release it when electric generation is limited from environmental factors. This study evaluates the extent to which the proposed Lake Onslow PHES could offset hydroelectric shortages during dry years.

A system-level energy and power model was developed using published design parameters such as a storage capacity of 7 TWh and the average hydraulic head of 615m. This model calculated stored and usable energy, discharge duration, and coverage ratios for dry-year shortfalls between 3 and 5 TWh. Assuming baseline data, the model provides around 5.6 TWh of usable energy and can cover a 5 TWh shortfall. Sensitivity analysis on the model showed storage availability is the greatest key performance indicator, where variations in hydraulic head have a modest effect. This highlights the importance of active storage volume in determining overall system performance.

Keywords: *pumped hydro energy storage, Lake Onslow, renewable energy storage, hydroelectricity, dry-year risk, energy security, New Zealand electricity systems, climate stress, round-trip efficiency, long-duration energy storage*

1 INTRODUCTION

The rising use of variable renewable energy sources such as wind and solar has created a growing need for large-scale energy storage systems. These systems need to be able to maintain reliable and flexible electricity networks (International Energy Agency [IEA], 2023).

Hydroelectric generation provides low-carbon electricity with immediate responses to change in demand, but the system is highly dependent on water availability (Ministry of Business, Innovation and

Employment [MBIE], 2022a). Extended periods of drought can have a large impact on the reservoir inflows and electric production, this creates challenges for electricity security (MBIE, 2022a).

Pumped hydro energy storage (PHES) stores surplus energy by pumping water into an elevated reservoir, when electricity is needed it releases the water which passes through turbines below in order to generate electricity (Papadakis et al., 2023). This system differs from traditional hydroelectric stations because PHES operates primarily as an energy storage system capable of moving energy availability over time. The large storage capacity and overall high efficiency make it one of the most practical technologies for long-term energy storage (Papadakis et al., 2023; Yang & Jackson, 2011).

New Zealand’s electrical system is particularly vulnerable to hydrological variances because hydroelectric generation produces such a large portion of the national electric supply (MBIE, 2022a). Years with rainfall shortages significantly decrease hydroelectric output, therefore creating energy deficits that must be met through alternative generation or stored energy reserves (MBIE, 2022a). A proposed solution is the Lake Onslow pumped hydro scheme; this has been considered as a large-scale energy storage project with a reported storage capacity of approximately 7 TWh assuming ideal operating conditions (Interim Climate Change Committee [ICCC], 2019).

The purpose of this study is to quantitatively determine the extent to which a large-scale pumped hydro system could offset the hydroelectric shortfalls during dry-year conditions in New Zealand; this study will use the proposed Lake Onslow outline as a representative case study. An energy and power model was developed to calculate stored energy, usable energy, discharge duration, and dry-year coverage. The Lake Onslow concept is reported to provide approximately 7 TWh of storage, although the source does not explicitly define the energy basis of this value. For the purpose of this model, the published 7 TWh value is assumed to represent the gross gravitational potential energy stored in the upper reservoir prior to round-trip losses. This assumption allows the active storage volume to be inferred using the gravitational potential energy relationship in Equation 1. Usable energy is then calculated separately by applying the round-trip efficiency in Equation 2. The mathematical model is then used to examine how variations in storage availability, round-trip efficiency, and hydraulic head influence the ability of pumped hydro energy storage in order to mitigate hydroelectric shortfalls under climate-stress conditions.

2 METHODOLOGY

2.1 System Scope and Modelling Approach

This study develops an energy and power model for a large pumped hydro energy storage (PHES) system using the proposed Lake Onslow project as a representative case study. The mathematical model evaluates the system as a reversible pump-turbine system capable of storing electrical energy as gravitational potential energy, then later recovers the energy during generation.

This analysis considers four key performance indicators: theoretical stored energy, usable electrical energy after losses from the round-trip system, discharge duration, and coverage of dry-year hydroelectric shortfalls. The model is simplified intentionally to provide a transparent framework for determining the overall effectiveness of the pumped hydro storage under various probable operating conditions.

2.2 Stored Energy Model

The energy stored in the system inside the upper reservoir is calculated using the gravitational potential energy equation:

$$E_{stored} = \rho g h V \quad (1)$$

where E_{stored} is the theoretical stored energy, ρ is the density of water, g is acceleration due to gravity, h is the average hydraulic head between the upper and lower reservoirs and V is the storage volume available.

Equation 1 establishes the basis for the analysis performed because it connects the physical characteristics of the model to the possible energy storage.

The value published for the Lake Onslow storage is a capacity of 7 TWh which is taken as a baseline value (Interim Climate Change Committee, 2019). The model in this paper uses Equation 1 to deduce the corresponding active storage volume and to determine how performance fluctuates when storage volumes vary.

2.3 Usable Energy and Round-Trip Efficiency

The system at Lake Onslow will not be able to recover all electrical output. The system will have losses during pumping, water conveyance, turbine operation, generation and electrical transmission. These losses are all taken into consideration with a single round-trip efficiency parameter:

$$E_{usable} = E_{stored} \cdot \eta_{rt} \quad (2)$$

where E_{usable} is the recoverable electrical energy after the lumped losses and E_{stored} is the theoretical stored energy as discussed in Equation 1 and η_{rt} is the aggregate round-trip efficiency term for the system.

Three efficiency scenarios are considered in this study:

- Low efficiency ($\eta_{rt} = 0.70$)
- Central efficiency ($\eta_{rt} = 0.80$)
- High efficiency ($\eta_{rt} = 0.85$)

These values represent the range of reported values in modern pumped hydro facilities and provide a basis for evaluating the system and its sensitivity to design (Papadakis et al., 2023).

2.4 Power Output and Discharge Duration

The electrical power generated is described by:

$$P_{out} = \rho g h Q \eta_{gen} \tag{3}$$

where P_{out} is the electrical output power, Q is the volumetric flow rate through the turbines, and η_{gen} is the turbine-generator efficiency. Equation 3 is used to verify that the adopted storage capacity, hydraulic head, and discharge power correspond to realistic flow rates.

The turbine-generator efficiency, η_{gen}, is distinct from the round-trip efficiency, η_{rt}, used elsewhere in this study. The round-trip efficiency represents the overall fraction of stored energy recovered after accounting for pumping, hydraulic, turbine-generator, and other system losses, whereas η_{gen} refers only to the efficiency of converting hydraulic power into electrical power during generation. In this study, a reported turbine-generator efficiency of 84.2% is used solely within Equation 3 to verify that the adopted hydraulic head and rated power produce realistic flow rates (Ministry of Business, Innovation and Employment, 2023).

The time for which the system can deliver power is calculated using:

$$t = \frac{E_{usable}}{P_{out}} \tag{4}$$

where t is the discharge duration, E_{usable} is the usable electrical energy, and P_{out} is the electrical output power. Equation 4 quantifies the energy-to-power ratio of the storage system and indicates the duration that energy can be supplied before the active storage volume is depleted.

The discharge durations reported in this study represent idealised energy-to-power ratios obtained by assuming the full usable energy reserve is discharged continuously at the rated output power of 1000 MW. It should therefore be interpreted as a theoretical measure of storage capacity rather than a prediction of actual operating duration.

2.5 Climate-Stress Scenarios

Dry-year conditions produce shortages in the active storage volume. This study will consider prolonged periods of reduced inflow without changing the design of the system.

Three storage volumes are considered: $V = V_0$, $V = 0.8V_0$, and $V = 0.6V_0$ where V_0 is the baseline active storage volume determined from the adopted 7 TWh storage capacity. Equation 1 is linear with respect to the volume, thus a reduction in active storage volume directly reduces the amount of energy that can be stored and delivered to the grid on demand.

2.6 Dry-Year Adequacy Assessment

The ability for the system to offset hydroelectric shortfalls is assessed using a coverage ratio:

$$C = \frac{E_{usable}}{\Delta E_{hydro}} \tag{5}$$

where C is the coverage ratio and ΔE_{hydro} is the dry-year hydroelectric energy shortfall being evaluated. A value of $C > 1$ indicates full energetic coverage, $C = 1$ indicates exact energetic coverage, and $C < 1$ indicates only partial coverage. Coverage is evaluated against representative dry-year shortfalls of 3 TWh, 4 TWh, and 5 TWh. This range of values spans the range commonly discussed in New Zealand dry-year planning documentation and provide a benchmark for assessment within the study (Ministry of Business, Innovation and Employment [MBIE], 2022b).

2.7 Head Sensitivity Analysis

The influence of hydraulic head is examined while holding the baseline storage volume constant. Three head values are considered in this study: 608 m, 615 m, and 650 m (Interim Climate Change Committee, 2019; Ministry of Business, Innovation and Employment [MBIE], 2023). Equation 1 is also linear with relationship to h the hydraulic head, it can be observed that increases in head produce proportional increases in stored energy. This analysis determines whether uncertainty in average hydraulic head affects the overall system sufficiency.

2.8 Uncertainty and Scenario Envelope

Rather than calculating single statistical uncertainty values, uncertainty within the design is represented through a range of plausible operating scenarios.

Three envelope cases are considered:

- Low envelope: $h = 608\, m, \eta_{rt} = 0.70, V = 0.8V_0$
- Central case: $h = 615\, m, \eta_{rt} = 0.80, V = V_0$
- High envelope: $h = 650\, m, \eta_{rt} = 0.85, V = V_0$

The low envelope represents a conservative but plausible scenario as opposed to extreme assumptions. While storage availability of $0.6V_o$ is considered separately in the climate stress analysis the central envelope is intended to represent a reasonable range on system performance. The high envelope assumes favourable hydraulic head and efficiency conditions but doesn't increase storage volume beyond the baseline value V_o.

3 RESULTS AND CALCULATIONS

3.1 Baseline Parameterisation

The analysis begins by establishing a baseline representation of the Lake Onslow pumped hydro scheme using the published storage capacity of 7 TWh, which is interpreted in this model as nominal gross-stored energy, and an average hydraulic head of 615 m. The values form the reference baselines for the remainder of the study.

First, the published storage capacity must be converted to SI units:

$$1\,TWh = 3.6 \times 10^{15} J$$

Therefore,

$$E_{stored,0} = 7 \times 3.6 \times 10^{15} = 2.52 \times 10^{16}\,J$$

The corresponding active storage volume can be found using Equation 1:

$$V_0 = \frac{E_{stored,0}}{\rho g h} = \frac{2.52 \times 10^{16}}{(1000)(9.81)(615)} = 4.1769 \times 10^{9}\,m^3$$

which is equivalent to approximately $4.18\,km^3$, or $4177\,Mm^3$.

This volume is physically plausible and within range of publicly available Lake Onslow studies. MBIE documentation describes conceptual design plans ranging from 5 TWh to 7.5 TWh while Climate Commission modelling includes a 7TWh case with average hydraulic head at 615 m (Interim Climate Change Committee, 2019; MBIE, 2023). The values therefore are consistent with the followed design assumptions.

Another check can be done with the discharge-power relationship. The procedure adopts the published nameplate output 1000 MW and uses the reported generation efficiency of 84.2%.

$$Q = \frac{P_{out}}{\rho g h \eta_{gen}} = \frac{1.0 \times 10^{9}}{(1000)(9.81)(615)(0.842)} = 196.9\,m^3 s^{-1}$$

MBIE turbines produce flow rates between 176 and 206 $m^3 s^{-1}$ taken at 1000 MW. The calculated value therefore is within range which provides further confidence the adapted storage capacity, hydraulic head and power output are mutually consistent.

Table 1: *Baseline design parameters and model validation*

Quantity	Published/design reference	Model value	Comment
Storage baseline	7.00 TWh	7.00 TWh	Adopted baseline parameter
Head (central)	615 m	615 m	Adopted central head
Inferred active volume V_0	Unspecified in a single public design value	4.177 km^3	Derived from Equation 1
Installed discharge power	1000 MW	1000 MW	Anchored to nameplate value
Turbine flow at 1 GW	176-206 $m^3 s^{-1}$	196.9 $m^3 s^{-1}$	Independent consistency check

Note: Table 1 summarizes the adopted design inputs with quantities derived from the baseline parameterization.

3.2 Efficiency Sensitivity

The capacity for Lake Onslow of 7 TWh represents the energy that can be stored within the upper reservoir theoretically. In reality, a portion of this energy is lost during operation due to pumping, transportation, turbine operation and the electrical generation. These losses are in Equation 2 above.

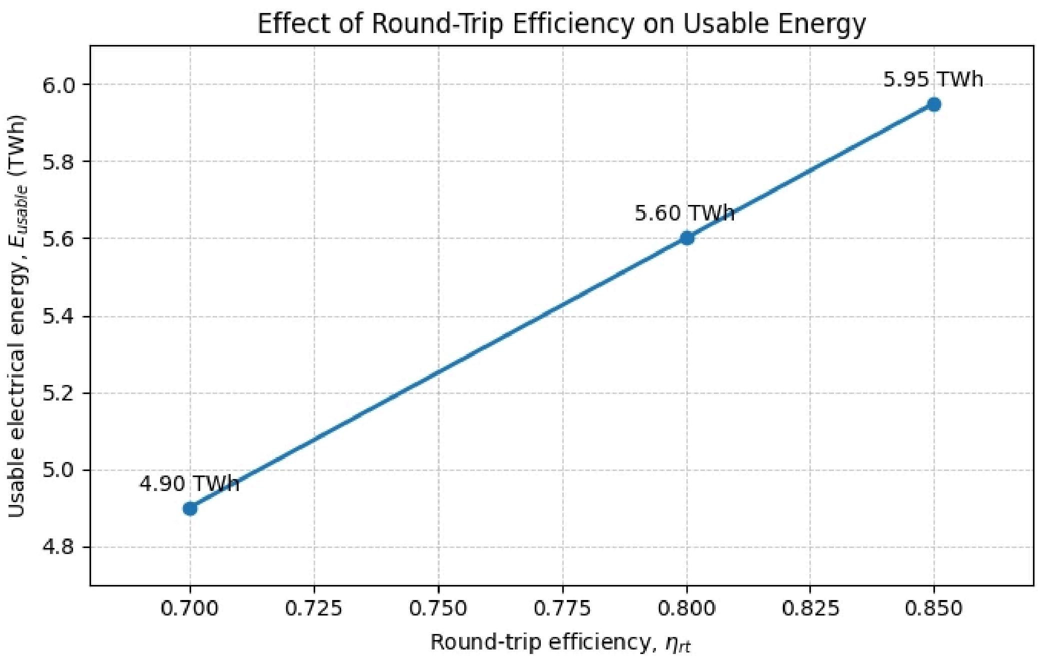
Using the low, central and high values where η_{rt} = 0.70, 0.80, and 0.85, the usable electrical energy was calculated from Equation 2. The results are summarized in Table 2 and Figure 1 below.

Table 2: *Usable energy and discharge duration under different round-trip efficiency assumptions*

η_{rt}	E_{usable} **(TWh)**	**Discharge duration (h)**	**Discharge duration (days)**
0.70	4.90	4900	204.2
0.80	5.60	5600	233.3
0.85	5.95	5950	247.9

Note: This table summarizes the usable electrical energy and corresponding discharge duration for low, central and high efficiency scenarios. Calculations were completed using assumed storage capacity of 7 TWh and constant discharge power of 1 GW.

Figure 1: *Effect of round-trip efficiency on usable energy*



Note: Figure 1 displays usable energy as a function of round-trip efficiency. The stored energy is a fixed 7 TWh and increases in recoverable energy occur from improvements in efficiency.

As expected from Equation 2, the relationship between usable energy and efficiency is linear due to the stored energy being fixed at 7 TWh. Increasing the efficiency from 70% to 85% increases the recovered energy from 4.90 TWh to 5.95 TWh which produces an improvement of 21%.

The discharge duration follows the same trend from output power being held constant at 1000 MW. Higher efficiency increases total energy available to the grid and the length of time that it can be supplied.

Each efficiency case still exceeds a 4 TWh dry-year shortfall. Where only the central and high efficiency case exceed a 5 TWh shortfall. This is a key indicator that efficiency is pivotal to providing the required energy coverage to handle dry-year deficits.

Figure 1 shows relatively small improvements in round-trip efficiency can produce substantial increases in usable energy. Even though efficiency does not alter the physical storage capacity of the Lake Onslow system, it directly influences the portion of energy that can be delivered to the grid.

3.3 Climate Stress Adequacy Results

The previous analysis assumed the full active storage volume was constant throughout operation. However, to examine the effect of long term dry conditions, the available storage volume was considered at the following values ranging from V_0, $0.8V_0$, and $0.6V_0$.

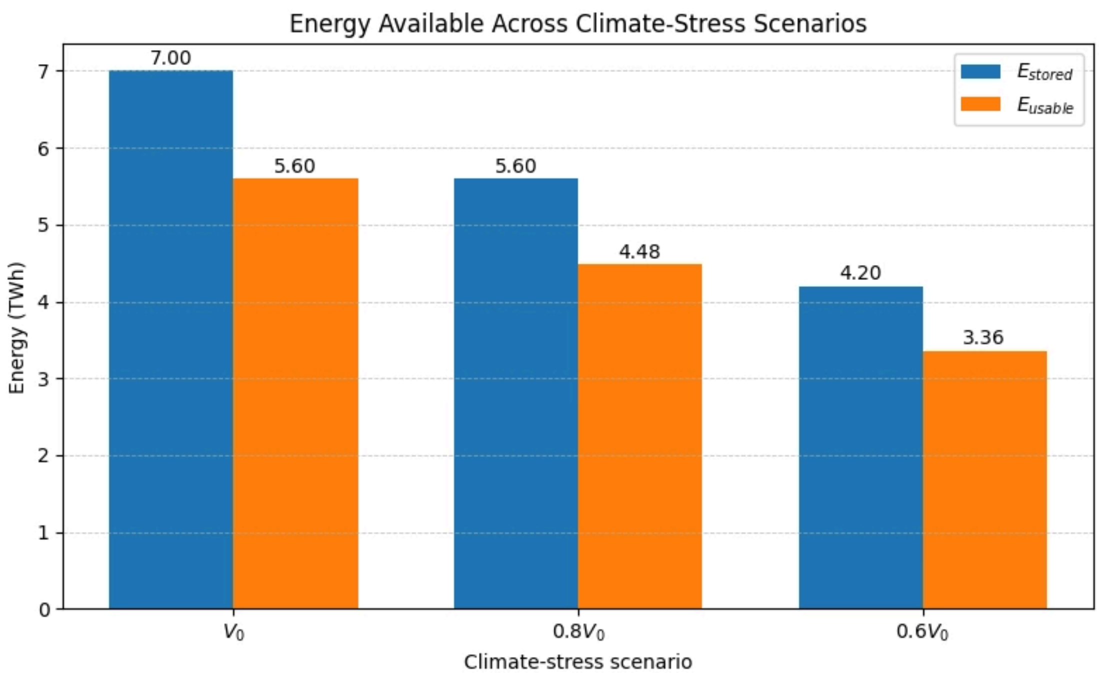
Since stored energy is proportional to storage volume, the theoretical storage capacities become 7.0 TWh, 5.6 TWh, and 4.2 TWh respectively. Table 3 was calculated using a round-trip efficiency of $\eta_{rt} = 0.80$.

Table 3: *Effect of storage volume reduction on usable energy, discharge duration (t), and dry-year coverage*

Scenario	Active volume(km^3)	E_{stored}(TWh)	E_{usable}(TWh)	t (h)	Coverage vs 3TWh	Coverage vs 4TWh	Coverage vs 5TWh
V_0	4.177	7.00	5.60	5600	1.876	1.400	1.120
$0.8V_0$	3.342	5.60	4.48	4480	1.493	1.120	0.896
$0.6V_0$	2.506	4.20	3.36	3360	1.120	0.840	0.672

Note: Table 3 shows how reducing available storage volume affects the overall performance of the proposed Lake Onslow plant.

Figure 2: *Energy available across climate-stress scenarios*



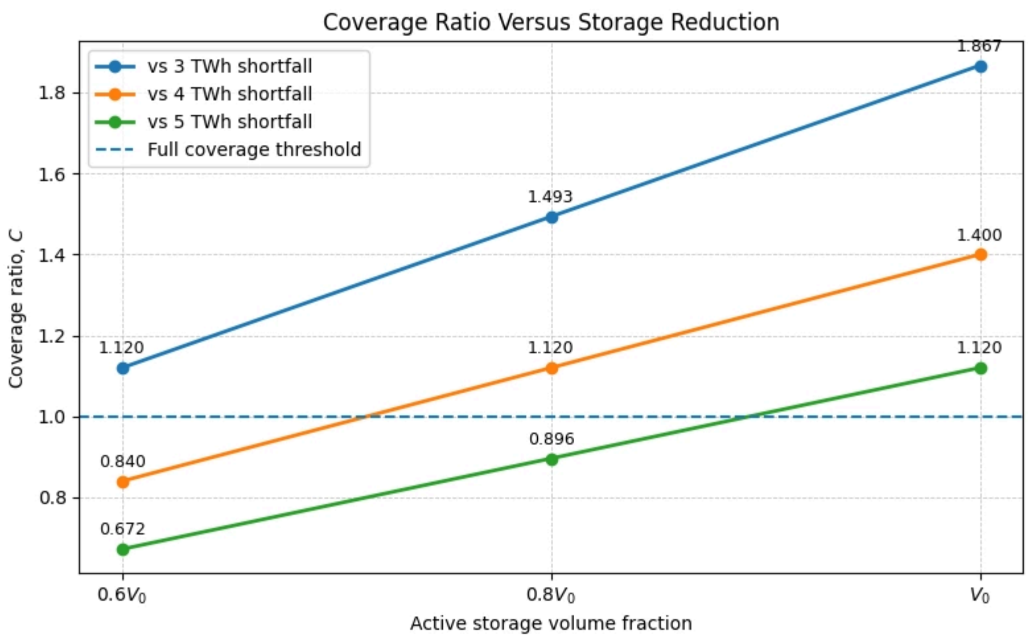
Note: Figure 2 shows the theoretical stored and usable energy for three climate-stress volume scenarios at a central efficiency of η_{rt} = 0.80. The difference between stored and usable energy is the round-trip loss.

The effect of reducing storage volume is evident in Figure 2 above. Under the baseline V_0 scenario, the scheme provides 5.60 TWh of usable energy which exceeds the dry-year benchmarks of 3 TWh, 4 TWh, and 5 TWh. Reducing storage availability to $0.8V_0$ lowers the usable energy to 4.48 TWh. This remains sufficient to cover the lower shortfalls but can no longer offset a possible 5 TWh deficit.

The reduction is far more noticeable in the $0.6V_0$ scenario where usable energy falls to 3.36 TWh. This energy amount remains higher than the lower end of the dry-year range, it does not produce enough energy to achieve the 4 TWh and 5 TWh benchmarks. This suggests storage of water becomes a driving factor in energy production under severe climate stress conditions.

Above in Equation 5 the coverage ratio was defined and calculated for each dry-year benchmark. Figure 3 gives a visual representation of the coverage ratios for each volume scenario considered at a constant round trip efficiency of eighty percent. Table 4 then expands upon this data and generates coverage ratios for all combinations of storage volume and round-trip efficiency values.

Figure 3: *Coverage ratio vs storage reduction*



Note: Figure 3 shows at η_{rt} = 0.80, the baseline V_0 case remains above C = 1 for all three dry-year benchmarks. When storage availability falls to $0.8V_0$ the plant still covers the 3 TWh and 4 TWh benchmarks, but falls below coverage for the 5 TWh case. At $0.6V_0$ only the 3 TWh benchmark remains fully covered.

Table 4: *Coverage ratios for combined storage-volume and round-trip efficiency scenarios*

Scenario	η_{rt}	C vs 3 TWh	C vs 4 TWh	C vs 5 TWh
100% V_0	0.70	1.633	1.225	0.980
100% V_0	0.80	1.867	1.400	1.120
100% V_0	0.85	1.983	1.488	1.190
80% V_0	0.70	1.307	0.980	0.784

80% V_0	0.80	1.493	1.120	0.896
80% V_0	0.85	1.587	1.190	0.952
60% V_0	0.70	0.980	0.735	0.588
60% V_0	0.80	1.120	0.840	0.672
60% V_0	0.85	1.190	0.892	0.714

Note: Table 4 provides further central-efficiency analysis by considering all combinations of storage volume and round-trip efficiency. Coverage ratios of 1 represent coverage for dry-year deficits, whereas values below 1 show incomplete coverage.

Table 4 has two key data points, the first is even when there is eighty five percent efficiency the $0.8V_o$ still does not fully cover a 5 TWh shortfall reaching a coverage ratio of 0.952. The other key data point is with the full baseline volume the low efficiency values are not enough to cover the 5 TWh energy supply with a coverage ratio of 0.980. This data shows that the 5 TWh dry-year target is sensitive to all factors, efficiency and also reduced storage will cause the system to be behind demand.

3.4 Head Sensitivity and Uncertainty

The previous sections covered storage availability and round-trip efficiency and how both data points influence the capabilities of the Lake Onslow plant. Another last consideration is the variability that is present in the hydraulic head between the upper and lower reservoirs. Keeping the baseline storage volume V_0 constant gives $E_{stored} \propto h$ and, at the central efficiency $\eta_{rt} = 0.80$, $E_{usable} \propto h$.

Table 5 below summarizes the resulting head sensitivity of the system. Varying average head from 608 m to 650 m changes the usable energy from 5.536 TWh to 5.919 TWh, corresponding to a change of approximately -1.1% to +5.7% relative to the central case.

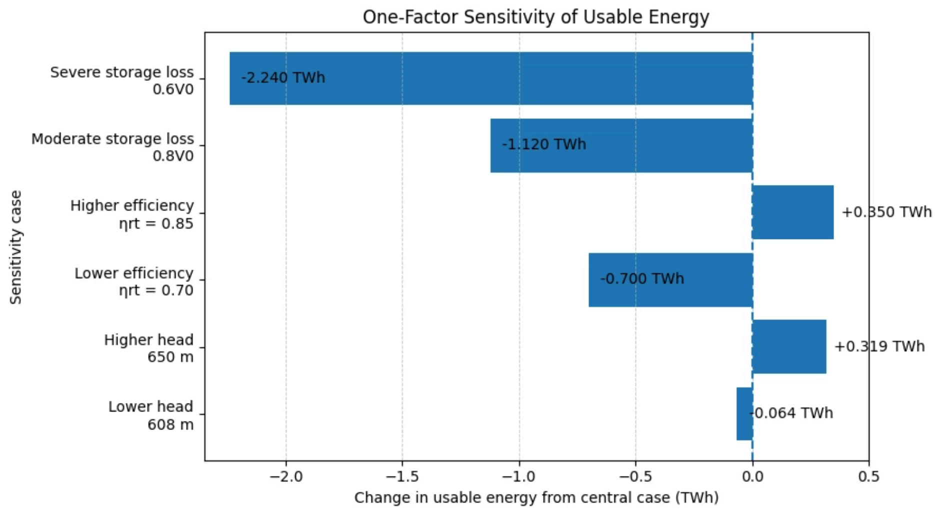
Table 5: *Effect of hydraulic head on stored energy, usable energy, discharge duration, and coverage of a 5 TWh dry-year shortfall*

Head(m)	E_{stored}(TWh)	E_{usable} at $\eta_{rt} = 0.80$ (TWh)	Discharge duration (h)	C vs 5 TWh
608	6.920	5.536	5536	1.107
615	7.000	5.600	5600	1.120
650	7.398	5.919	5919	1.184

Note: Table 5 provides discrete data on the sensitivity of system performance due to changes in average hydraulic head. All calculations are considered using a baseline storage volume and round-trip efficiency of 80%.

Hydraulic head has only a modest influence on system performance compared with storage volume and round-trip efficiency. Despite the variation in average head, all three scenarios produce more than the 5 TWh dry-year benchmark across the adopted head range.

Figure 4: *A comparison of the effects of all one-factor variations relative to the central case*



Note: Figure 4 visually represents one-factor sensitivity of usable energy relative to the central case values (h=615 m, η_{rt} =0.80 and V=V_o) Each bar is the change in usable energy when a single variable is varied and all others are held constant at central values.

Figure 4 displays the sensitivities in parameters, reductions in active storage volume produce the largest changes in usable energy. Where we can see the smallest variation in performance comes from hydraulic head losses. This indicates that storage availability is the most critical variable to the scheme.

To compare the combined effect of the uncertainties within the system, three operating envelopes were created using the low, central and high parameter combinations defined in the methodology above.

Table 6: *Low, central and high uncertainty-envelope scenario and system performance metrics*

Case	Head(m)	η_{rt}	$\frac{V}{V_0}$	$E_{usable}(TWh)$	Discharge duration(h)	C vs 4 Twh	C vs 5 TWh
Low envelope	608	0.70	0.8	3.875	3875	0.969	0.775
Central case	615	0.80	1.0	5.600	5600	1.400	1.120
High envelope	650	0.85	1.0	6.289	6289	1.572	1.258

Note: Table 6 summarises three operating envelopes of data from combinations of hydraulic head, round-trip efficiency, and available storage volume. All sets of data are plausible bounds on system performance and can estimate the range of usable energy under different operating conditions.

The low data set, representing reduced storage and low efficiency produces 3.875 TWh of usable energy and falls just short of the full coverage 4 TWh dry-year deficit target with a coverage ratio of 0.969. Whereas the high envelope produces 6.289 TWh of usable energy and exceeds the same target of energy with a coverage ratio of 1.572. Whereas the middle data set envelope can still execute the desired 4 TWh target.

The uncertainty envelope further solidifies the values that were concluded in the sensitivity analysis above. Changes in storage availability and efficiency are the largest drivers of Lake Onslow's ability to offset dry-year shortfalls. In contrast, the hydraulic head only produces small differences in the overall outcome of the system. After completing all analysis it can be seen that the active storage volume is the most dominant factor in the plant's ability to produce energy, the round-trip efficiency is the second most sensitive variable to the system with the hydraulic head producing the smallest difference in energy delivered to the output.

4 CONCLUSION

This study demonstrates that the Lake Onslow-scale pumped hydro energy scheme has sufficient energetic capacity to substantially mitigate New Zealand's dry-year hydroelectric shortfalls. Using baseline assumptions, the model produced roughly 5.6 TWh of usable energy and was fully capable of covering a 5 TWh dry-year supply demand. However, the system's capacity to supply energy decreased drastically as active storage volume and round-trip efficiency decreased. Across all analysis within this paper, storage availability was the most dominating factor indicating performance of the plant, where round-trip efficiency was the second most leading factor and hydraulic head had relatively small effects upon performance.

Though losses were represented using aggregate efficiency parameters, these losses originate from real hydraulic and electromechanical processes (Papadakis et al., 2023). In reality reducing friction losses within waterways, optimizing the pump-turbine and generator systems will also improve the system's capacity to supply more power. It's possible to also utilize other renewable energy in order to also increase the amount of energy that can be created, integrating the system with wind and or solar panels would create another possibility for energy storage and recovery (IEA, 2023; Papadakis et al., 2023).

This study has several limitations that should be taken into consideration when interpreting the results. The published Lake Onslow storage capacity of 7 TWh is described by ICCC simply as "storage" and does not explicitly distinguish between gross gravitational potential energy and deliverable electrical energy. For the purposes of this model, the value is assumed to represent the gross gravitational potential energy of the upper reservoir prior to round-trip losses. While this assumption provides a consistent basis for the calculations, alternative interpretations of the published value would provide different estimates of usable energy.

The model also represents system losses using a single lumped round-trip efficiency. In reality, overall efficiency varies with pump performance, turbine-generator efficiency, hydraulic friction losses, electrical conversion losses, and operating conditions. Similarly, the model assumes continuous discharge at the rated output of 1000 MW. Consequently, the reported discharge durations represent idealised energy-to-power ratios rather than operational forecasts. Actual operation would depend on electricity demand, renewable generation, market dispatch, reservoir management, and changing hydrological conditions.

Additionally, reservoir inflows, pumping during operation, transmission constraints, or electricity network limitations are not accounted for in this model. The coverage ratio therefore represents an energetic comparison between available stored energy and the total dry-year shortfall, but does not consider when shortages occur or how they are distributed over time. The results should therefore be interpreted as indicators of overall energetic adequacy rather than a complete simulation of real-world operation.

This paper uses simplified assumptions, but provides a thorough outline for evaluating the long-term energy storage with various climate stressed conditions. This study supports the conclusion that pumped hydro energy storage is one of the best technically viable technologies for delivering such large amounts of usable energy even during prolonged dry-year conditions.

AUTHOR BIOGRAPHY

Derek (Xiangwen) Ding is a 12th Grade student at ACG Parnell College in Auckland, New Zealand. He is interested in physics and engineering, specifically the application of quantitative modelling on real-world problems. He plans to pursue further study in engineering or applied physics at university.

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