The Future NZ Power System in 2050

Decarbonisation & Challenges

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Abstract and Summary

Uncertainty is a feature characterising any long-lived asset within the NZ power system. New generation often requires substantial up-front capital that is only recovered after several decades of operation.

Lack of certainty in future power system outcomes combined with an absence of long-term counterparties make uncertainty and risk critical considerations before funding approval occurs. Board approval for capital is tied strongly to a desire to use money prudently.

Here we present a high-level overview of what and why Meridian thinks about the future, risks involved, and focus on some specific details about the challenges facing the future power system.

Increasingly this conversation is being driven by local and global debates about carbon reduction within wider economies and energy systems.

Introduction and overview

Meridian maintains a long-term view of power and energy system issues, out to 2050:

- Understanding & planning for the future.
- Engaging with policy & regulatory direction.
- Long-life asset investment risks & opportunities.

Our general approach is to focus on:

- Supply and demand fundamentals.
- Secure & efficient power system operation.
- Scenario analysis.

We create narratives of how the industry might evolve over time and of our role in this future.

Guiding methodology is to maintain efficient power system & market operation through time:

- Reflecting the intent of NZ market design, especially price signals that encourage an appropriate market response.

1. Productive efficiency: cost-reflective offer behaviour and storage management.
2. Dynamic efficiency: investment decisions that maximise national welfare (ie projects that are revenue adequate).

Today we focus on the outputs of this approach in 2050 via two future scenarios.

We also aim to focus on some specific detailed power system challenges rather than on the more usual high level scenario overview.

i. First some context,

ii. Then some 2050 details.

Context: Scenarios and Key Macro Assumptions

Large number of macro assumptions required and significant uncertainties out to 2050

Evolution: An adaptive BAU scenario

- Underlying electricity demand growth is moderate with efficiency measures steady.
- Decarbonisation efforts modest.
- Climate disruption impacts on load & fuel.
- Demand-side technology growth steady.
- Significant new grid generation:
  - A supporting role for peaking gas plant remains clear.
- ETS price rises to $50/t CO_2e:
  - Power system CO_2 emissions fall.
  - Modest emissions removed from wider economy.
- Renewable share metric rises to 95+%
- Prices steady at $80/MWh until 2035, before falling towards $75.

Revolution: A global low carbon scenario

- Underlying electricity demand growth is low with strong efficiency measures.
- Decarbonisation efforts are strong.
- Climate disruption impacts on load & fuel.
- Demand-side technology growth strong.
- Significant new grid generation:
  - An essential role for dispatchable demand emerges.
- ETS price rises to $100/t CO_2e:
  - Power system CO_2 emissions fall.
  - Significant emissions removed from wider economy.
- Renewable share metric rises to 100%
- Prices steady at $80/MWh until 2035, before falling towards $60.

Context: Modelling Framework

LPcon is a traditional NZ power system modelling approach.

A macro state for the power system is assumed: both now and into the future. Given this macro state, 2 phases occur:

I. Stochastic reservoir optimisation.
II. Detailed power system simulation.

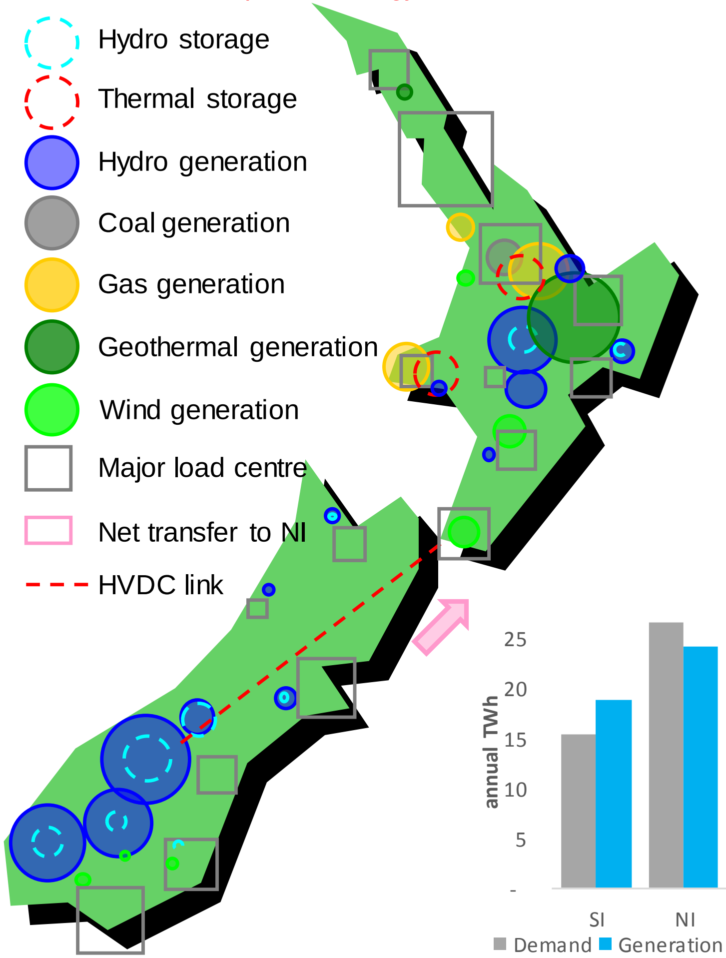
Transmission flows (DC-OPF), losses, & constraints (n-1 & security)	Detailed regional & nodal demand, 15 demand blocks per week
Co-optimised instantaneous risk & reserves for DC and generation	Reservoir management, hydro flexibility, historic flows, wind & solar
Co-optimised regulation risk & reserves for wind and solar intermittency	Intermittency, temporal and geographic correlations for wind, solar, EV charging.
Simple thermal station & offers, demand response & shortage	Geothermal, co-gen & embedded gen
BESS, BEV, roof-top solar	Outages: planned & forced

Objective 1: Seeking to minimise system operating costs. Balance the costs of excess spill, cost-reflective market offers, and the costs of system shortage.

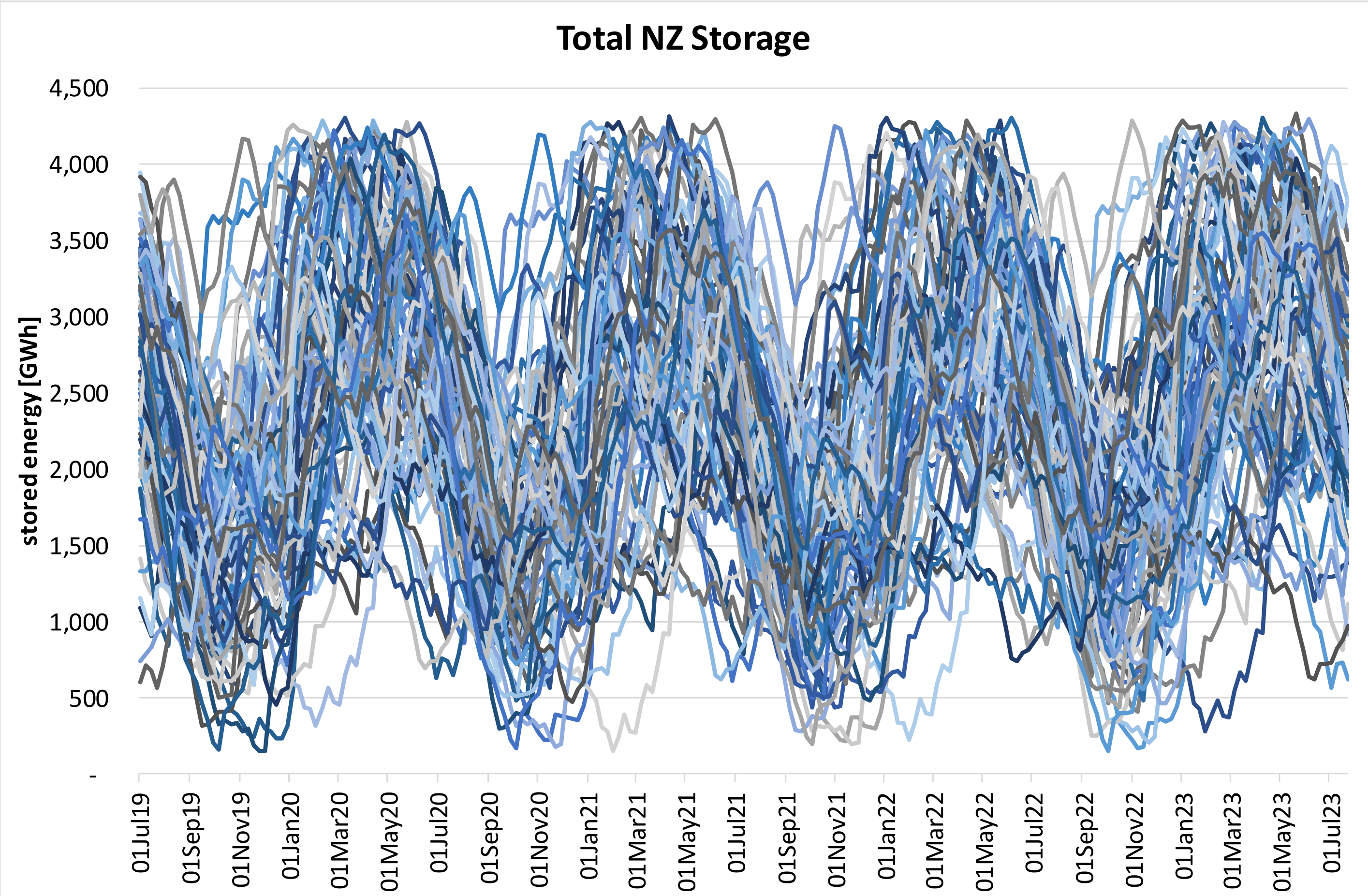
Objective 2: Over time minimise new generation (and tx) capex and annual operating costs. This is resolved manually rather than via a MIP or stochastic investment formulation.

Major Generation Sources

Scaled to size of expected energy contribution in 2018

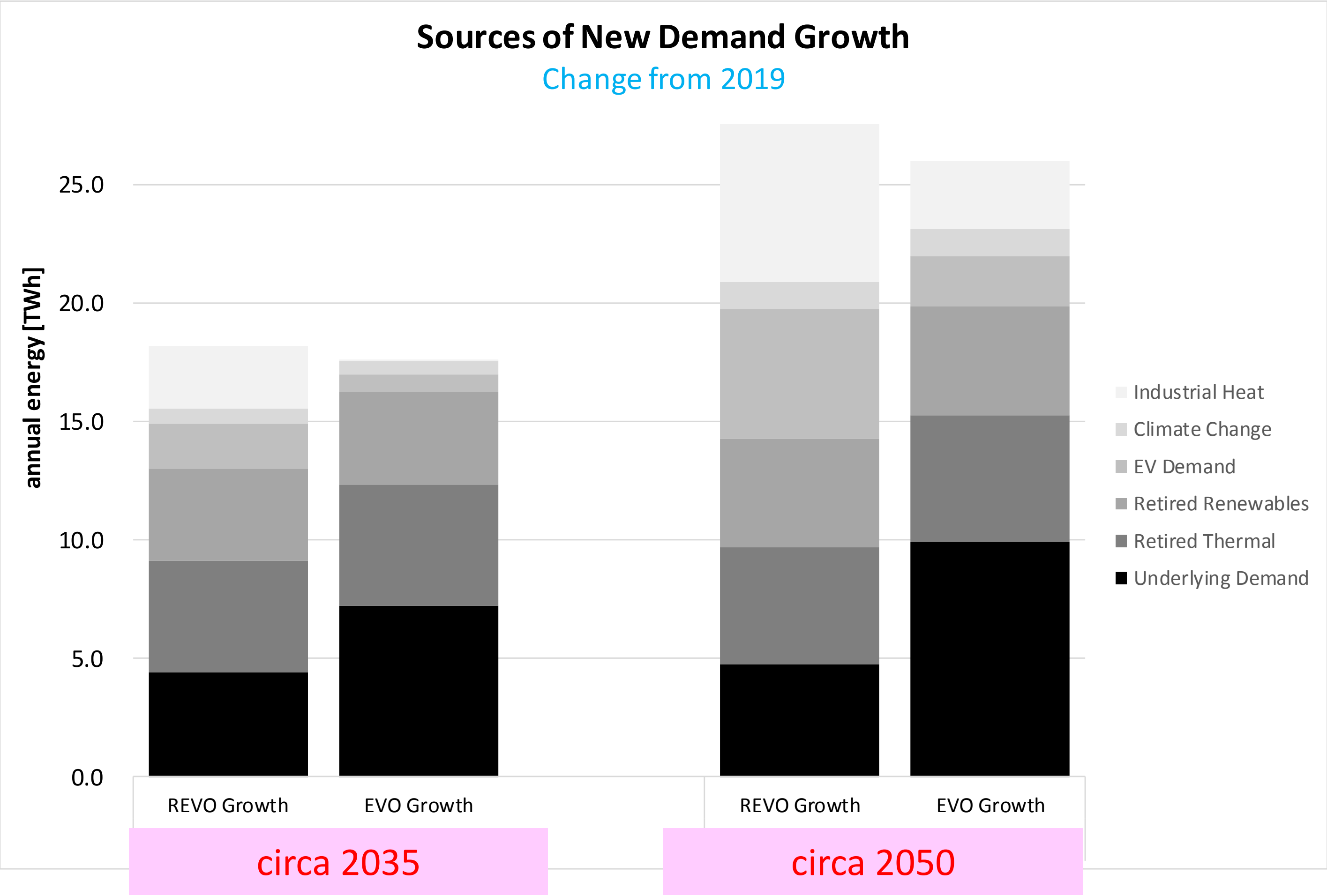


Context: Modelling Output



- Large volume of model simulation output.
- 30 years of weekly data x 86 hydrological outcomes, each week decomposed in 15 demand blocks.
- = 2M values for each modelled power system and market element:
  - Prices
  - Generation
  - Storage
  - Revenues
  - Line flow
  - Reserves
  - Renewable spill
  - Demand response
  - Etc…

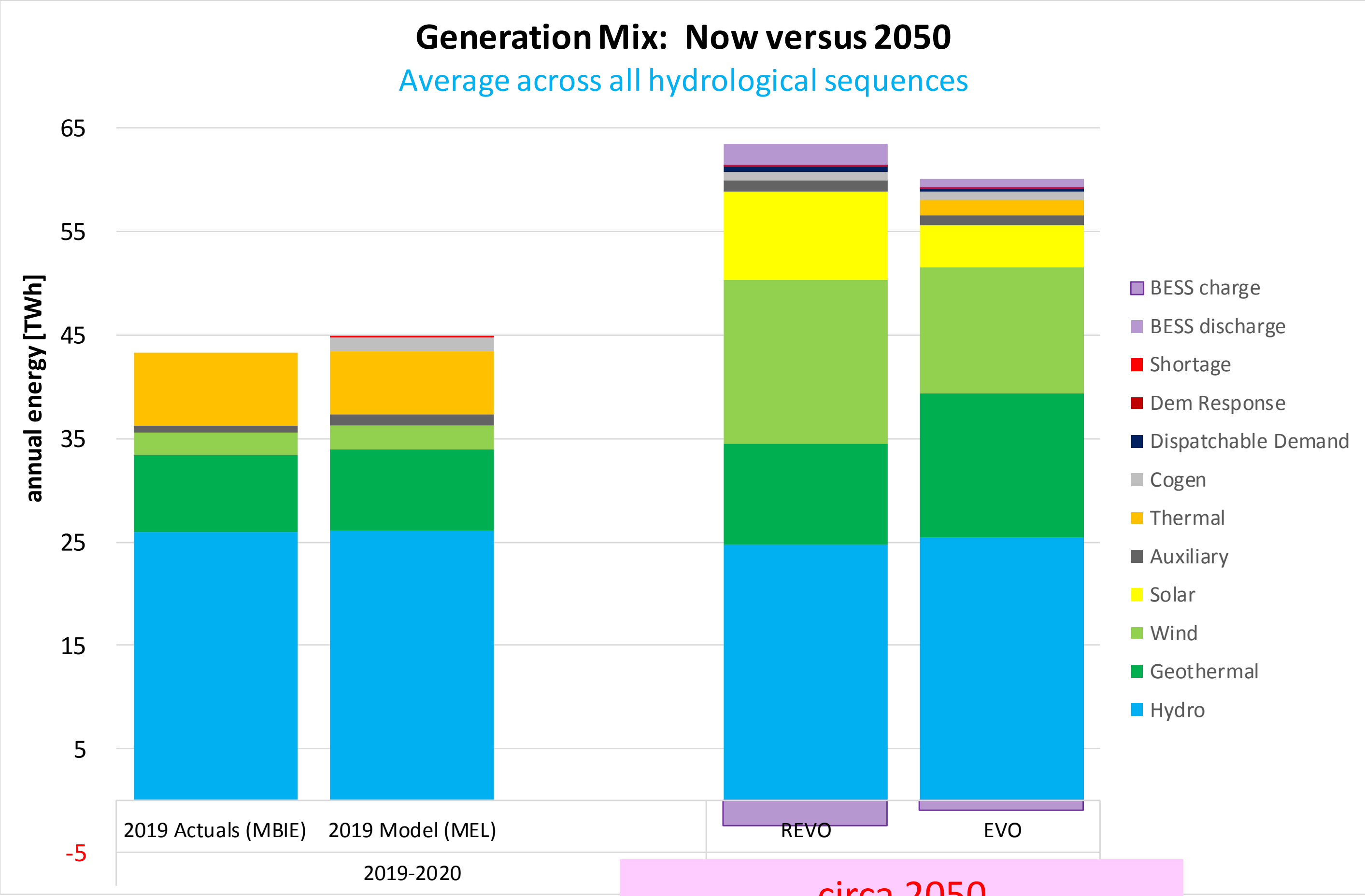
Context: Future power system demand & growth



- Large uncertainties in scale and timing of underlying demand growth.
- Large uncertainties in timing of thermal plant closure and renewable repowering.
- Timing and scale of new decarbonised electricity demand & impacts of climate disruption opaque.

Challenges: uncertainty, scale, and timing

Context: Future power system generation mix



circa 2050	
$13.5B grid gen + tx	$15B grid gen + tx

- The 2050 power system will be greener and larger than today.
- Likely regardless of decarbonisation as renewable costs continue to decline.
- Broad consensus on these points and on choice of technologies.
- Divergence in how much growth, and how much thermal plant are assumed.
- Scale of new generation and capital required is significant.

Challenges: scale, funding, consenting

Context: Energy trilemma

Challenges: an amazingly good news story mathematically. Need to put it into practise

Security Reliability

Sufficient flexibility in generation & tx to keep shortage metrics stabile despite large increases in intermittent generation sources

Well regulated, energy-only, efficient market mechanisms

All new generation projects are revenue adequate at standard WACC.

Maximise what is good about current system.

ETS remains primary regulator lever.

RMA reform likely needed to unlock optionality.

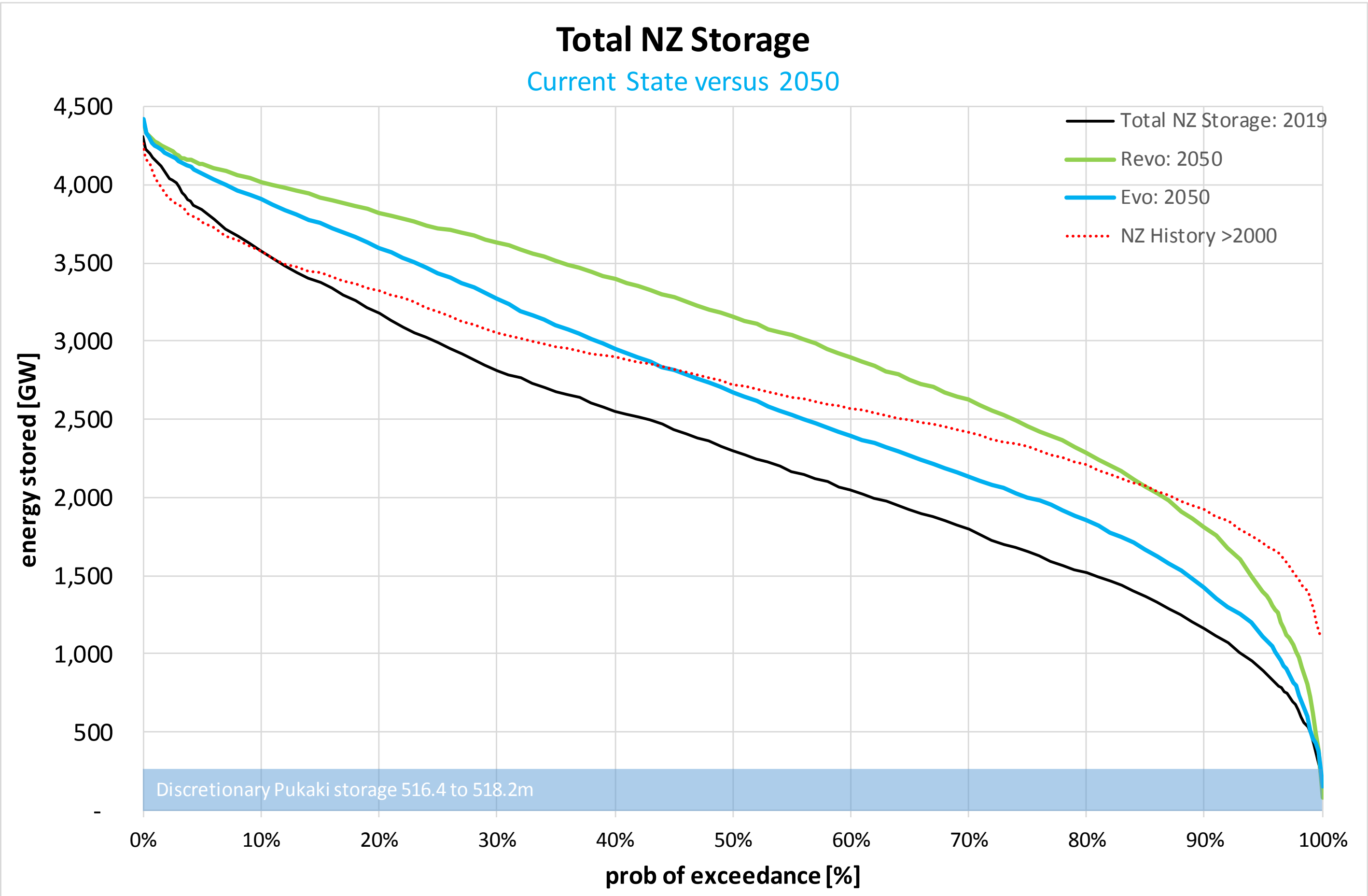
Sustainability CO_2

CO_2 emissions fall as big thermal plant retire. Low levels of CO_2 remain due to geothermal & peakers.

Price Cost

TWAP steady at ~$80/MWh. Technology cost decline offers prospect of price decreases over time.

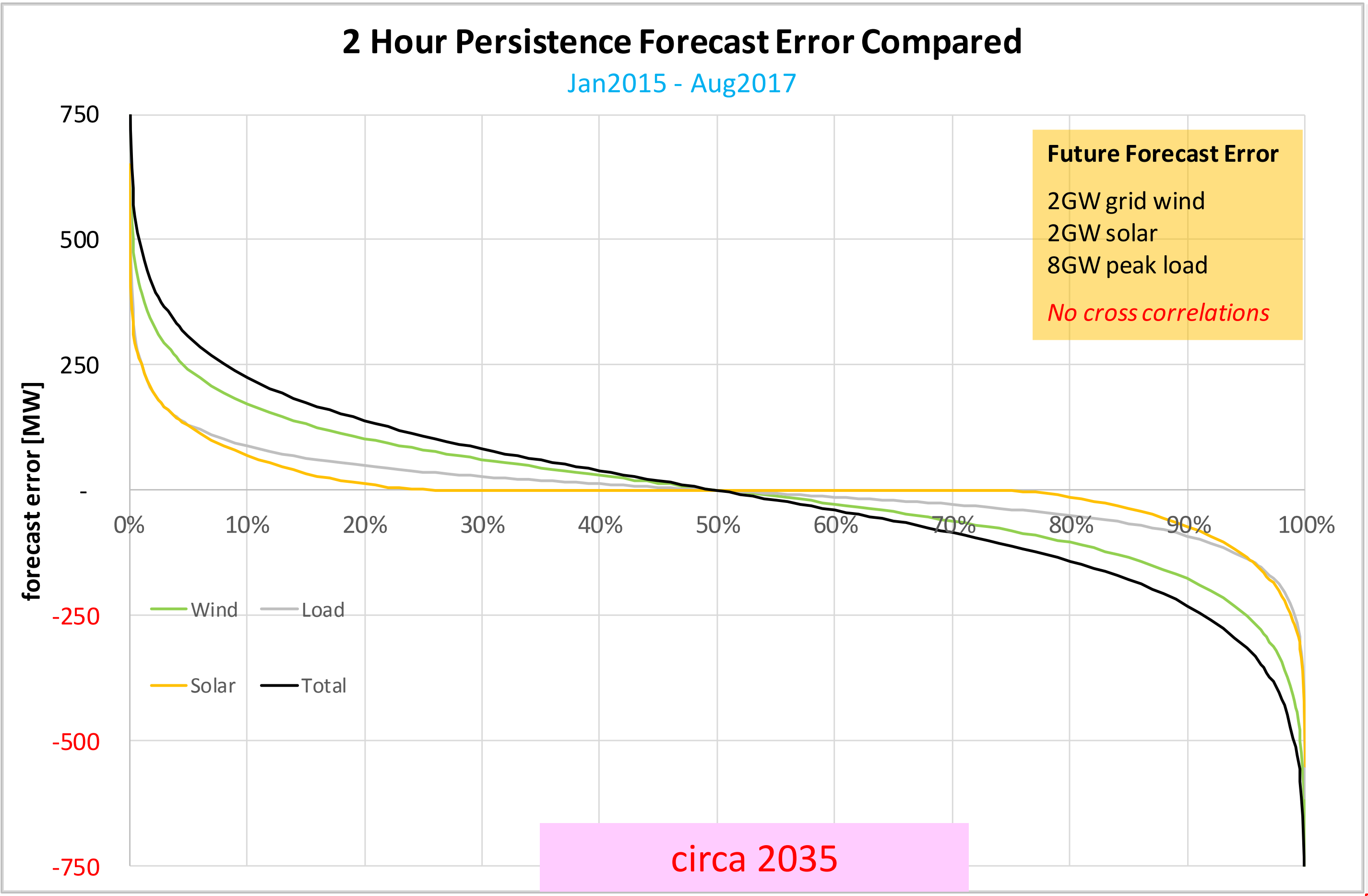
Details: Hydro Storage



- Increasing levels of renewables.
- Large thermal generation retired.
- As a consequence hydro lakes are typically held higher.
- Creates 'insurance' against dry year and other low energy events.
- Note that the full storage range is still used.
- Contrast this with the risk aversion inherent in the current ERCs (HRC).

Challenges: use full range, access more

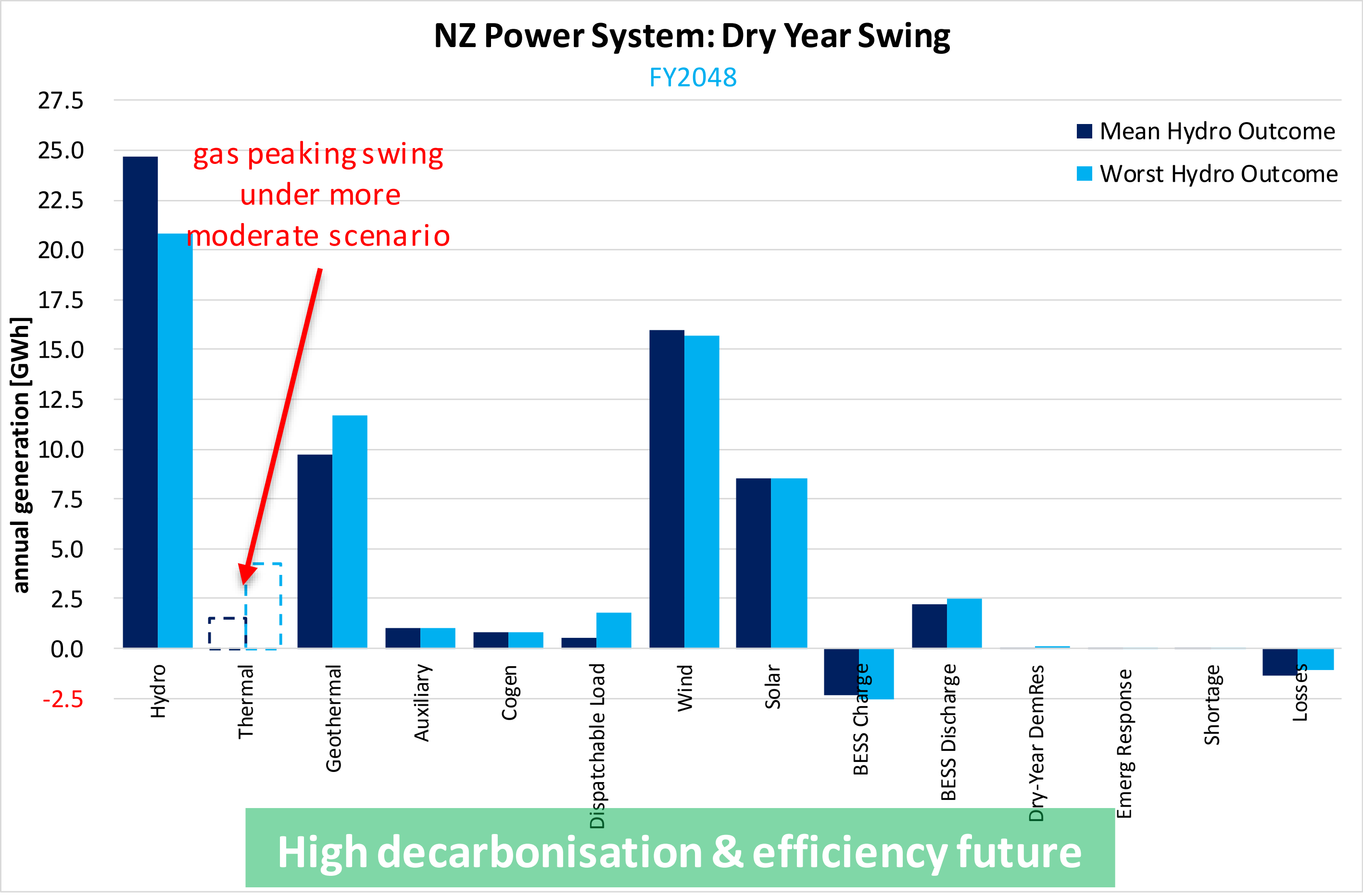
Details: Intermittency



- Intermittent generation sources will increase dramatically from today.
- Power output is uncertain across the day.
- Both 'intermittency' and 'capacity value' are resolved by appropriate investment decisions combined with current and new forms of flexibility.
- Preserving and unlocking current hydro and transmission capability key.
- A new category of frequency 'regulation reserve' will likely be required in time.

Challenges: flexibility, good market design

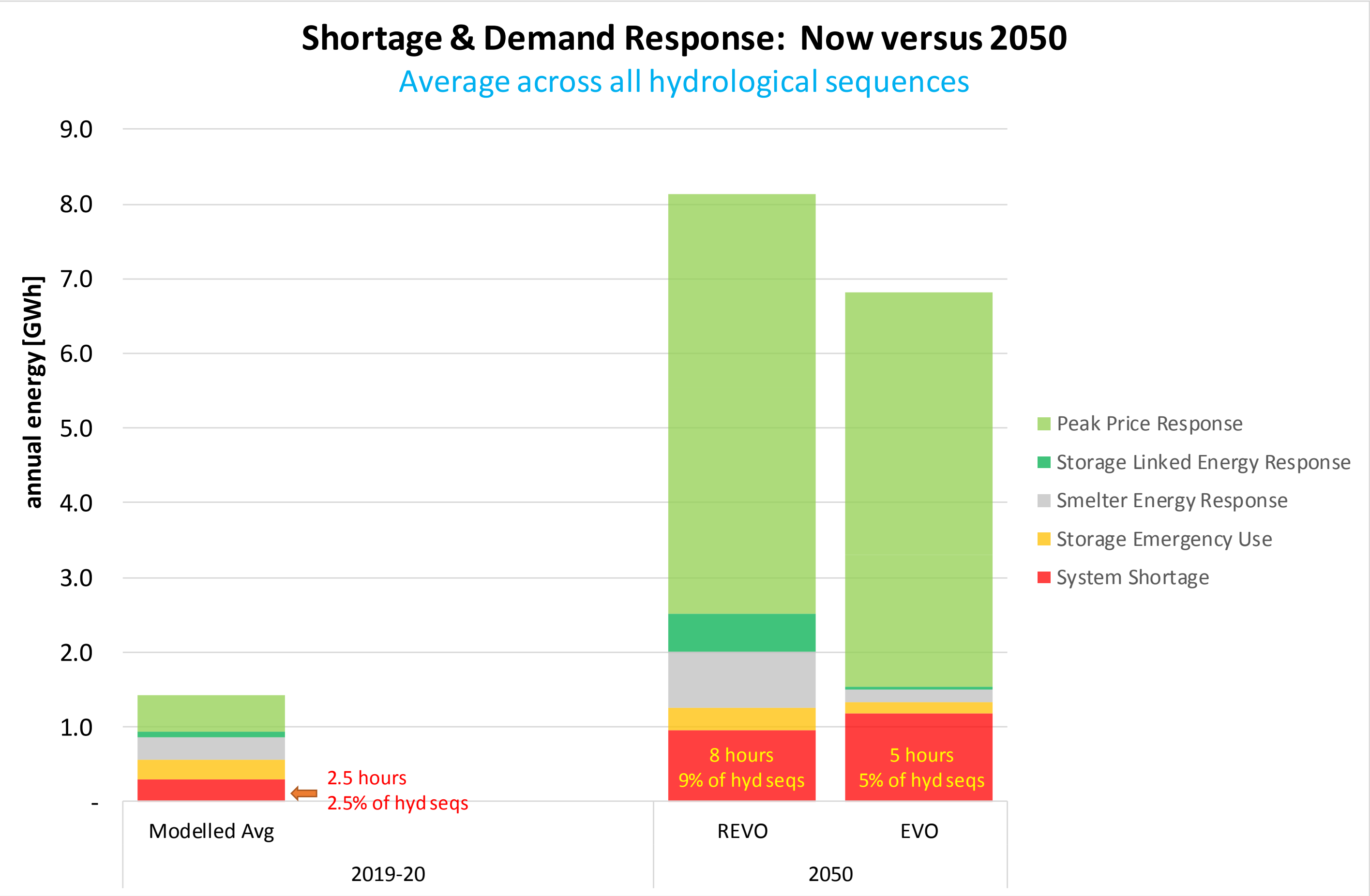
Details: Dry Year Hydro Firming



- The power system will move away from large thermal generation.
- Thermal peakers can play a traditional dry-year firming role and still help deliver a power system 95+% renewable.
- However, thermal generation may retire from the market entirely.
- In this case, new forms of flexibility are required.
- Dispatchable load, geothermal part loading, and hydro management all have a role to play

Challenges: demand side market, gas yes/no?

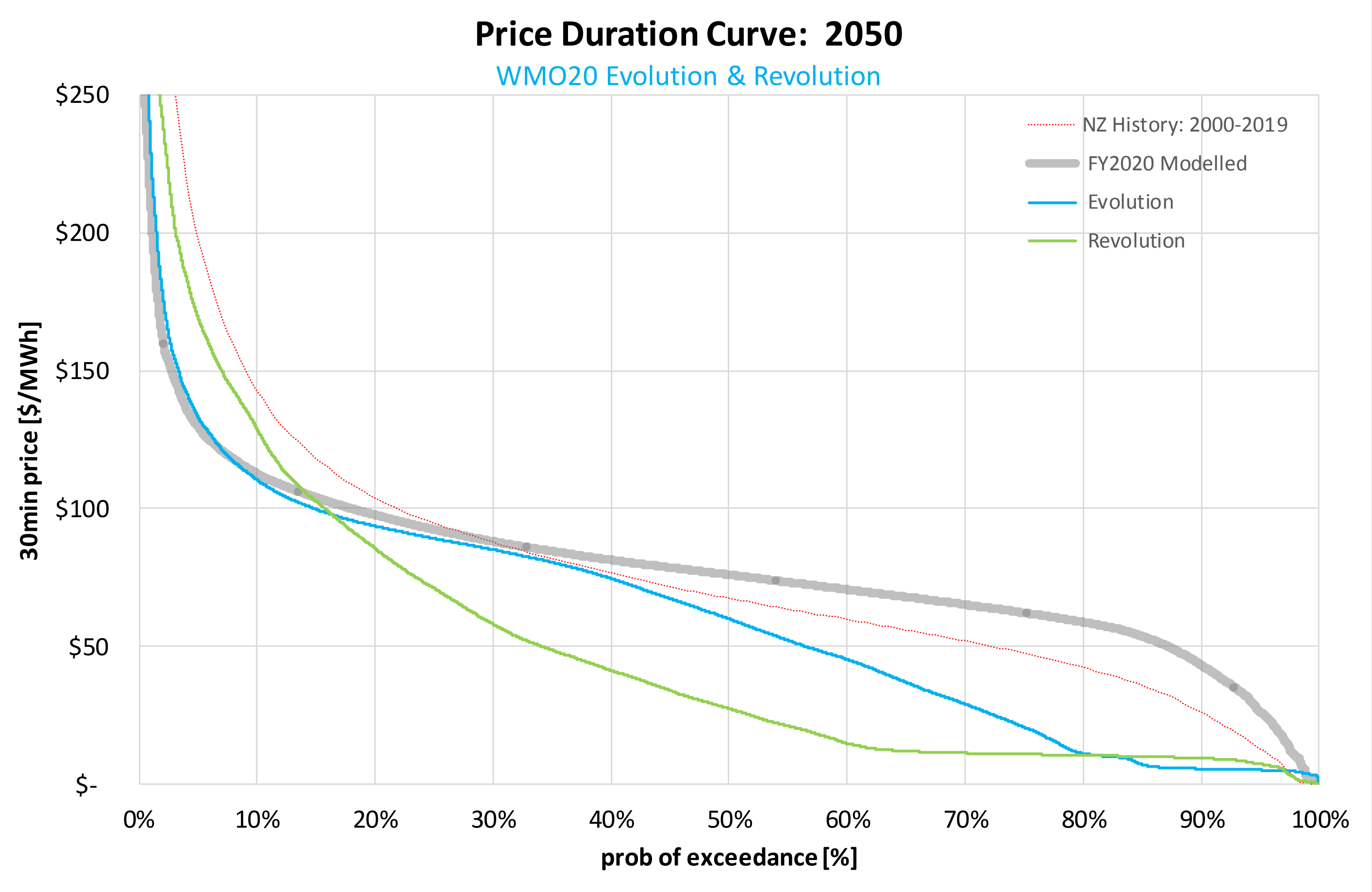
Details: Emergency Demand Response and Shortage



- Historical system security standards used internationally (LOLE, LOLP, EUE, …) may not be fit for purpose in a NZ renewable future.
- NZ standards (winter energy & peak margins) are physical and based on a snap-shot in time.
- A dynamic economic based expansion of the power system suggests security standards that are markedly different from today but are still low & infrequent.

Challenges: future proof standards, market based

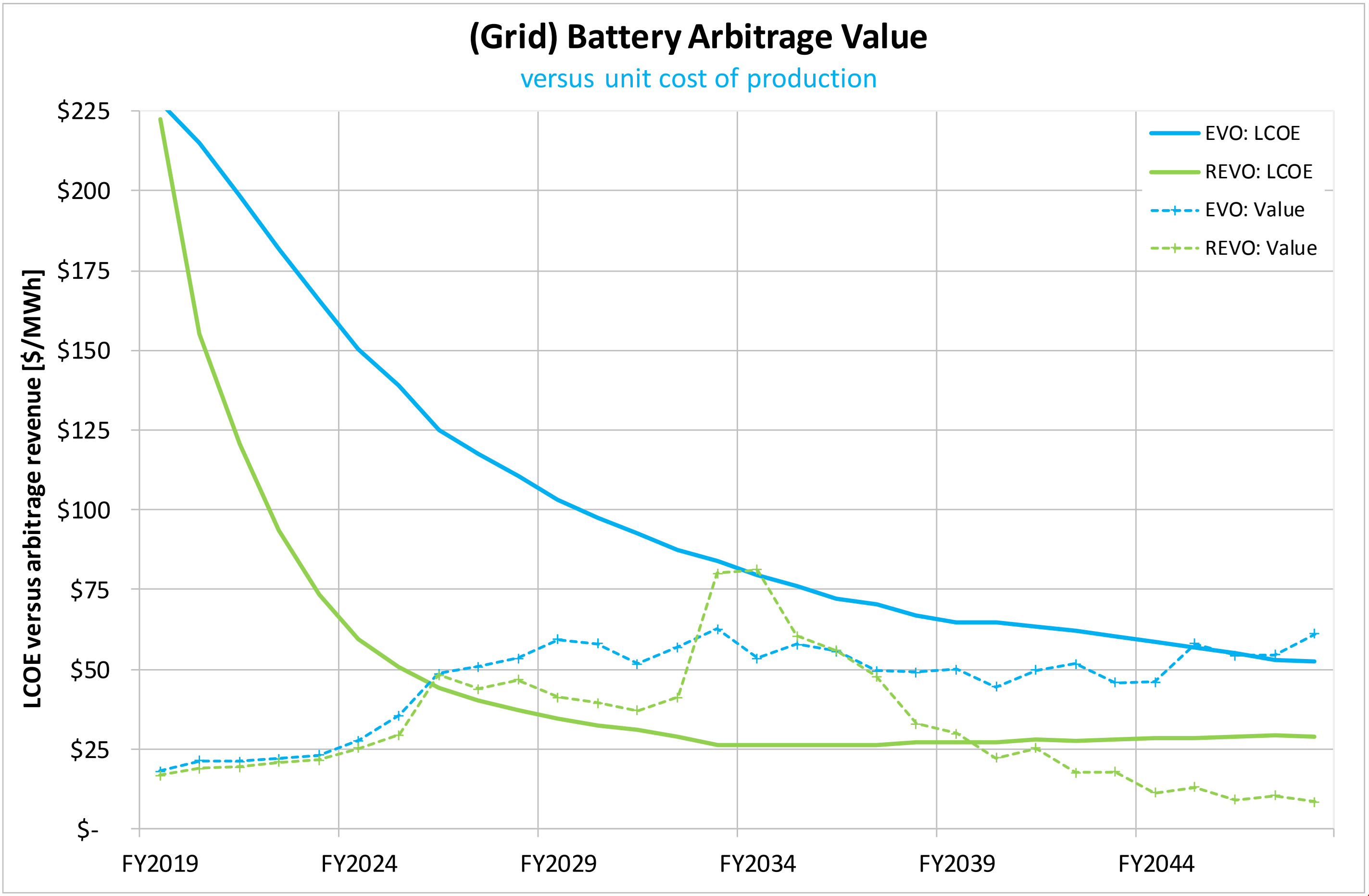
Details: Price Distribution



- Market prices will be much more volatile than observed historically.
- Need new ways to access the average and to manage volatility.
- The value of flexibility will increase over all time-frames.
- A role exists for gas-peakers, batteries, V2G, long-term storage, and dispatchable demand.
- BUT saturation of part of the flex market may occur.

Challenges: monetise flex, manage volatility

Details: Battery Arbitrage Value



- With sufficient short-term flexibility day-night pricing may begin to flatten out.
- The value of short-term flexibility is likely to increase as thermal generation retires BUT may reach eventual saturation despite large quantities of wind & PV.
- V2G has the potential to bring large quantities of free storage flexibility to the market: eg 1M BEV =~ 25GW x 10% (say) =~ 2.5GW

Challenges: invest in flex at right time & scale

Market Design: Can the current system rise to the challenge?

The electricity market we have today has evolved significantly over 25 years:

- Ancillary services.
- Futures.
- Financial Transmission Rights.
- Operational enhancements.
- Etc

The current model has performed well:

- Managing scarcity with no energy driven shortage since the start of the market in 1995.
- Significant new Investment in generation ($10B) and transmission ($2.5B).
- Increased level of renewables and declining emissions with 4MT CO_2e down from 10MT.
- Wholesale prices that have averaged $80/MWh (at least until the 2018 gas event).

Future development of the system comes with significant uncertainty & challenges:

- Demand growth.
- Technology costs.
- Technology change.
- Locational choice (& transmission).
- Impacts of intermittency.
- Climate change impacts & policy.

Investment will reflect different views. Adding regulatory uncertainty & inconsistency to this is a recipe for inertia in decision making and capital flight.

Economically (mathematically) the power system and existing structures can deliver.

Evolving with change to meet the challenges of decarbonisation as it unfolds rather than "assume it, build it and they will come" would seem to be the prudent option.