Onslow pumped storage: a market perspective

Malcolm Taylor. Acknowledgements to Earl Bardsley, Mohammed Majeed
Outline

• Background of Electricity generation in NZ
• The change to a market
• The issues
• Policy background
• The changed situation from July
• Onslow scheme configuration overview
• Onslow in the market
  • Some wider impacts of Onslow pumped hydro
  • A response to some criticisms
  • Environmental impacts
Reefton Power house - 1888
Further development

- Waipori Falls 1904
- Lake Coleridge 1914
- Wairua Falls 1916
- Kings Wharf 1920 (coal)
- Mangahao 1924
- Evans Bay 1924 (coal)
- Palmerston North 1924 (diesel)
- Tuai 1929
- Waitaki 1934
Geothermal
Nuclear

In 1968 Nuclear power was planned for Oyster Point on the Kaipara Harbour

Project abandoned in 1972

New Zealand’s reactor at Canterbury University was shut down in 1981
National Grid

HVDC link established in 1965

Power generated in one part of NZ can be used in any other part

Generators from one area can be available as backup for other areas

Natural scenery spoiled by lines of transmission towers
Wind Energy

Brooklyn Wellington 1993
Wind Power

New Zealand has 20 wind farms either operating or under construction. These wind farms currently have a combined installed capacity of 830 megawatts. They supply about 6% of New Zealand’s annual electricity generation.

From New Zealand Wind Energy Association
Electricity Market Concept

Generators offer energy at increasing volume and price

Purchasers bid for energy at decreasing volume and price

Where the Bid quantity and offer quantity meet the price is set

Generators offer 5 tranches, Purchasers bid 10 tranches

Higher priced generation is not dispatched
Electricity Market

- Only 4 line for energy
- Only 2 lines of energy information to and from Transpower
- Everything else is financial

The Final Cut

ECNZ split into three competing SOEs announced 1998
- Take effect from 1999
- Later partially sold off as listed companies

Restrictions on Generators from also being retailers was removed
Network companies permitted to own small amounts of generation

Contact Energy privatised

22 retail companies
Cumulative price distribution at ROX2201

2017 – 2020
The Issues

Political decision to decarbonise NZ’s Electricity generation

Greater reliance on Intermittent Generation – difficult to match supply and demand

Increased reliance on hydro as baseload generation

Increased risk of shortages during dry years

Fewer options for ancillary services
  - Instantaneous Reserve
  - Frequency keeping
  - Voltage support
Hydro power will remain a dominant component of NZ electricity generation, going into the future

- So how to buffer hydro against dry years in a future electrified low-emissions electrified economy, and compensate for intermittent generation?
Winter and peak demand is still the biggest challenge to solve

How, with low energy storage options, does the system reliably meet demand peaks, particularly in dry years and cold winters?

Electrifying New Zealand’s economy also represents a concentration of risk. With more and more of the national economy dependent on electricity, the resilience and reliability of the electricity system becomes all the more critical to the country.
Generation Characteristics


Thermal: Cheap to build. Very expensive to run. Very slow start. Slow ramp rates

Geothermal: Expensive to build. Cheap to run. Slow start. No ramping

Wind: Very cheap to build. Cheap to run. Starts when it wants to. Ramps when it wants to

Solar: Getting cheaper. No real running costs. Starts at Sunrise. Ramps up to midday then ramps down again.

Tidal: Very expensive to build. Super expensive to run. Starts with the tide. Ramps with the tide

Wave: Very expensive to build. Super expensive to run. Starts when it wants to, Ramps when it wants to.
Policy position before July 2020
ICCC Original briefing: seek means to achieve 100% renewable electricity generation in a “normal hydrological year” by 2035

Later 100% renewable electricity downgraded to an “aspirational goal” because of supposed high cost to get the last few % renewable electricity.
2019: “overbuild model” against dry years gained some favour

Everybody knows there will need to be some over-build in order to get to the 100% renewable target.
Megan Woods, Sep. 2019

From ICCC report: overbuild would increase electricity price for households by 14% and for industry by 39%

Morphed into: “getting the last few % to 100% renewable electricity would be expensive”

All that happens, electricity prices go up and that's what Miss Ardern's own experts are telling her... According to the experts, 14 percent up for residential, big numbers for industrial and commercial.
But there were also some suggestions in New Zealand that *increased energy storage capacity* could be an alternative approach to the dry year issue.
Then in New Zealand, everything changed from July 26...
The Government wants 100 per cent green electricity by adding 'battery' power to hydro power.

Woods has commissioned a detailed business case to see if pumped hydro storage stacks up in New Zealand, in particular at Lake Onslow in Central Otago.

Pumped storage explicitly mentioned for evaluation in the Speech From the Throne, 26 November (opening of New Parliament)
The business case has been largely done
Onslow will probably go ahead
You should prepare for it in planning

Onslow overview
Standard overseas model of pumped storage

(Small water volumes are shifted between upper and lower reservoirs)

- Power generated (water flows down) during times of high power prices or low river flows
- Power used (water pumped) at times of low power prices or high river flows
For *water flow volume*, Onslow will be a midget compared to Roxburgh.
Onslow has much higher *turbine head*

Roxburgh installed capacity 320 MW
Onslow installed capacity 1,200 MW
Onslow (8 TWh)

World’s largest scheme by energy storage capacity

The real feature of Onslow is its *large energy storage capacity* (as is required for 100% renewable power)
Figure 3.11 Gravitational potential energy of the pumped storage reservoir in the Onslow depression, showing elevation/storage and elevation/area relationships.
2020 national hydro storage, incorporating 8TWh Onslow storage capacity
Onslow configuration

- Onslow: 720 – 780 metres
- + Manorburn: 760-780 metres

Tunnel to Lake Roxburgh or Clutha River

Mckenzie's Beach, Lake Roxburgh
Requires extensive water-blasting to clean rock exposure within the range – significant employment (35 km$^2$ of land)
Lake Onslow at maximum level at 780 metres outer contour. Manorburn component not shown.

Lake Onslow at maximum dry year drawdown (grey region, defined by 720 metre contour).

40-75 km² lake area range
Suggested extent of lake level variation, with energy storage capacity
Tunnel option to Clutha River

- Shortest tunnel (15 km)
- Smaller tunnel diameter
- Expensive works at Clutha River
- No spill reduction at Roxburgh dam

Tunnel option to Lake Roxburgh

- Longer tunnel (23 km)
- Larger tunnel diameter
- Less expensive works at Lake Roxburgh
- Spill reduction at Roxburgh Dam
- Effectively increases Lake Roxburgh storage for Contact Energy

Image from *Otago Daily Times* (extending to 800 metres rather than 780)
Dam site on Upper Manorburn (for 780 metres)
Upper Manorburn
Extent of Onslow Dam at 780 metres
Spills – no way to run a hydro system

Roxburgh spill

Benmore spill

Lost generation opportunity (lost income)
Potential increased power output from spill reductions (simulations for 1998-2012)

40 MW (average) increased power yield from Roxburgh + Clyde (Lake Hawea management + intake at Lake Roxburgh)

100 MW (average) increased power yield from Waitaki Scheme
Onslow in the market
Cumulative price distribution at ROX2201

2017 – 2020

- Hydro RoR
- CCGT
- Gas Peakers
- Wind and geothermal
- Whirinaki
Assumptions

1. No change to Market Rules, other than pumping is dispatched
2. 10 generators each 120 MW
3. 7 connected to ROX2201 and 3 connected to ROX1101
4. Total efficiency > 75% (1 MW pumped results in >0.75 MW generated)
5. Pumping gains 0.138 cumecs/MW. Generating uses 0.180 cumecs/MW (at 760 masl)
6. Each 100 MW dispatched generation caps price by up to $30 less than final price on day studied
7. Each 100 MW dispatched Pumping floors price by up to $4 more than final price on day studied
8. Aim: To increase storage in preparation for a dry year.
### Final prices 02/02/2020

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### ROX2201 Final price 02/02/2020

![ROX2201 Price Chart](image-url)
## Bids and Offers

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### Effect on prices

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Some Onslow potential operational impacts

Fossil fuel power generation would become uneconomic
Simulated Onslow levels with maximum spill reduction (hydro lake mid-range target levels)
Potential for increased summer discharge in lower Waitaki
Simulated Onslow effect on Lower Waitaki discharges
Reduced level fluctuations

**Hawea**

**Tekapo**

**Pukaki**

**Manapouri**
Lower Waitaki flood risk reduction with Onslow pumped storage

But what about the negative comments...?
The role of Manapouri post-Tiwai

- 9 TWh of energy required for Onslow to get to full storage capacity
- Keep the smelter operational until pumping starts
- Meridian sells 9 TWh of energy for pumped storage (not all at once) (1 TWh of dead storage)
The ICCC redefined its brief away from 100% renewables in normal hydrological years to “Accelerated electrification” as a less costly alternative for emission reduction. Leaving some fossil fuel contribution in normal years.

## 2019 Responses to the “overbuild” cost issue

### (1) Green hydrogen exports

*What hydrogen provides is an exciting opportunity, is a way for us to make that over-build, that over-capacity, economic and to actually create a whole new export opportunity.*


### (2) Accelerated electrification

The ICCC *redefined* its brief away from 100% renewables in normal hydrological years to “Accelerated electrification” as a less costly alternative for emission reduction. Leaving some fossil fuel contribution in normal years.
Meanwhile.. over in Australia

$50 million fund to support new energy storage projects to make electricity more affordable and reliable in SA

“Proposals involving pumped hydro energy storage, hydrogen and natural gas storage, bioenergy, solar thermal and batteries are examples that could be submitted”
Meridian chairman Mark Verbiest said pumped hydro could prove uneconomic and may crowd out private investment. "Public investment in pumped hydro could lead to an uneconomic generation overbuild, crowd out private investment and push up electricity prices —slowing down the electrification of the economy."

Contact says Lake Onslow scheme would 'paralyse' investment in renewables

But Contact chairman Robert McDonald told shareholders at the company’s annual meeting on Wednesday that the scheme could dissuade power companies from investing in additional renewable energy “in the meantime”.

$4 billion Lake Onslow pumped hydro scheme could 'tip electricity market on head'

Enerlytica analyst John Kidd said the “sheer scale” of the proposed scheme had left the industry shell-shocked. The Government’s proposed Lake Onslow hydro scheme would be likely to lower and smooth out wholesale electricity pricing, but could tip the industry on its head.

Industry figures say Lake Onslow hydro project not worth it

Stakeholders in the electricity industry say its probably not worth the investment to build a large hydro storage scheme in order to service the odd time the country has a lack of electricity.
• Consensus is for less extreme wholesale prices, with a net lowering effect
• Onslow would aid development on intermittent renewables – especially wind
• Onslow would serve multiple ancillary functions in normal hydrological years
Contact Energy

• Provide funding support for intake on Lake Roxburgh
• Roxburgh hydro generates more income by:
  • Reduced spill
  • Reduced generation during low prices
  • Increased generation during high prices
Onslow – the far future – Onslow will be around for a long time

- Only small streams flow into Lake Onslow.
- Gentle rolling rock relief with minimal erosion.
- Minimal sediment input from natural inflows or pumped Clutha water.
High-water erosion effect at Lake Pukaki – no way to run a scenic lake
Likelihood of *alternative hydro lake operating mode* with Onslow pumped storage
Wetland impact
Tunnel options and geology
How the Onslow Dam *should* look -
Critical importance of landscape architects
Benmore Dam

“Hydro dam” at Lake Waikaremoana – a better model