Storage Management and Risk Appetite

in a highly renewable Aotearoa New Zealand power system

Grant Telfar, Meridian Energy

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Introduction

Storage management, risk appetite, market power incentives, and the power system trilemma

Volatile hydrology, small storage reservoirs, hydro fleet scale, all combined with the operational style of reservoir management can have significant impacts on power system outcomes

There is clear *potential* for market power misuse implicit in medium-term reservoir management

Today that potential and the influence of reservoir owners is moderated by:

- regulation: Section 36 and the Code
- competition from discretionary thermal
- competition between hydro operators
- competition from generation entering / exiting
- competition from demand entering / exiting
- new demand response technologies
- political and regulatory 'license to operate'
- desire to be a good corporate citizen
- the modest scale of the reservoirs
- the modest scale of additional reservoir profits

As thermal generation diminishes or exits the market entirely there are concerns that a reduction in competition for discretionary flexibility may enable hydro operators to exploit their market position

Approach

Storage management, risk appetite, market power incentives, and the power system trilemma

Trying to find the 'best' reservoir management model for Aotearoa NZ

Efficient, cost-reflective power-system S(C)DDP reservoir modelling is used to reflect different storage management strategies

Reservoir strategies are distinguished by a simple, rational, economic risk-aversion methodology:

- Different levels of conservatism are used to set-up reservoir operating rules
- A priori, thermal costs, demand response costs including VoLL, and inflow volatilities are all assumed higher/lower (for optimization) than they are expected to be ex post (for simulation)
- All reservoir owners have the same approach to reservoir risk aversion

Assessed:

1. In the near-term, (investment locked in), and
2. In a highly renewable future where investment can respond to price signals

Reflecting the market in *equilibrium:*

- **In the short-term**, equilibrium is maintained via ensuring the same average consumer price – using small adjustments to hypothetical backup generation
- **In the long-term**, equilibrium is maintained via ensuring the same average investment signals – using adjustments to assumed level of new generation

A WEC style energy trilemma perspective is used to assess outcomes

Risk aversion and security standards

What does ‘best’ for Aotearoa New Zealand mean?

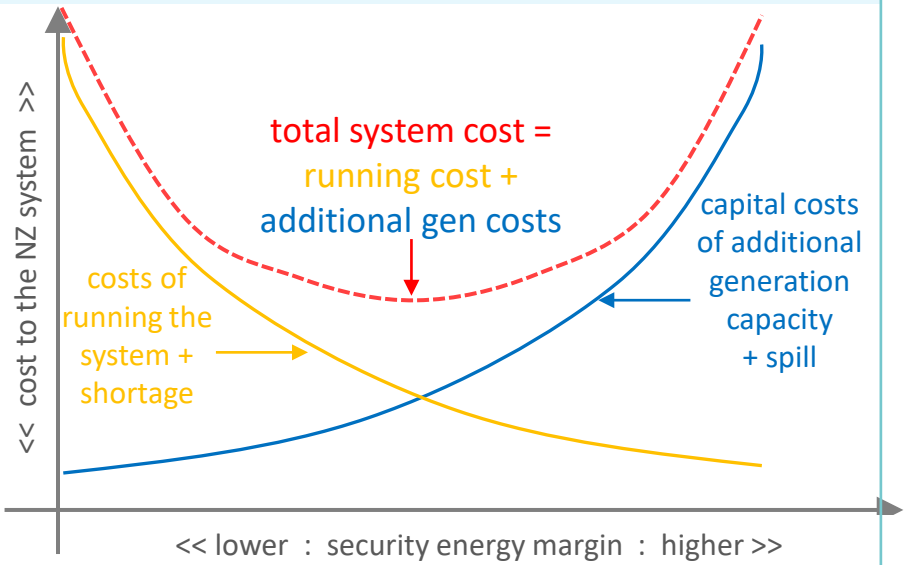
Exploring simple risk-aversion modes and applying them to storage management:

- Influence operating rules, to drive more/less aggressive behaviour
- A good proxy for the level of dry-year security at the bottom of the lakes

When considering costs, similar to the approach used for system security margins:

- For **low** security, expect higher system running costs, but limited additional ‘backup’ generation capital costs
- For **high** security, expect lower system running costs, but higher backup reserve generation capital costs
- In between lies the ‘best’ balance

Beyond cost, it is not always clear what ‘best’ means, so we will come back to this



There is a unique flavour to this balancing act for reservoir owners:

- Concerns about emptying storage lakes have long dominated NZ energy market design and market studies
- Equally, the visibility of and regulatory attention to reservoir spill can also be painfully clear

Meridian.

2024 lake management

in the near-term power system

Near-term storage

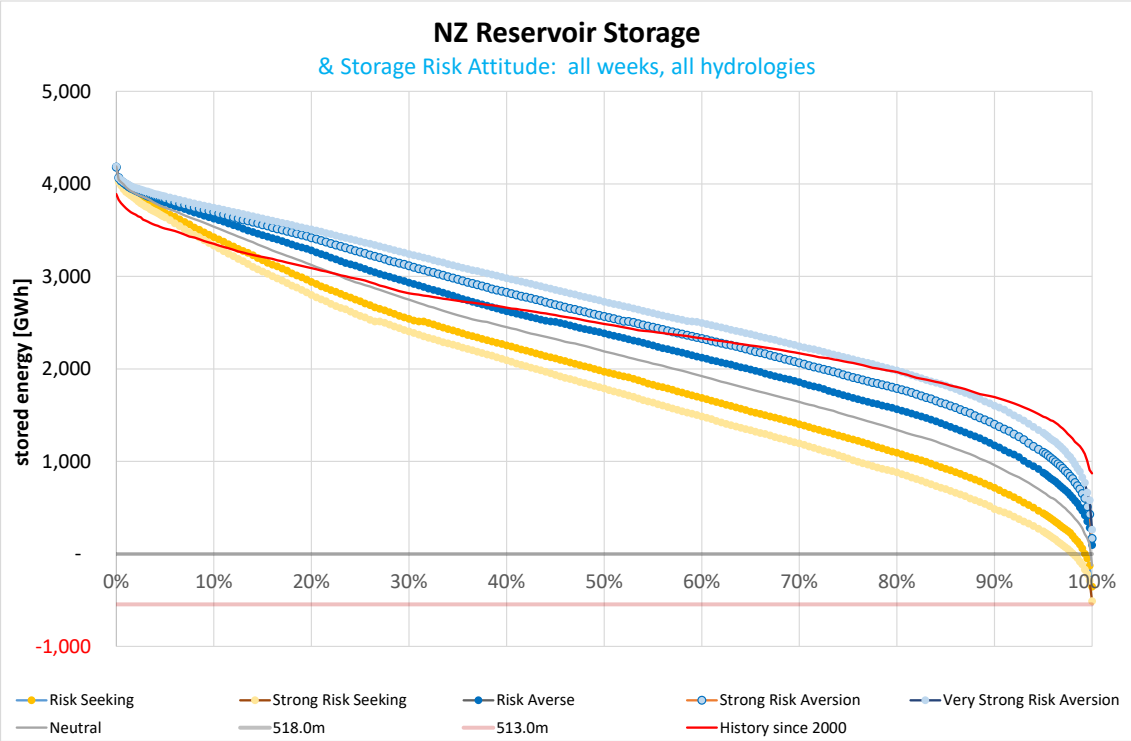
And operational attitude to storage risk

Six distinct storage risk appetite modes are assumed:

- Very strong risk aversion -> risk neutrality - > strong risk seeking
- A wide range of storage levels are possible
- Even with almost identical views of market supply & demand
- Most views of storage lie below historically observed levels
- Lake minima are almost never reached but *are* used in extremes;
- Excessive spill management at the top of the lakes is only infrequently seen

No obviously 'correct' storage management and a simple system management approach to risk can produce a wide range of defendable physical outcomes

… let's look at other metrics



(contingent storage included only in extremes)

Near-term system (producer) costs

And operational attitude to storage risk

Risk seeking drives modestly lower system costs on average than risk aversion:

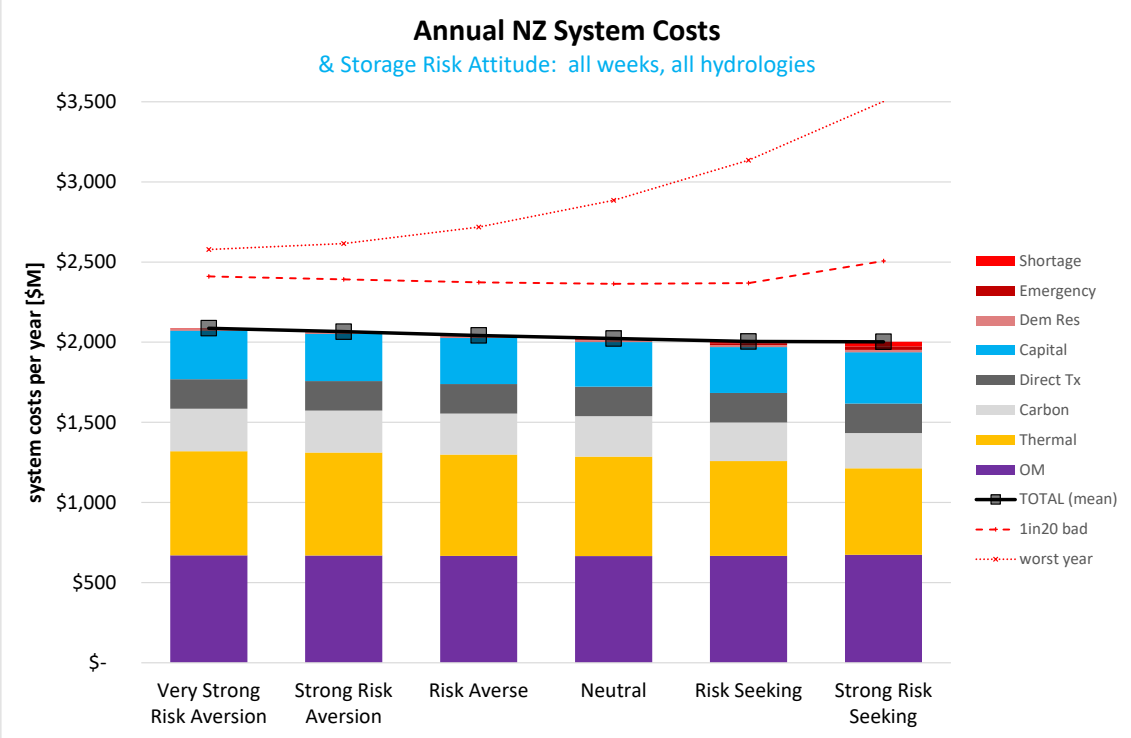
- But a surprisingly narrow range of expected annual system costs
- Capital and shortage *increase* along with risk seeking; while thermal fuel and carbon costs *decrease*
- Only small differences in total costs between very different storage outcomes

Additional insights beyond the mean, especially the dry extremes:

- Extreme costs become significantly better under strong risk aversion
- Worst case outcomes often drive the regulatory and political attention

A wide range of storage outcomes can occur with broadly similar average system costs and mixed insights on risk aversion

… let's look at other metrics



Near-term system prices

And operational attitude to storage risk

Storage outcomes all occur with the same average consumer price (=LWAP):

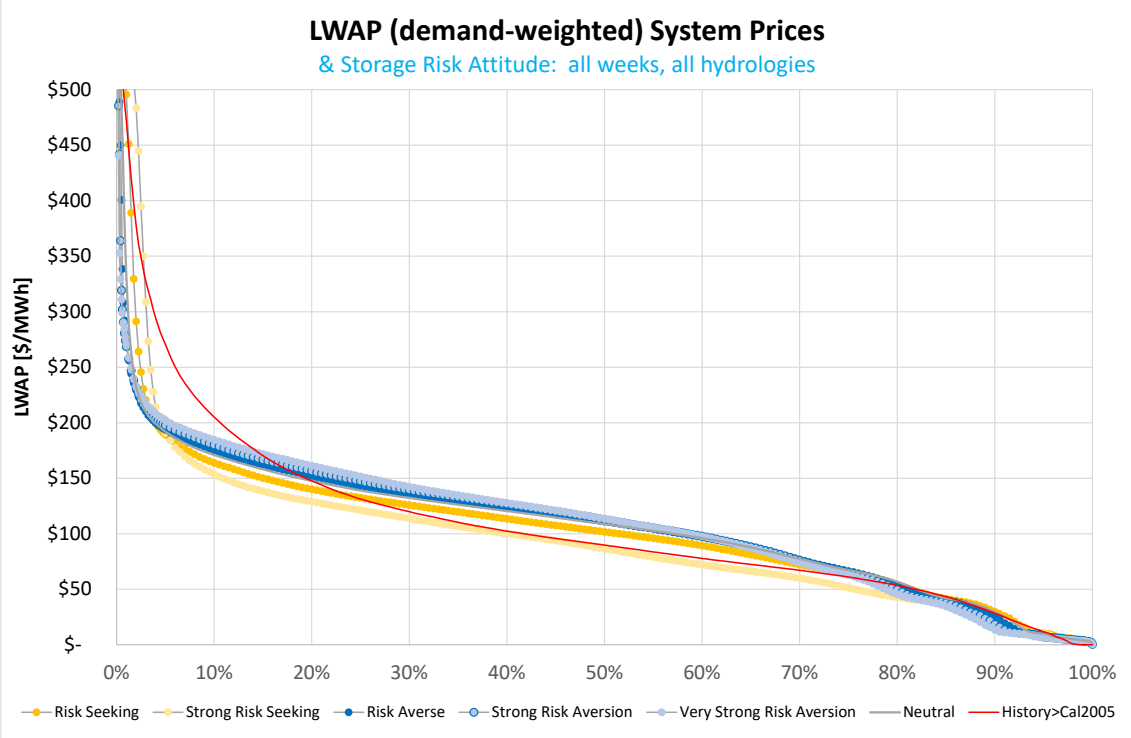
- No difference in expected wealth for consumers (regions may vary)
- Large increase in extreme *annual* prices, as risk seeking increases
- Volatility of weekly prices grows strongly with risk seeking behaviour

The full distribution of weekly prices shows distinct differences, *all for the same average price*:

- Results struggle to reflect historical peak pricing in the P00 – p10 range
- As risk seeking behaviour increases, prices in the P05-P100 range are increasingly suppressed, while peak prices become higher, more often
- Peak prices send clear signals to existing and new generation and demand that money can be made if flexibility can be brought to bear

Some support for risk aversion?

…let's look at other metrics



Near-term system carbon emissions

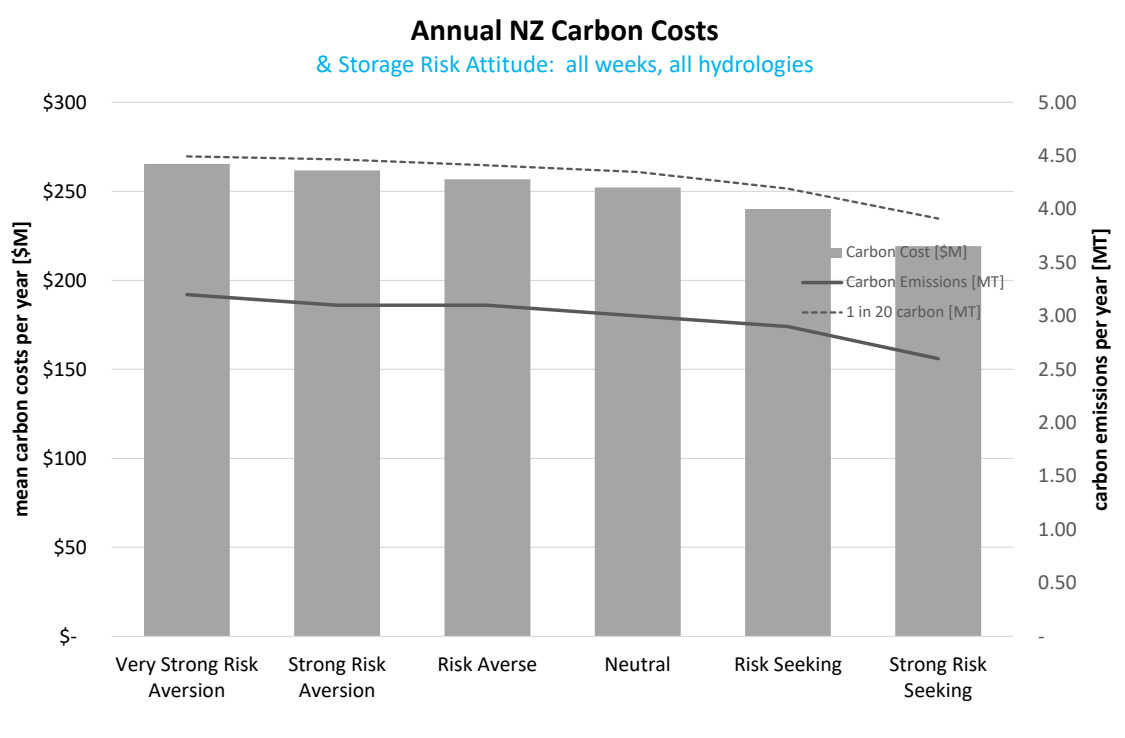
And operational attitude to storage risk

The more aggressive the storage management pursued, the lower the carbon emissions:

- On average and in extremes
- Driven by lower reservoir spill seen with lower lake levels
- The annual reduction is solid, but small in the context of NZ's 80MT total

Risk seeking looks like a good news story for reducing power system emissions … but wait

…let's look at other metrics



Near-term system shortage and demand-response

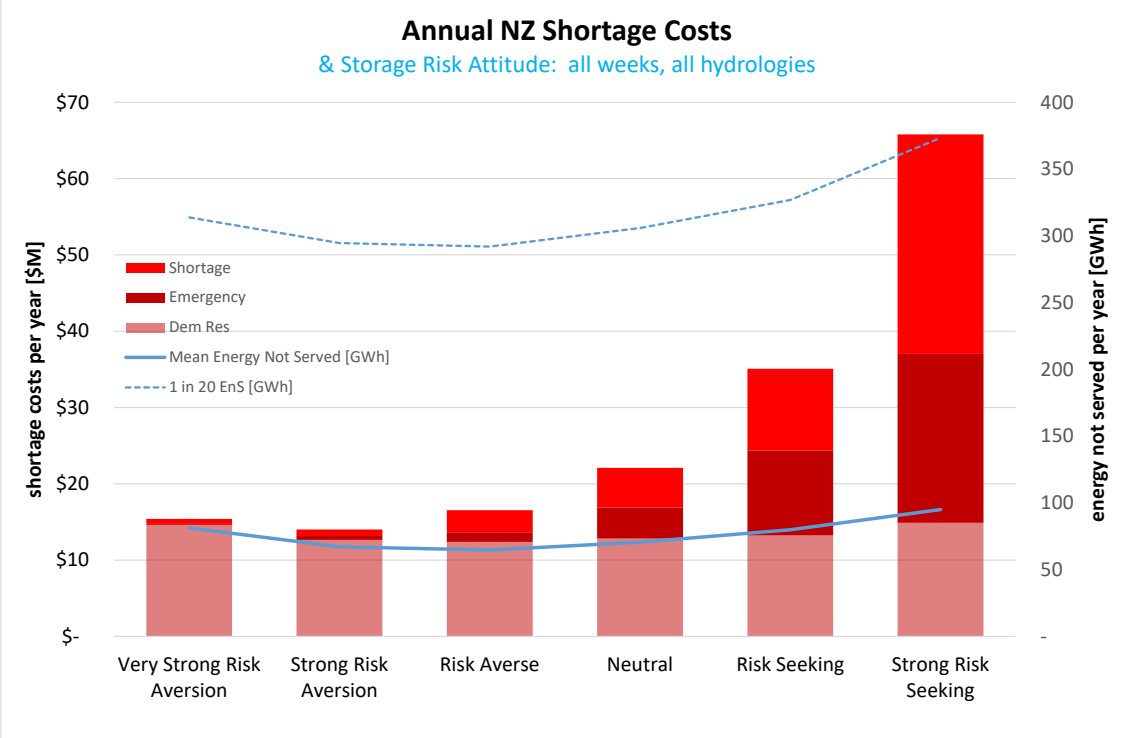
And operational attitude to storage risk

The more aggressive the storage management pursued, the greater the frequency and depth of emergency demand response, ENS, and economic costs to NZ:

- Dry year results can be dramatically worse
- There is no such thing as a perfect power system
- *But* the politics of prolonged shortage – when one happens – can not be understated

Conservatism (politically) combined with small emissions gains available suggest that modest risk-aversion may be a prudent compromise, but…

…let's look at other metrics



Near-term approach to storage management

What attitude to reservoir risk is best for Aotearoa NZ?

No single style of storage management *always* produces good outcomes for NZ or for Meridian

A compromise/balance is needed; not an exact science with multiple perspectives

Modest-to-strong storage risk aversion appears to be in the best interests of New Zealand:

- Other views and metrics may be relevant
- Precautionary principle: avoiding extremes; leaving room for "unknown unknowns"
- Tension in some trade-offs: eg security & CO2
- *But* there is no black-and-white position

Meridian has strong incentives to avoid both *excess* risk aversion and risk seeking behaviours but with *some* risk aversion being preferred:

- Unlikely that other hydro operators will differ

Risk averse storage management appears prudent for NZ **and** is also in the best interests of Meridian

…but what about the future?

best precautionary compromise storage management

New Zealand Preferred Storage Management and Attitude to Risk

system outcome	energy trilemma	wgt	Very Strong Risk Aversion	Strong Risk Aversion	Risk Aversion	Risk Neutral	Risk Seeking	Strong Risk Seeking
Hydro Storage Buffer	security	2.1%	1	2	3	4	5	6
P01 Storage	security	2.1%	1	2	3	4	5	6
New Generation Capital	cost	4.2%	5	4	2	1	2	6
System Costs: Average	cost	8.3%	6	5	4	3	1	1
Costs: Dry Extreme	cost	4.2%	1	1	3	4	5	6
Consumer Prices: Average	cost	8.3%	1	1	1	1	1	1
Price: Volatility	cost	8.3%	1	2	3	4	5	6
System CO_2 Emissions	carbon	33.3%	6	4	4	3	2	1
System Shortage	security	25.0%	1	1	3	4	5	6
System Spill	security	4.2%	6	5	4	3	2	1
Weighted Score	total	100.0%	**3.5**	**2.8**	**3.3**	**3.2**	**3.1**	**3.3**

Undesirable
Neutral
Desirable

Meridian Preferred Storage Management and Attitude to Risk

MEL Generation	portfolio	16.7%	6	5	3	3	2	1
MEL Gen Rev	portfolio	16.7%	5	3	1	1	3	6
MEL Price Participation	portfolio	16.7%	3	1	1	3	5	6
Pūkaki P01 Storage	risk	16.7%	1	2	3	4	5	6
MEL Net Income	portfolio	16.7%	4	2	1	2	5	6
MEL Dry-year Risk	portfolio	16.7%	3	1	1	3	5	6
Weighted Score	total	100.0%	**3.7**	**2.3**	**1.7**	**2.7**	**4.2**	**5.2**

2040 lake management

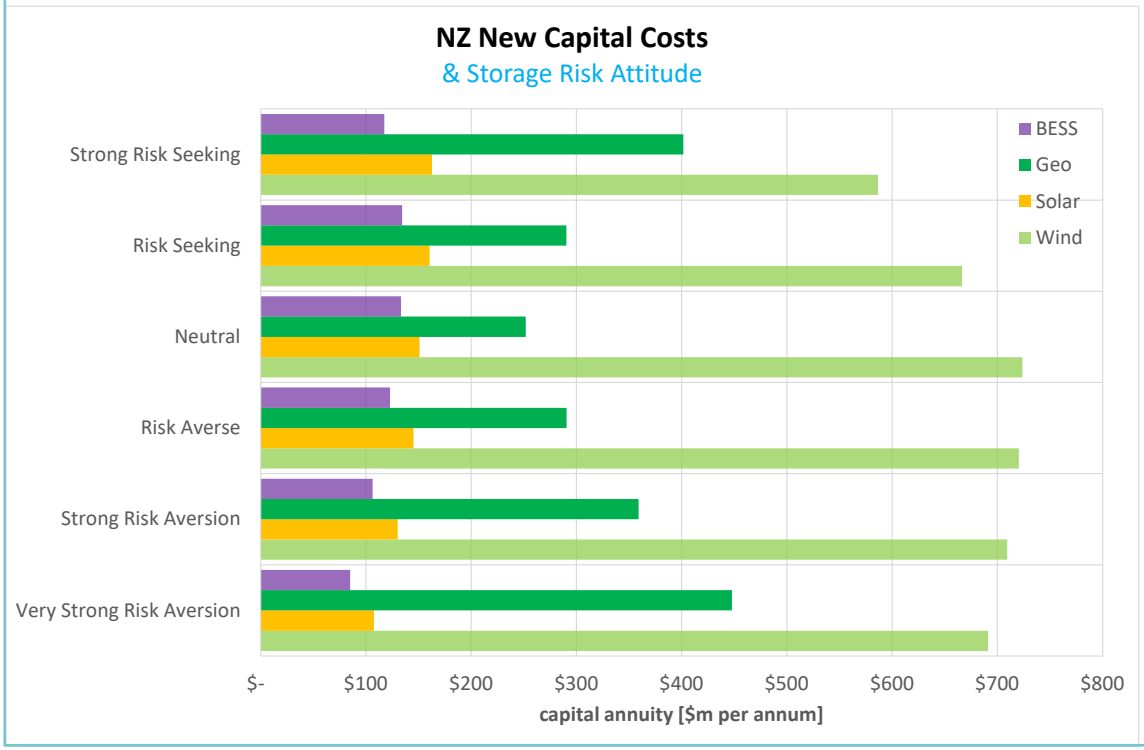
in a highly renewable
future power system

Future storage management and a market in equilibrium

And attitudes to storage risk, system costs, and investment

For each distinct mode of risk, the power system is represented in *dynamic investment equilibrium*:

- No dynamic switching between modes of reservoir operation
- Investment adequacy is risk neutral, sufficient to return a small hurdle above WACC on average
- Generation investment is 100% renewable, along with BESS and 'beyond market' DER technologies
- Technological improvements are still expected (costs down and efficiencies up)

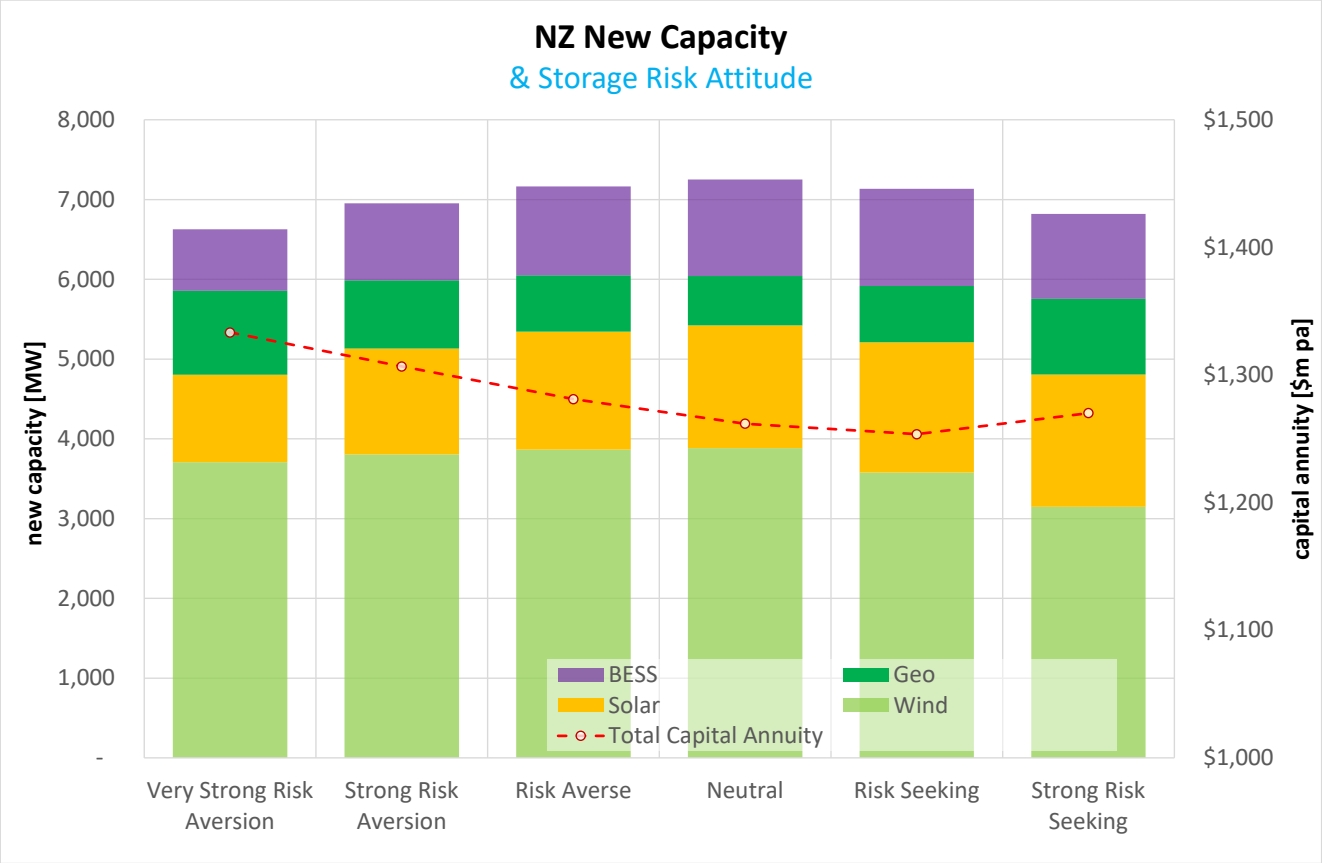


Revenues for different classes of new generation can be affected by style of storage management:

- Reservoir management, applied consistently, can affect how much of each generation class we would expect in an efficient market
- Any additional inconsistency in operational mode will challenge efficient investment beyond that shown here, to the detriment of Aotearoa

Future new generation capacity

And attitudes to storage risk, system costs, and investment

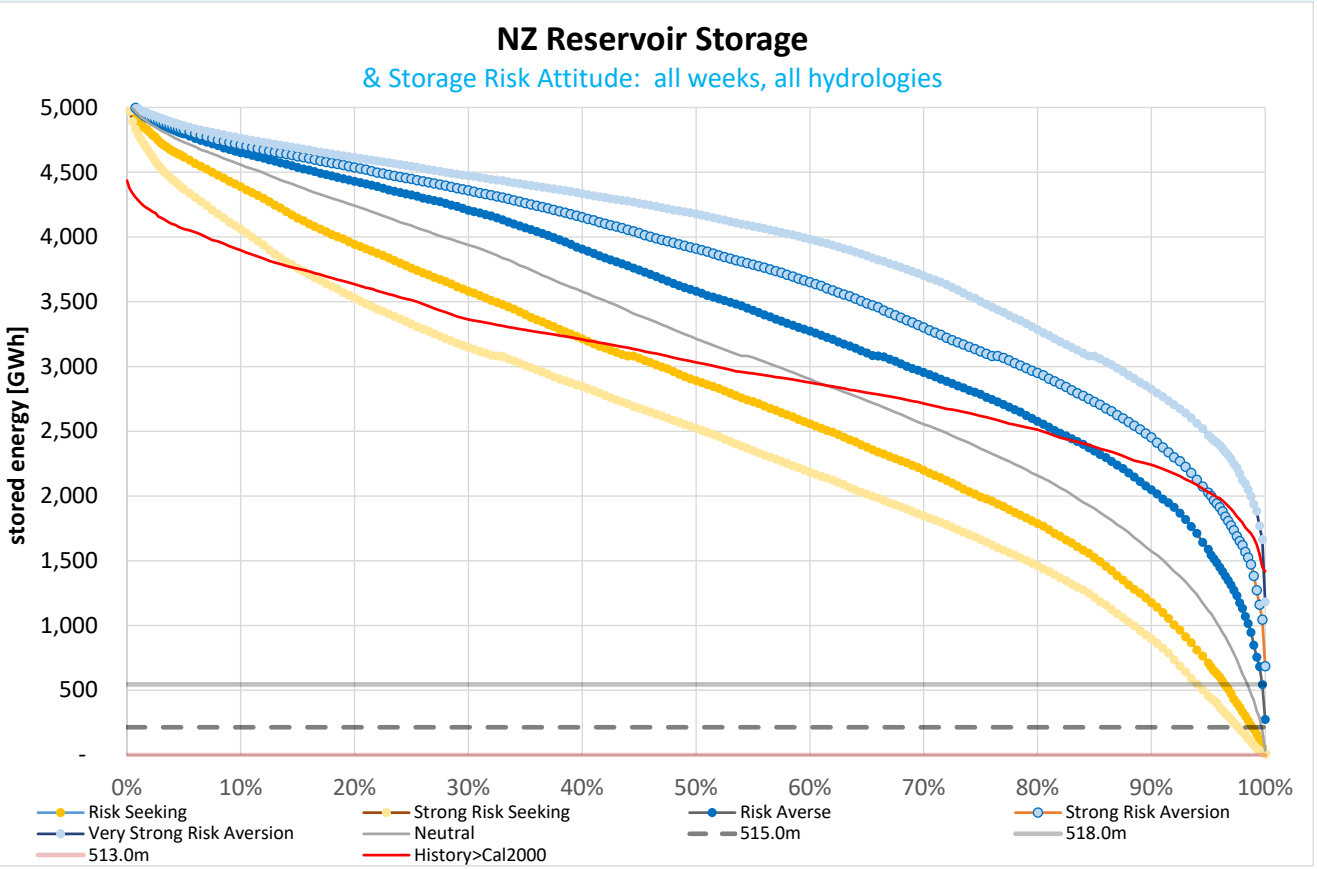


Consistently applying the same mode of risk management could drive as much as 50% more solar investment or 25% more wind and a reduction in other technologies

Reservoir owners, via mode of storage operation, have a clear collective *ability* to influence the generation mix that merchant investment would efficiently prefer

Future storage

And operational attitude to storage risk



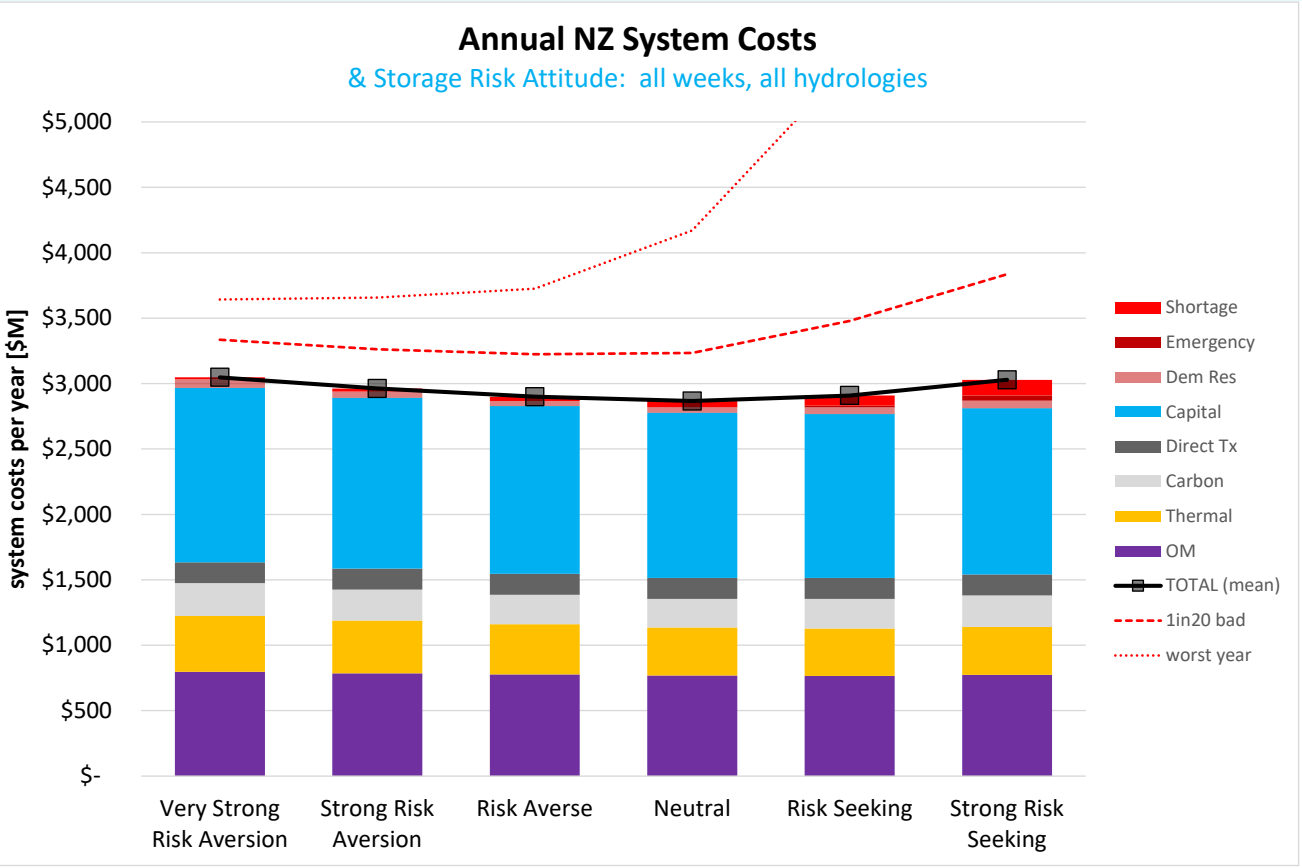
Storage outcomes are both more distinct and more volatile than in the early 2020s, but the full storage range is still used with the extremes only rarely being reached when warranted

(now includes unfettered use of contingent and some additional new storage)

As with the early 2020s analysis, in the future power system, we still see that a wide range of storage outcomes can occur

Future costs

And operational attitude to storage risk

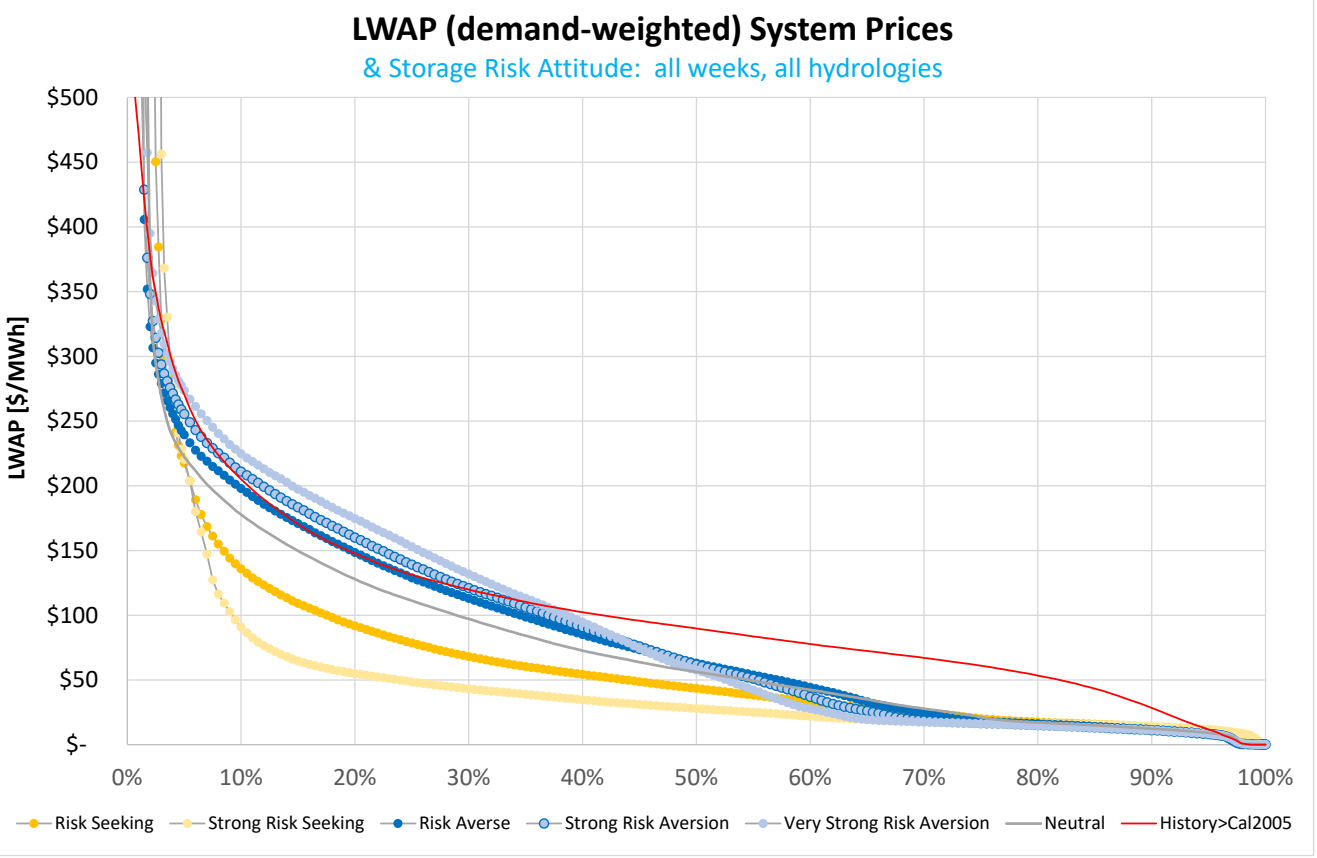


Once again, a wide range of storage outcomes are associated with a surprisingly small difference in *average* annual costs

Improvements in costs available in dry-year extremes again suggest that a risk averse setting is likely to be (politically) prudent for the system

Future prices

And operational attitude to storage risk



Prices are a lot more volatile than in the early 2020s, seasonality is markedly different, and low prices can dominate for long periods – but the wide range of price distributions and storage outcomes still shows only a small difference in *average* consumer prices

Volatility and prices at extremes are now far more pronounced than in the early 2020s and are more easily influenced by mode of reservoir management

Best use of reservoir storage circa 2040

And operational attitude to storage risk

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MEL Price Participation	portfolio	16.7%	5	3	2	1	4	6
Pūkaki P01 Storage	risk	16.7%	1	2	3	4	5	6
MEL Energy Margin	portfolio	16.7%	6	4	3	1	2	5
MEL EM downside risk	portfolio	16.7%	5	4	2	1	2	6
Weighted Score	total	100.0%	**4.8**	**3.7**	**2.7**	**1.5**	**2.7**	**5.2**

Neither strong risk aversion nor risk seeking are in the best interests of either Aotearoa or Meridian

Significant additional costs and emissions can be avoided by mild risk aversion, or even risk neutrality, which are now more attractive positions for NZ to adopt

Risk neutrality is now the strongly preferred position for Meridian

Absent moderating influences, reservoir owners have stronger incentives to apply a little less risk aversion than may be ideal from a NZ perspective

Summary and conclusions

Near term power system

A wide range of reservoir outcomes are possible, reflecting different modes of risk management:

- Possible for very similar costs
- Mixed trilemma outcomes, often in conflict
- No single style of management will produce a good outcome all the time
- Modest-to-strong risk aversion is the best approach for NZ and for Meridian

Future power system

We still see a wide range of storage outcomes possible for similar *expected* costs:

- Volatility is far more pronounced
- Mild risk aversion is now best for NZ
- Meridian's incentives shift towards neutrality
- Self moderation may yet align private preferences with the national position

There is no 'right' …. but there is a lot of 'obviously wrong'

The mode of reservoir management and how system risk aversion is best accounted for becomes more important in a highly renewable future than it is today, especially as thermal plant retire

Regulatory clarity as to how trilemma outcomes should be considered and balanced will become more important to the stability and enduring nature of power system operation and market design

These concerns will be moderated over time by (yet uncertain) new demand-side technologies, as consumers respond to growing commercial investment signals

Looking beyond the mean and looking beyond system cost are essential in reaching an enduring solution