There is potential for Pump Hydro Energy Storage in New Zealand

EEA conference

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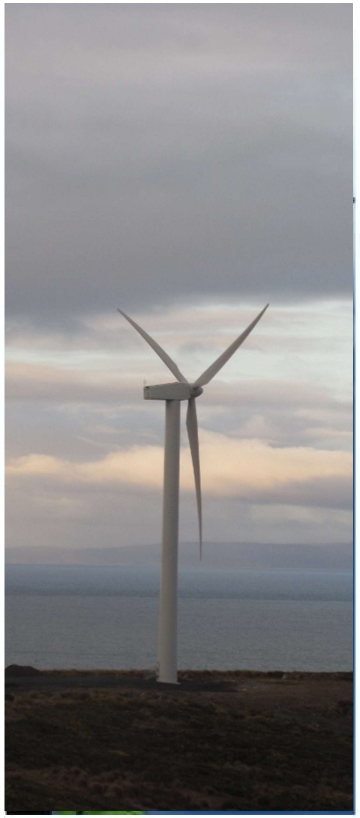
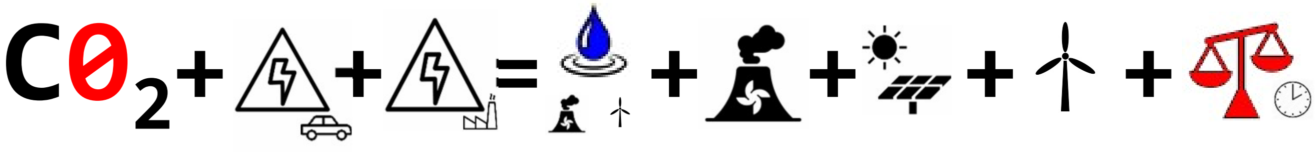
EPECentre
ELECTRIC POWER ENGINEERING CENTRE

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND



Maintaining balance



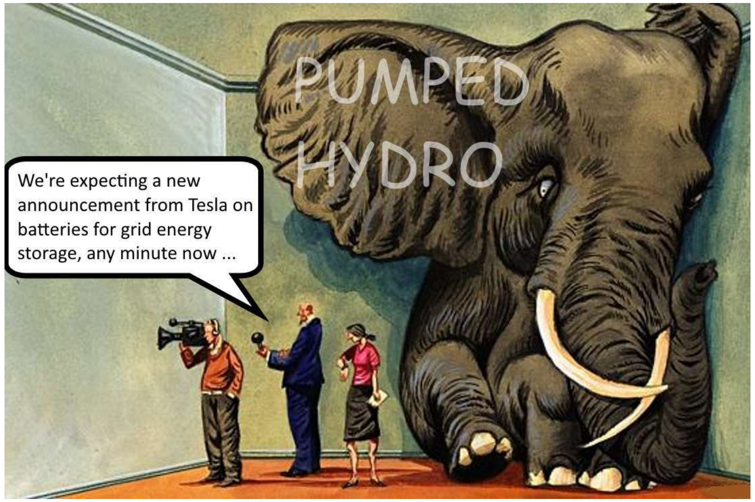
1550 MW / 368 GWh 100% (Mason, 2013)
5000 MW 2050 (Transpower, Te Mauri Hiko)

Daily, synoptic, seasonal

Stability (inertia, reserves, black start)

Mercury 1 MW / 2 MWh (longevity, capacity)

Elephants



https://scottishscientist.wordpress.com/2015/04/15/worlds-biggest-ever-pumped-storage-hydro-scheme-for-scotland/

http://pickeringpost.com/story/the-green-elephant-in-the-snowy-mountains-/8517

Pump Hydro Energy Storage

>95% of active storage worldwide

Economic at scale

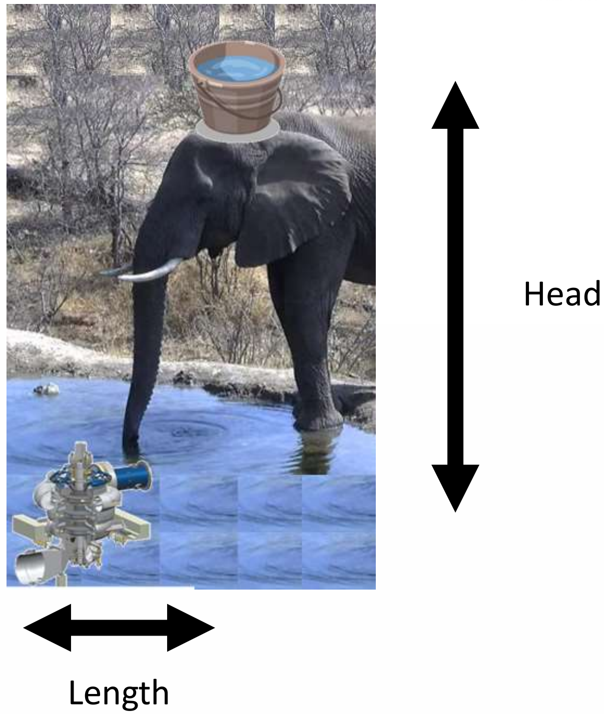
Capable (synchronous), flexible

Longevity, resilience, integration

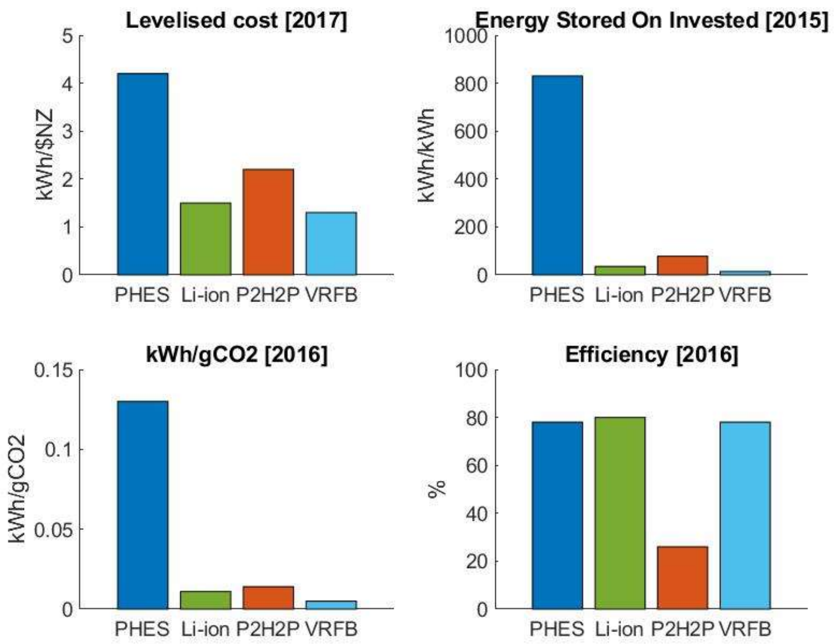
Economically circular

Scheme Types

1. **Existing reservoirs**
2. **New upper reservoir**
3. **Brown fields**
4. **New upper and lower reservoirs**



Elephant or mouse?



- Medium time frame (4.5h)
- Grid connected
- Long lifetime (50y)

PHES: Pump Hydro Energy Storage
Li-ion: Lithium Ion Battery
P2H2P: Power to Hydrogen to Power
VRFB: Vanadium Redox Flow Battery

Existing projects

Name	Date	Country / Reference	Capacity [MW]	Storage [GWh]	Head [m]	Length [km]	H/L
Bath County	1985	USA	3030	24	400	1.8	0.22
El Hierro	2016	Spain	11	0.6	653	2.4	0.28
Edolo	1985	Italy	1000	53	1265	9.7	0.13
Kiev	1972	Ukraine	235		70	0.5	0.14




New Zealand

- “Pumped hydro is seen by most as prohibitively costly”[1]
- “using hydro to pump hydro (clearly stupid) “[2]
- “Under the present market regime, no rational generator would contemplate such a development” [3]
- “high capital cost and is probably environmentally and economically infeasible” [5]
- “Will the Greens let them create a huge artificial lake that has massive six-monthly fluctuations in water level?” [6]
- “Pumped hydro doesn't make sense now..” [4]

- “This skewed perception may, in part, be due to the high projected economic cost of the Manorburn-Onslow proposal” [1]
- “Pumped hydro makes sense now” [4]

1. Kear G, Chapman R, 2013, ‘Reserving judgement’: Perceptions of pumped hydro and utility-scale batteries for electricity storage and reserve generation in New Zealand, Renewable Energy, 57, 249-261
2. PaulL, 2010, https://www.kiwiblog.co.nz/2010/03/farewell_from_colin.html
3. Leyland B, 2018, The Future of Electricity Supplies in New Zealand, New Zealand Centre for Policy Research
4. Pragmatist, Brendon, 2019, https://www.interest.co.nz/opinion/97543/brendon-harre-sees-future-%C2%A0hydrogen-trains-and-end-carbon%C2%A0era-hydrogen-powers-heavy
5. Low-emissions economy –Draft report, Productivity Commission
6. https://www.whaleoil.co.nz/2018/11/theres-a-cuckoo-in-the-woods/

Proposed

Name	Date	Country / Reference	Capacity [MW]	Storage [GWh]	Head [m]	Length [km]	H/L
Lake Onslow	2006	Bardesley		12000	650	20	0.033
	2019	Majeed	1300	7000	615	24.0	0.026
Wanaka / Hawea	2012	Bardesley	120	211	65	2	0.033
Pukaki / Tekapo	2018	NZ Productivity Commission					
Stewart Island	2016	Mason		0.000032	75	0.5	0.150

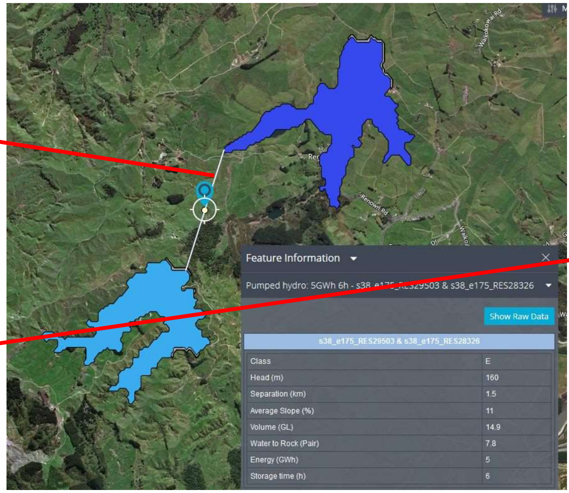
1938 MW / 379 MWh in 12 sites: McCarthy T, Jolly S, 2015, **Optimisation of Pumped Seawater Hydro Energy Storage Locations in New Zealand**, Final Year Project, Dept. of Civil and Natural Resources Engineering, University of Canterbury

"The canal was designed to carry flows in both directions between Lake Tekapo and Lake Pukaki in case of a later need for pumped storage, and this capability was confirmed as part of the commissioning." Zero Carbon Bill: Submission by Dr A.G. Barnett, 2018

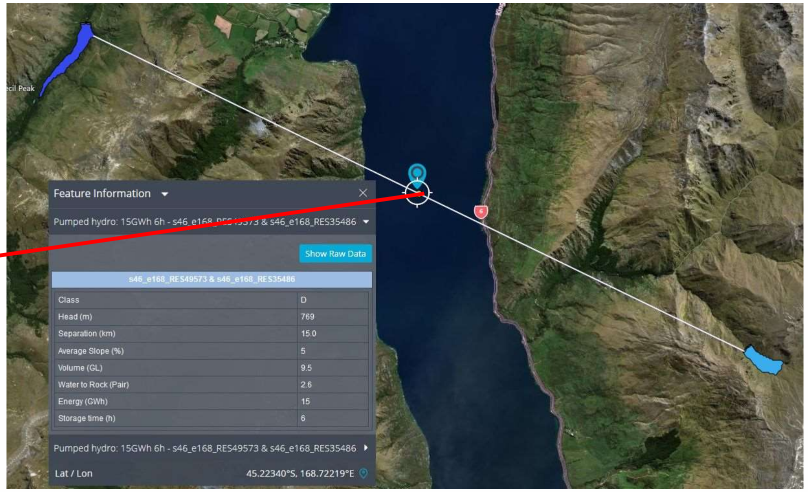
ANU Atlas

The lot

The good



The bad



http://re100.eng.anu.edu.au/global/

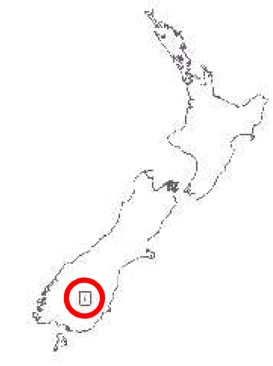
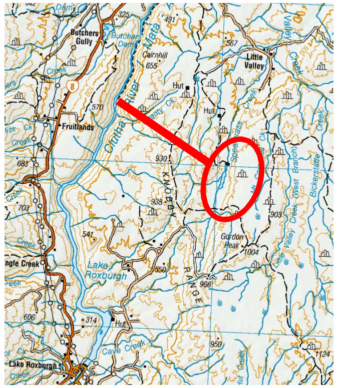
Type 1 – Existing reservoirs

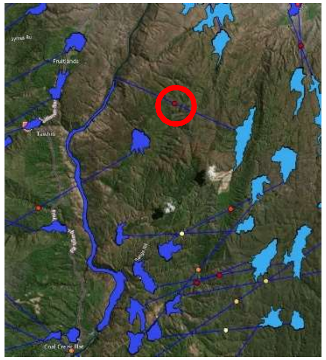
Search pairs of LINZ water bodies. Filter DOC, small, H/L > 0.066

Lower reservoir	Upper reservoir	Storage [GWh]	Range [m]	Length [km]	Head [m]	H/L	Barrier
Wakatipu	**Lake Johnson**	**0.28**	**5**	**1.2**	**91**	**0.08**	**Low H/L**
Wakatipu	Lake Luna	2.2	5	4.2	502	0.12	Remote
Wakatipu	Lake Dispute	0.57	5	1.1	160	0.14	Recreation area
Wakatipu	Lagoon Creek	1.0	5	1.2	116	0.09	Remote
Lake Sumner	Lake Mason	1.0	5	2.2	151	0.07	Remote
Loch Katrine	Lake Mason	1.0	5	1.9	153	0.08	Remote
Lake Aviemore	Lake Benmore	17	1	0.2	93	0.40	Existing power scheme
Lake Roxburgh	**Speargrass Creek**	**1.4**	**5**	**7.3**	**514**	**0.07**	**Small storage**
Lake Roxburgh	Butchers Dam	0.6	5	1.5	159	0.11	Recreational area
Karapiro	Arapuni	3.6	3	0.1	58	0.43	Existing power scheme
Waikaremoana	Waikareiti	0	0	2.6	310	0.12	Kaitiakitanga

Lake Roxburgh – Options

Type	1	2	3	4
Description	Existing water bodies	New upper	Brownfields	Closed loop
Name	Speargrass Creek	Onslow	Irrigation pond	Speargrass Creek (ANU)
Head [m]	514	650	264	515
Distance [km]	7	20	0.75	7
H/L	0.07	0.03	0.35	0.07
Storage [GWh]	1.4	12000	0.05	15

Type 2 – new upper reservoir

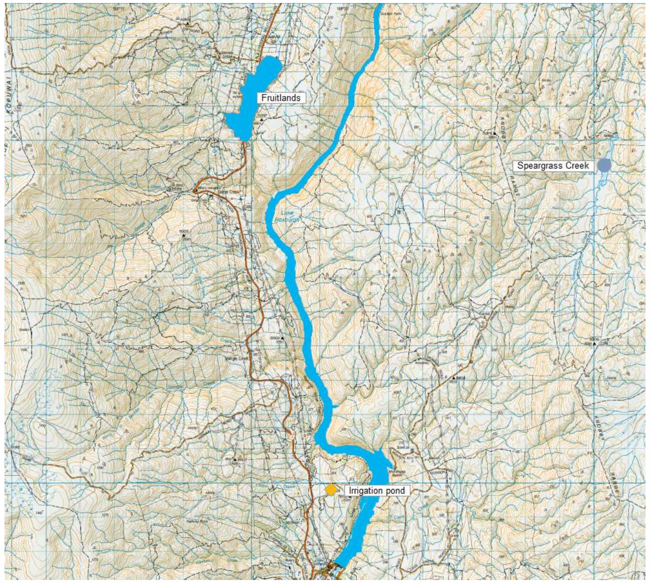
- Particle Swarm Optimisation (Quasi-optimal)

- Contour tracing algorithm
- 3D earth fill rock core dam, penstock, powerhouse

- Construction
  - Powerhouse deep in gorge
  - Geotechnical risks (Fruitlands fault; inactive)

- Land value
  - Reservoir covers the main road
  - 33 kV lines flooded
  - Sites of interest

Roxburgh - Fruitlands



	Fruitlands
Head [m]	264
Distance [km]	1.7
H/L	0.15
Storage [GWh]	8.2
Cost [NZ$M]	228

Type 3 – Brown fields

Scheme	Water source	Capacity [MW]	Head [m]	Length [m]	Volume [Mm3]	Energy [GWh]	H/L
Macraes mine			200	330	1	0.49	0.61
Dairy Creek	Lake Dunstan	0.3	75	1100	0.01	0.002	0.07
Hakataramea	Waitaki River	2.0	145	975	0.02	0.007	0.15

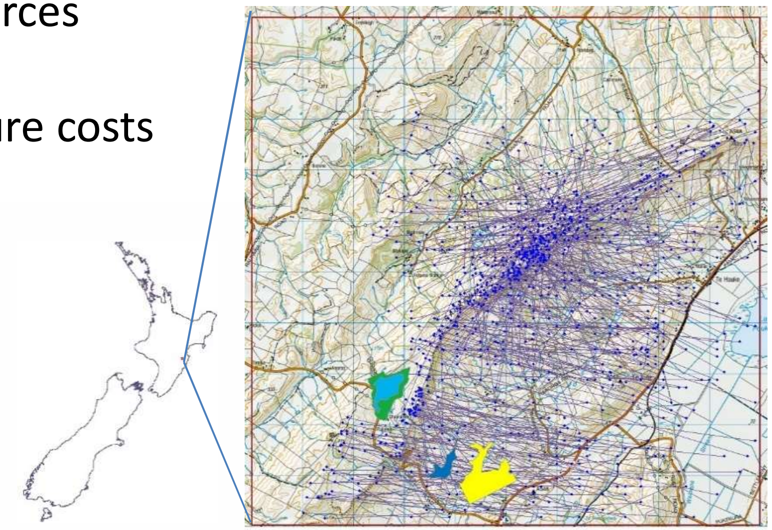


Type 4 – New reservoirs

Closed loop
Hydrological resources unmodified
Added infrastructure costs

Raukawa Range
(Hawkes Bay)

200 MW



Comparison

	Best Guess	PSO
Head	180	205
Distance	1547	1654
H/L	0.12	0.12
Storage [GWh]	0.25	1.5
Cost [NZ$M]	216	246

Summary – PHES in NZ

- Mature, lowest CO2, best ESOI, circular benefits
- Little investigation to date
- Good scope for projects using existing or new reservoirs
- Capital intensive with complex risks (incl. geotechnical) requires careful planning
- Development of automated search and design tools

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