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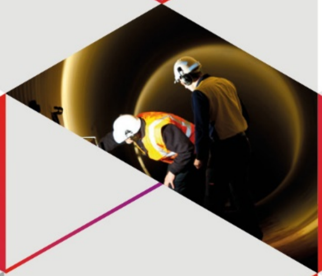
The power of natural thinking

PUMPED HYDRO

Engineering features and overcoming barriers to development

Nick West – 20th March 2018



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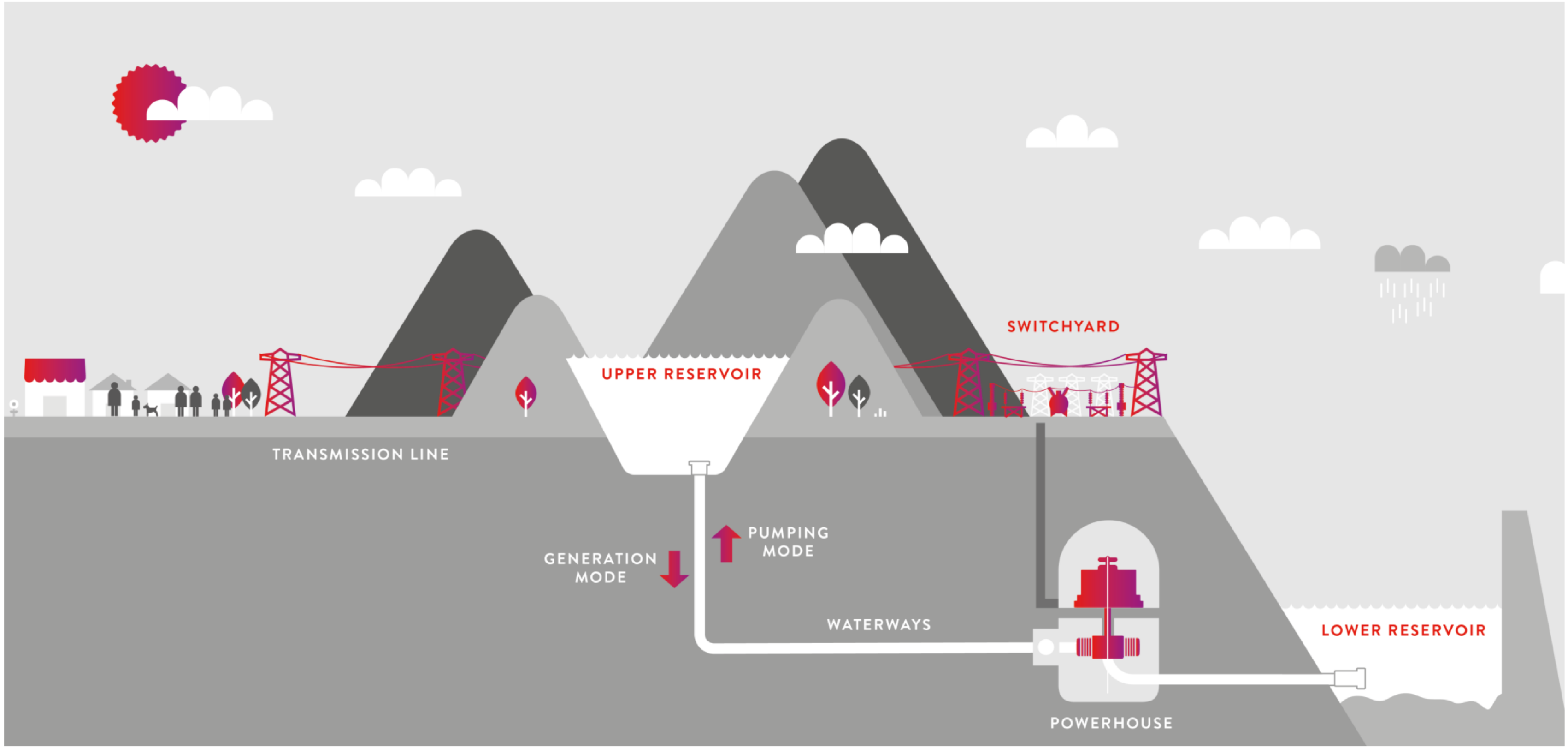
CONTENTS

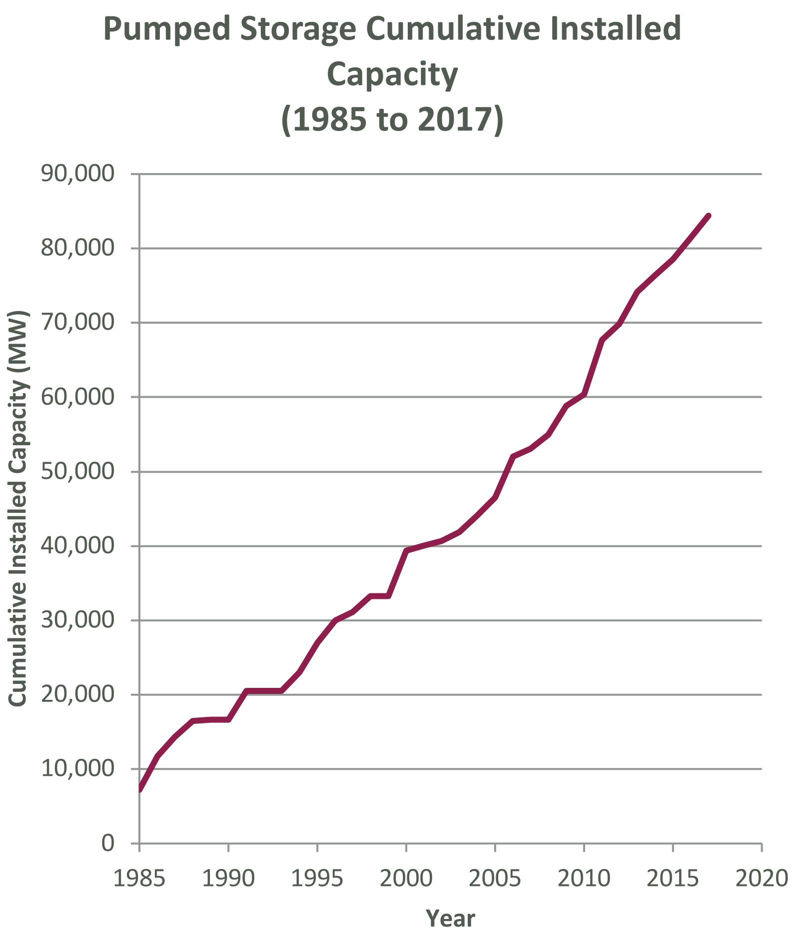
- Engineering features or pumped hydro projects
- Case study – Kidston Pumped Storage Project
- Barriers to development of pumped hydro projects
- Case Study – Battery of the Nation – Tasmanian Pumped Hydro Options Study

HOW DOES PUMPED HYDRO WORK?



A FORGOTTEN TECHNOLGY

- Pumped storage is by far the most widely used grid-scale energy storage technology.
- Australia has just three projects, with the last commissioned in 1984.
- Since 1984, the rest of the world has installed about 85 GW of pumped storage capacity in more than 120 projects.
- Historic barriers to development in Australia include:
  - cheap, abundant fossil fuels
  - limited arbitrage opportunities
  - high development costs.



ENGINEERING FEATURES

- A pumped hydro project is usually comprised of:
  - Two reservoirs (upper reservoir, lower reservoir)
  - Waterways (intakes, pressure conduits, outlets)
  - Powerhouse complex (including mechanical and electrical equipment)
  - Transmission infrastructure

https://www.masterbuilder.co.in/india-improve-renewable-power-storage-pumped-storage-system/

DAMS

- Traditionally two dams across streams at different elevations.
- Recent developments use "closed loop" where off stream dams are used (eg turkey nests, mining pits).
- Advantages of closed loop include site selection advantages and reduced flood risk.
- Increased risks due to the length of the embankment, potential for "overpumping".

WATERWAYS

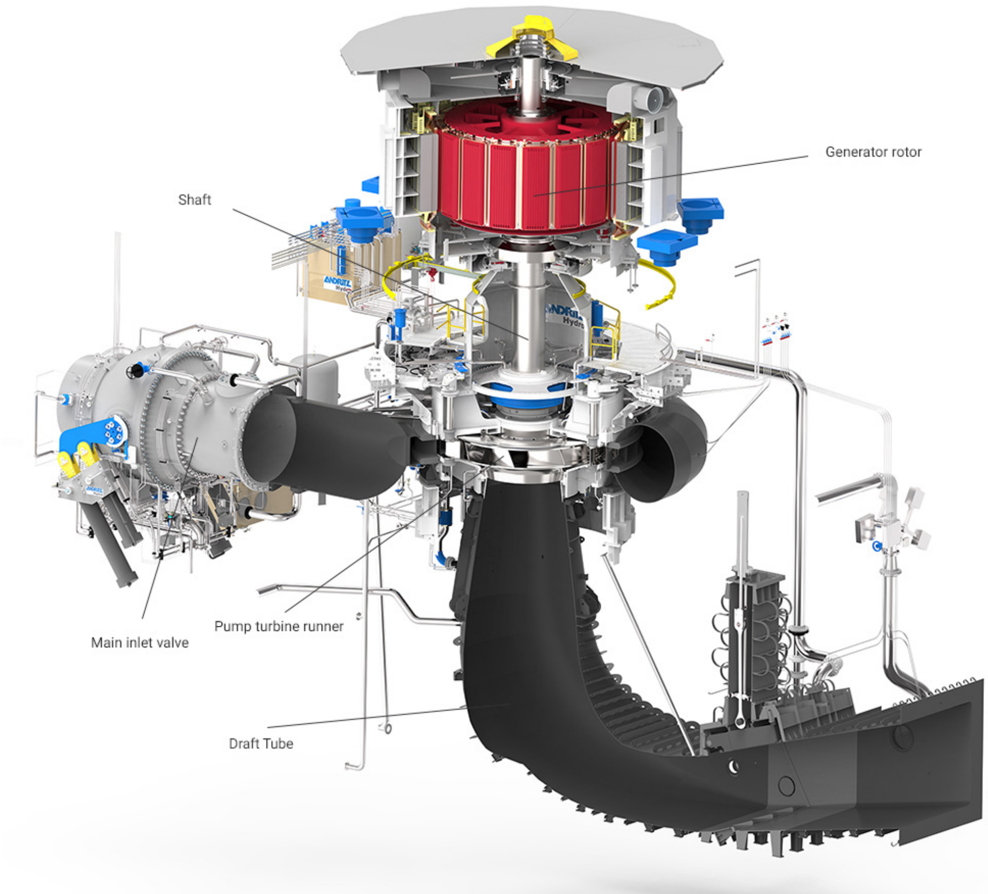
- Pumped storage project viability of often dependent on the waterways arrangement.
- Common conduits are used for both pumping and generating.
- Longer waterways cost more and have higher losses. Headloss is counted twice for a pumped storage project – both generating and pumping modes.
- Intakes also act as outlets in a pumped storage project meaning their design is different to that of a normal hydropower project.

POWERHOUSE

- Powerhouses are often located underground for pumped storage projects.
- Prevention of cavitation in pumping mode determines submergence of pump-turbines. Submergence can be as much as 50m in some instances.
- Pumped storage powerhouses are similar in layout to traditional hydropower projects but additional electrical auxiliaries make planning the payout a challenging task.
- Main inlet valves are usually located in the powerhouse. Tailrace gates and stoplogs are often located in separate caverns.

ELECTRO-MECHANICAL EQUIPMENT

- Pump turbines are coupled directly to a motor generator, which rotates in both directions.
- For high head applications, turbine runners are separated from pumps.
- The most common turbine type is a Francis turbine, which has a large head range and can operate as both a pump and a turbine.



https://www.andritz.com/china-en/news/andritz-to-supply-pump-turbines-for-the-world-s-largest-pumped-storage-power-station

TRANSMISSION INFRASTRUCTURE

- Transmission is a significant cost for a pumped storage scheme.
- If a project is located close to the transmission network, it's more likely to be viable.
- Transmission contributes significantly to losses, which also include transformer losses, generator efficiency, pump-turbine efficiency and headlosses.
- Project location and transmission infrastructure also impact on Marginal Loss Factors, which, in turn impact on project revenue.

http://www.entura.com.au/art-solar-grid-connection/

PROJECT COSTS

- Typically project costs are split in thirds – civil works, EM equipment supply & install and transmission.
- Worldwide, average costs for pumped storage projects are approaching $3m/MW installed.
- Pumped storage in Australia will be built for less than $2m/MW and perhaps as low as $1m/MW.

http://www.entura.com.au/batteries-vs-pumped-storage-hydropower-are-they-sustainable/

WHY DO WE NEED PUMPED STORAGE?

- In many developed countries, pumped storage projects have been constructed to act as a load for nuclear plant during periods of low demand (eg overnight).
- In Australia, the need for pumped storage is only now emerging.
- In renewables dominated energy markets, pumped storage not only provides capacity to fill solar and wind "droughts" but also provides services that stabilise the power system.

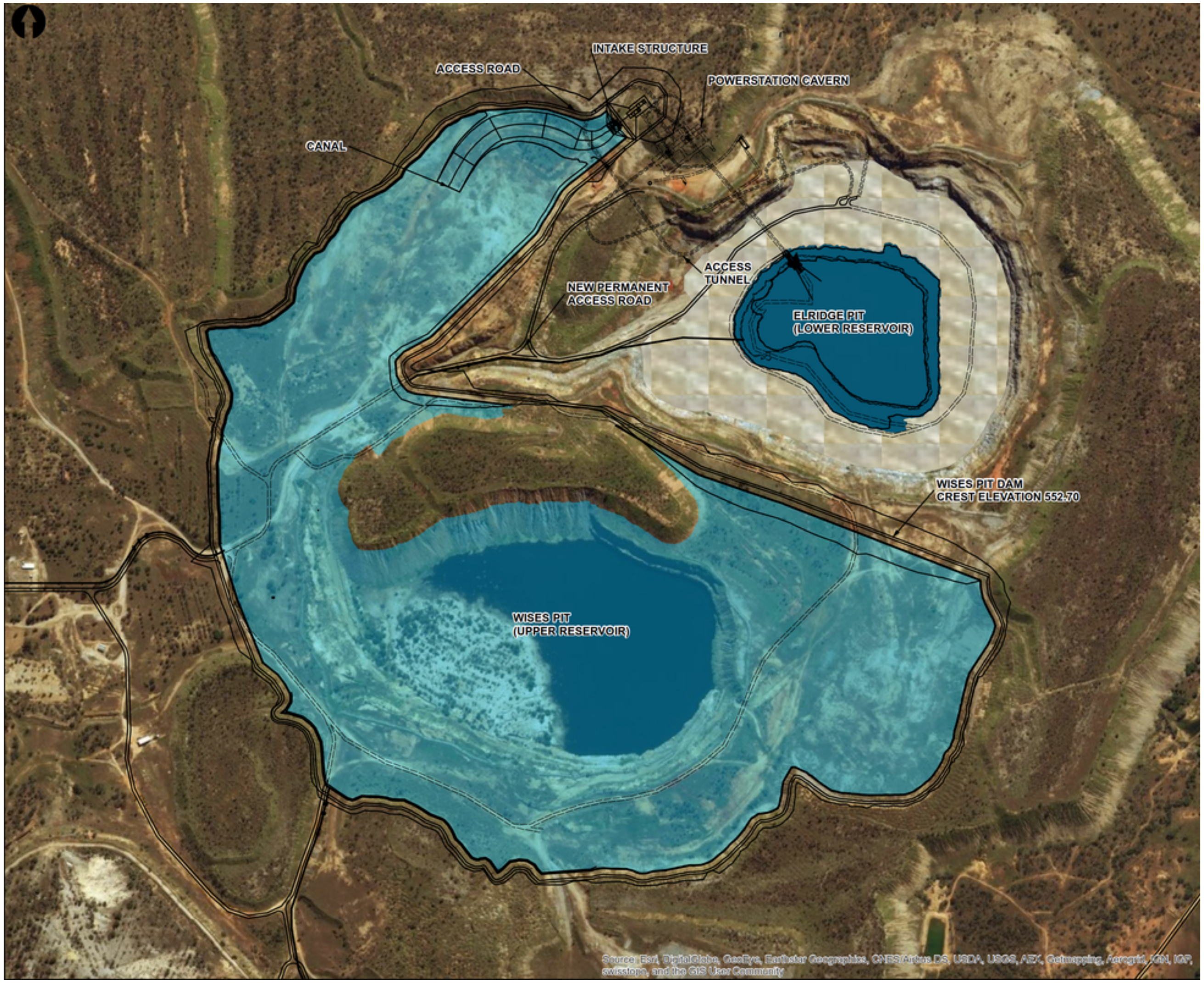
http://www.entura.com.au/batteries-vs-pumped-storage-hydropower-a-place-for-both/

CASE STUDY – KIDSTON PUMPED STORAGE PROJECT (QUEENSLAND)

- The Kidston Pumped Storage Project is located in north Queensland, about 5 hours west of Townsville and Cairns.
- The project will utilise two existing, disused mine pits as upper and lower reservoir.
- A vertical shaft will convey water to a powerhouse containing two reversible pump turbines.
- Installed capacity is about 250MW, with about 2,000MWh of energy in storage.
- Financial Close should be achieved in the second half of 2018.

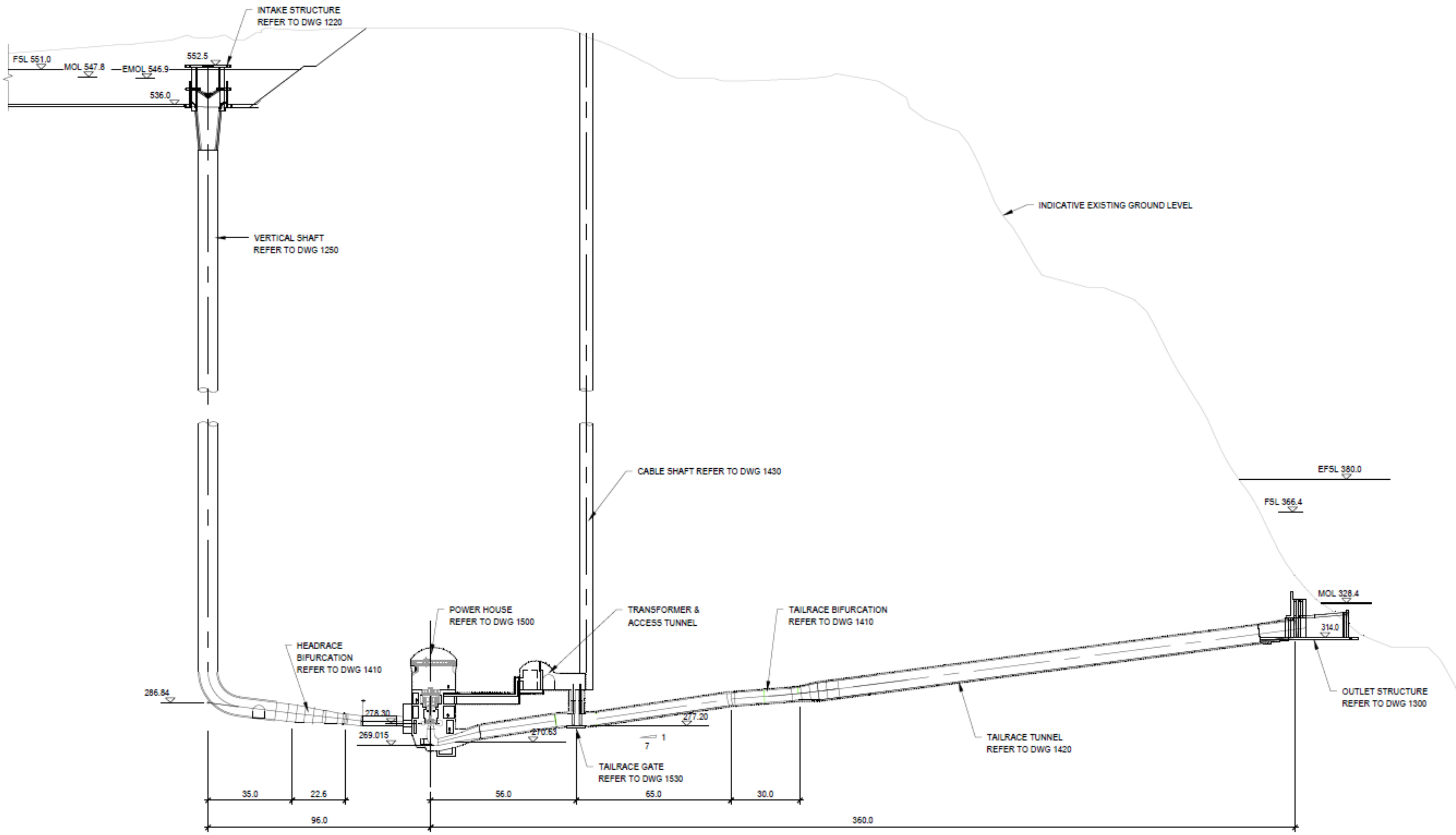
https://arena.gov.au/news/one-step-closer-giant-kidston-solar-pumped-hydro/

KIDSTON PUMPED STORAGE PROJECT LAYOUT



http://www.genexpower.com.au/project-details.html

KIDSTON PUMPED STORAGE PROJECT LAYOUT



KEY CHALLENGE - WATER MANAGEMENT

- Water quality in the pits is not good enough to release without treatment.
- The water level in Eldridge pit (lower reservoir) has to be drawn down sufficiently to allow construction of the powerhosue to occur.
- Several options were considered for treating the water but none were considered cost effective.
- Construction sequencing presents a challenge. The Wises Pit (upper reservoir) dam needs to be constructed to hold the water from Eldridge pit.
- This puts dam construction and pit dewatering on the critical path.

The Kidston Pumped Storage Project will be the first project of its kind built in Australia. Everyone in the industry is hoping to see it implemented successfully.

BARRIERS TO DEVELOPMENT OF PUMPED STORAGE IN AUSTRALIA

- Finding the right site.
  - Tools such as that developed by the ANU as well as Google Earth etc make identifying pumped hydro sites easier.
  - Concept studies can quickly determine the potential of a site.
- The high cost of development activities
  - Pumped storage projects are expensive to develop – typically 5% to 8% of capital costs.
  - Long lead times – typically 4 to 7 years – mean early investments carry a high risk.
  - A developer can reduce their risk by staging the development of a project.

BARRIERS TO DEVELOPMENT OF PUMPED STORAGE IN AUSTRALIA

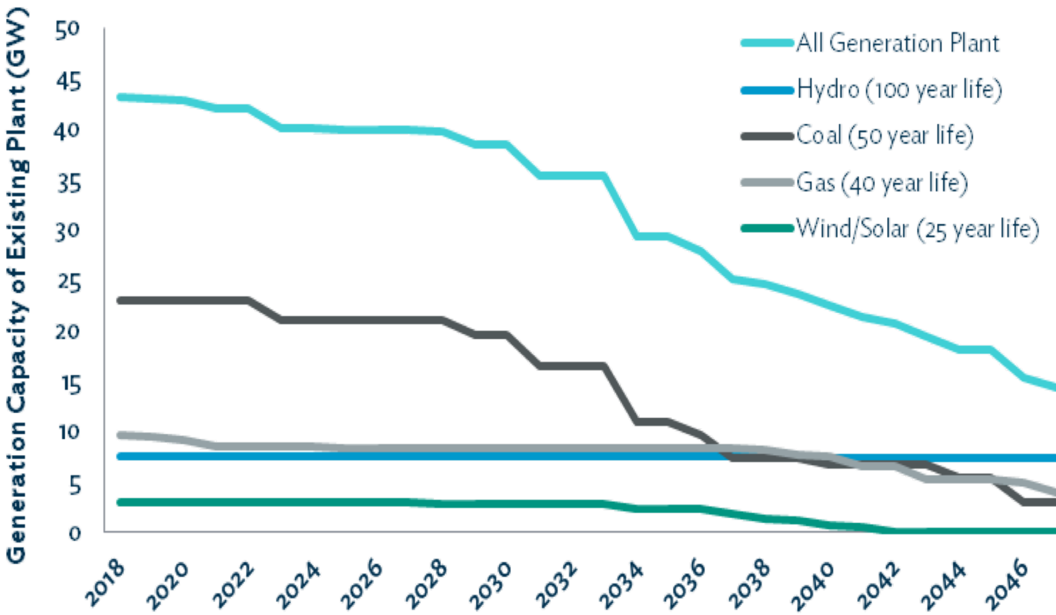
- Investment barriers
  - The CEFC and ARENA are working together to accelerate the development of large-scale energy storage projects.
  - State governments can also help with investment such as the Queensland Government's "Powering North Queensland" initiative.
- Competition
  - Battery technology is developing rapidly but is not considered a direct competitor to pumped storage for the next 20 years due to their cost.
  - Concentrated solar power (solar thermal) technology is developing and will compete with pumped storage with storage of up to 8 hours. CSP faces similar siting issues as pumped hydro projects.

ARENA
Australian Government
Australian Renewable Energy Agency

CEFC
CLEAN ENERGY FINANCE CORP

CASE STUDY – BATTERY OF THE NATION

- The National Electricity Market is facing an unprecedented challenge.
- Planned retirement of a significant proportion of our current fossil fuel fired generation fleet and the fact it will be mainly replaced by variable renewable energy means we are on the cusp of a national transformation.
- A strategic plan is essential to strike a balance between short term, easy to deploy assets and longer term strategic investments.



CASE STUDY – BATTERY OF THE NATION

Tasmania has:

- High quality, undeveloped wind resources – 1000s of MW…
  - It just needs access to customers on the mainland.
- A well established hydropower system…
  - Traditionally focussed on 24-7 energy provision in Tasmania.
  - Could be used in a different market setting to provide high value capacity and "firming" services for new renewable energy generation.
- This value in the hydropower system could be amplified by selective investment in pumped hydro technology…
  - Increasing system controllability which is a valuable asset in a world full of non-dispatchable wind and solar generation.

…But more interconnection is required.

CASE STUDY – BATTERY OF THE NATION

Tasmanian Pumped Hydro Options Assessment

- The original objective was 2,500 MW of Tasmanian Pumped Hydro development opportunity.
- Key results of first stage of assessment:
  - Substantial pumped hydro development potential in Tasmania – more than is needed – with very attractive "cost to construct" estimates.
- Options include:
  - Converting existing hydropower stations
  - Linking existing reservoirs together
  - Utilising existing reservoirs and linking to a new off-stream reservoir

WHAT DOES THE FUTURE HOLD?

- The need for 'dispatchable renewables' will inevitably lead to a diversity of storage and supply solutions.
- Pumped storage is a cost-effective means of storing and releasing large amounts of energy at times when it's needed.
- Achieving the optimum storage solution will depend on careful planning and finding the best fit for the particular circumstances.

CONTACTS

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