

Pumped Hydro Energy Storage

Presentation to Sustainable Engineering Society (SENG)

Tim Forcey

28 October, 2014

Every bit of greenhouse gas - is doing us harm.





Seaside Heights, New Jersey - 2012

Marysville, Victoria - 2009





DATA SOURCES Bold (2010a). Special Climate Statement 40 - externe heat in January 2012, Bold. (2010b). Special Climate Statement 44 - externe solital and fiscolng in coastal Claveraland and New South Wales.



Australian Parliament Celebration of carbon price repeal: June 2014

and the state of the state

Energy storage questions

What technology?

What scale? What impact?

What benefits? What costs?

What risks?

Who wins... and who loses?

Arup-MEI pumped hydro energy storage research

Patrick Hearps, Rager Dargaville, Dylan McConnell Mike Sondiford, Tim Forcey, Peter Seligman

Tumut 3 Power Station - NSW

Pumped Hydro - Myths to Dispel

•Australia doesn't have any pumped hydro.

•The pumped hydro in Australia isn't used.

•We can't build any more pumped hydro.

•It has no value in future.

•If pumped hydro were useful, commercial interests would be looking at it. They are!

Yes we do. Yes it was. Yes we can. It should!

PHES: The world's *most-used* energy storage technology

Figure 4: Current global installed grid-connected electricity storage capacity (MW)

Source: IEA analysis and EPRI (Electric Power Research Institute) (2010), "Electrical Energy Storage Technology Options", Report, EPRI, Palo Alto, California.

Pumped hydro operation

Daytime: Water flows downhill through turbines, producing electricity

Nightime: Water pumped uphill to reservoir for tomorrow's use

www.water.usgs.gov

Forms of pumped hydro energy storage (PHES)

Raccoon Mountain, USA 1,652 MW Bath County Virginia, USA 3,030 MW pumped storage "world's biggest battery"

Existing large-scale pumped hydro in Australia

Tumut 3, 600 MW, Snowy Mountains, 1973

Shoalhaven, 240 MW southern NSW, 1977

Wivenhoe, 500 MW, southern QLD, 1984

Total = 1.34 GW

None built in the last 30 years.

Figure 3.3 – Shoalhaven Scheme

Bendeela Pondage and Bendeela Pumping and Power Station

Shoalhaven NSW operation data, June 2011

Pumped hydro arbitrage analysis

Heat waves / wholesale electricity price spikes

"South Australian electricity wholesale prices

spike to \$10,515 / MWh due to heatwave"

Adelaide Advertiser, 14 January

"The Price Of Electricity Is Astronomical In The Heatwave."

Business Insider Australia, 15 January

"Heatwave sends power prices soaring..."

Business Spectator, 16 January

"Pumped hydro arbitrage value index" – South Australia

Arbitrage Value – depends on hot days

Adelaide days with max. temp. over 38 C.

Source: AEMO South Australia Supply and Demand Outlook

"PHES arbitrage value index" – by state

AEMO – Integrating Renewable Energy

Identified potential grid issues with:

•system inertia

- •frequency control
- Interconnector limits

...potentially resulting in curtailment of future wind energy.

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INTEGRATING RENEWABLE ENERGY - WIND INTEGRATION STUDIES REPORT

For the National Electricity Market (NEM)

Published by

AEMO

Autobalan Energy Warket Operator ABN 94 072 010 327

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Reasons the world is looking at pumped hydro again, 30 years later

- For energy consumers:
 - a moderating effect on wholesale electricity prices.
- For renewable energy project owners and developers, and other low-cost generators
 - increase value for electricity generated during low-price periods.
- For electricity transmission companies
 - defer expansion.
- For grid operators:
 - provides stability.

Global pumped hydro growth spurt, using "turkey-nest" dams

La Muela, Spain (completed in 2013)

Tianhuangping, China

- Europe: 11 GW under construction or in planning.
- China: 10 GW under construction.
- USA: New legislation to spur development.

But can we do pumped hydro in Aus? Where can it be built?

Need to understand,

pumped hydro is not conventional hydro!

Conventional hydroelectricity generation

Snowy Mountains scheme

Conventional hydro – large dams & reservoirs required

Lake Eucumbene (NSW) ~ 15,000 hectares

Gordon Dam (Tasmania) ~ 27,000 hectares

Comparing:	Conventional Hydro	Pumped Hydro	
Purpose	Energy generation, irrigation, flood control, recreation	Short-term energy storage and use	
Electricity output	High	High	
Water requirement	Once-through, no recycling	Recycled. Make-up required for evaporation minus rainfall	AN an ME
Water storage period	Months or years	Hours	
Reservoir size	Can be > 10,000 hectares	5 to 50 hectares	
Located on river?	Yes	Doesn't have to be. Can use "turkey-nest".	
No. of possible Aus. sites	Limited	Thousands	

Comparing reservoir size

Conventional hydro

Pumped hydro - upper and lower

"Turkey nest" pumped hydro (freshwater)

If suitable valley not available, use a "turkey nest" dam.

Rural Australia "turkey nest" water reservoir

Australia – examples of inland pumped hydro site mapping

Australian National University (ANU),

and

ROAM Consulting

Seawater pumped hydro – Okinawa, Japan

1 seawater PHES facility in the world: Yanbaru, Okinawa (1999). Cliff-tor "turkey nest" style. 30 MW.

Upper pond covers only 5 hectares.

MEI cost model - components

Costs for PHES components converted to mathematical formulas, to aid site mapping.

Cost-based seawater PHES site identification (MEI)

White contours - locations of PHES earthen dams with cost less than a specified threshhold.

White dot (18) - cheapest location for earthen dam.

Red contours and dot (29) - results for roller-compacted-concrete dams.

Site identification, Fleurieu Peninsula SA

Existing wind farm

Adequate cliff-top elevation difference for seawater pumped hydro.

Google Earth

PHES costs for 7 sites, 100 MW, 10 hrs storage, 1000 MWh

Arup-MEI pumped hydro energy storage paper

Opportunities for Pumped Hydro Energy Storage in Australia Arup-MEI Research 27 February 2014

AELIOURNE NERGY INSTITUTE

Patrick Hearps, Bager Dargaville, Dylan McConnell Mike Sandiford, Tim Forcey, Peter Seligman Available at

University of Melbourne

Energy Institute website:

http://www.energy.unimelb.edu.au/library