Firming Solar
No Silver Bullet

May 2019

Sally Torgoman
Managing Director – ILA
PwC
Why renewable energy needs storage?

**Shifting energy markets**
Energy markets are changing rapidly driven by emission reduction targets, the ageing coal generation fleet and the availability of distributed technologies including utility scale renewable assets, rooftop solar and smart grid solutions. The network is facing new challenges, which also unlocks opportunities for existing energy market participants to blend legacy regulated assets with unregulated investments and create value in new ways.

**Role of energy storage**
Energy storage is expected to play a key role in the transition from centralised, dispatchable fossil-fuel fired generation to de-centralised, intermittent renewable generation.

Utilities have expanded investments in disruptive energy technology to deliver future strategic advantages. For example, gentailers are pursuing pumped hydro opportunities to secure dispatchable energy sources to replace retiring coal plants.
Disruptive forces that are driving storage solutions

Energy landscape forces

Technologies and services
Blockchain and other technology will make it easier for energy buyers to choose between products and services.

Improved energy productivity
Energy users will share resource and services.

Multi-directional exchanges of energy
Two way power flows allows for the exchange of energy and information.

Diverse energy generation
Mix of generation types including, solar, hydro, gas and coal to supply energy users.

Distributed energy resources
Greater use of microgrids, embedded networks and smart meters.

Microgrids and embedded networks
Generation located closer to end users, creating and efficient resource use.

Market dynamics and drivers

- Uncertainty surrounding future direction of national energy policy
- Recommendations from the ACCC Retail Electricity Inquiry and recent Gas Inquiry 2017-2020 to be adopted
- Proliferation of renewables into the local grid and impact on prices
- Continued uptake of rooftop solar creating less demand for the Network and Distribution businesses
- Price path for utility scale batteries and their adoption by renewable generation assets
- Supply-demand balance
  - Project pipeline: withdrawals vs. announcements
  - AEMO’s interventions
  - Debates over future of Liddell Power Station
  - Snowy 2.0 outlook
- Coal generation fleet retirements and how these retirements will impact future price wholesale price projections
Globally over 70 PHES plants operating, with over 15 in construction, all over 1GW in capacity. China expects pumped hydro to reach 90GW by 2025

Wasted electricity from solar and wind projects has often been in double-figure percentages and is driving the governments push to develop over 60GW of PHES in the next 7 years.

China is using PHES and Ultra-High Voltage transmission to shift energy from the west to the east.

**Case study project**

- State Grid developing 3,600 MW Fengning plant in Hebei Province
- Using 12 x 300MW pump-turbine units housed in underground cavern
- Construction of the project began in May 2013
- Total cost of the project is expected to be US$1.87bn
- Expected completion in 2021
- Annual power generation is expected to be 3.424 TWh
- The station will be connected with two 500-kV lines
- State Grid Corporation stated the project is for “peak shaving, frequency modulation, phase modulation and emergency backup”
Germany is innovating PHES and combining with renewables, battery technologies and planning to reutilise old coal mines

- Naturstromspeicher project, a **hybrid wind and pumped-storage** plant consisting of a **13.6 MW wind farm and a 16 MW pumped-storage system**, where the bases of the wind turbines act as the upper reservoirs. The hybrid system is designed to guarantee a firm power output and balance short-term fluctuations.

- New battery energy storage system combined with pumped hydro storage in Bavaria, Germany, completed by Engie.

- The battery will provide **primary balancing services**, **helping to mitigate fluctuations in frequency within 30 seconds** of receiving a signal from the grid, aiding the integration of variable renewable energy sources.

- The pumped storage plant being fitted with batteries is **responsible for about 5% of all balancing power delivered to Germany's grid network** and about 1% of total balancing power in Western Europe’s transmission network.

- Germany is investigating using many of its **aging coal mines for pumped hydro**, with the **networks of tunnels in the old mines extending hundreds of metres deep** and holding large caverns capable of storing significant amounts of water.
PHES uses **proven technology** to pump and store **water** allowing generation to the **grid** from a suitable **site**

1. Water is pumped to an upper reservoir using base load power, solar, or wind, creating gravitational potential energy.
2. Water is released when solar and wind cannot generate sufficient electricity or when demand is high.
3. The flow of water through the turbine generates mechanical energy.
4. The turbine’s mechanical energy spins the generator, creating electrical energy.
5. Before electricity is transmitted through the grid, step-up transformers increase the voltage to reduce losses in the transmission lines.
PHES will firm renewable supply

The proliferation of renewables and disruption technologies will continue to grow in the coming years, impacting the network by:

- Allowing consumers to more accurately manage their energy consumption.
- Allowing consumers to trade between each other through micro-grids and virtual power plants.
- Providing a greater amount of ‘behind the meter’ flexibility for retail and industry customers.
- Forcing down electricity prices and demand during periods of high renewable generation.
- Forcing traditional baseload power generators, such as coal power plants, to run at levels below their efficient operating level and possibly close for periods during the day.

Transition period energy market imbalance

Future energy market balance

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PHES uses and revenue sources

PHES assets can serve a number of other purposes which can provide value to owners of the asset as well as to the electricity network.

<table>
<thead>
<tr>
<th>Cap Contracts</th>
<th>Form of derivative that are generally used as part of a electricity purchaser’s hedging strategy.</th>
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<tbody>
<tr>
<td></td>
<td>They provide price certainty to the electricity purchaser and generator by trading a fixed volume of energy for a fixed price when the spot market exceeds the strike price. In the NEM, the standard contract traded is a “$300 Cap”. If the spot price of electricity exceeds $300/MWh, the seller of the cap is required to pay the buyer the excess for a fixed generation volume.</td>
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<td>Caps are traded at a premium to offset the one-sided payment obligations exposed to the seller.</td>
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<thead>
<tr>
<th>Firming</th>
<th>Ability of generation sources to respond to variations in the supply and demand balance of other more intermittent generation types (wind and solar).</th>
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<td>A firming contract enables a PHES operator to lock in the market revenue under a medium to long term arrangement by effectively securing supply to the counterparty.</td>
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<td>An example of this could be purchasing the intermittent generation of a renewable asset and selling a ‘firm’ generation profile at a premium.</td>
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<thead>
<tr>
<th>Frequency Control Ancillary Service (FCAS)</th>
<th>Revenues are undervalued and uncertain in Australia. Ireland for example has introduced fixed dollars per MWh for ancillary services as a way of providing certainty.</th>
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<tbody>
<tr>
<td></td>
<td>FCAS are a group of services that are used to keep frequency in the network within the desired range.</td>
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<td>There are eight separate markets operated by AEMO to deliver FCAS – 2 Regulation and 6 contingency.</td>
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<td>A dispatchable generator cannot be contracted as a FCAS asset and also operate in the general market.</td>
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<tr>
<th>System Restart Ancillary Service (SRAS)</th>
<th>Provides the capability to restart generation units, in agreed timeframes, in the event of a major disruption.</th>
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<td>Requires a black start; the generation asset must be able to self-start without requiring power from the grid.</td>
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<td>PHES and gas turbines are the common generating units contracted through AEMO for the purpose of SRAS.</td>
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<th>Inertia</th>
<th>A measure of the ability of the system to resist changes in frequency due to sudden changes in supply and demand.</th>
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<td>It is naturally provided by synchronous generators such as coal, hydro and gas-fired power stations.</td>
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<td>Inertia limits frequency variations in the case of sudden load or generation changes.</td>
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</tbody>
</table>
PHES projects operating and in development across Australia

- **Highbury Pumped Hydro Energy Storage**
  - Tilt Renewables
  - 570MW
  - Publicly announced

- **Goat Hill Pumped Hydro**
  - Altura Group / Delta Electricity
  - 230MW
  - Publicly announced

- **Cultana Pumped Hydro Project**
  - Energy Australia, Arup Group and Melbourne Energy Institute
  - 250MW
  - Publicly announced

- **Middleback Ranges (Iron Duchess North)**
  - GFG Alliance
  - 90MW
  - Publicly announced

- **Baroota Pumped Hydro**
  - Rise Renewables, SNC Lavalin
  - 250MW
  - Publicly announced

- **Kanmantoo Copper Mine**
  - AGL
  - 250MW
  - Publicly announced

- **Battery of the Nation**
  - Hydro Tasmania
  - PHES only: Lake Cethana 600MW; Lake Rowallan 600MW; Lake Plimsoll and Lake Murchison 500MW.
  - Publicly announced

- **Kidston PHES**
  - Genex Power Limited
  - 250MW
  - Publicly announced

- **Awoonga Dam**
  - Gladstone Area Water Board
  - 97MW
  - Feasibility study

- **Wivenhoe**
  - CS Energy
  - 570MW
  - Operational; commissioned in 1984

- **Bells Mountain/Muswellbrook**
  - AGL
  - 250MW
  - Feasibility study

- **Shoalhaven**
  - Origin Energy Eraring Pty Ltd
  - 160MW and proposed 235MW expansion
  - Operational since 1977

- **Snowy Hydro**
  - Snowy Hydro Ltd
  - Tumut 3 1800MW; Jindabyne 1MW
  - Operational since 1973

- **Snowy Hydro 2.0**
  - Snowy Hydro Ltd
  - 2000MW
  - Publicly announced

Advised by PwC Infrastructure Lead Advisory
Commissioned PHES
Development projects

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Why should you include PHES in your portfolio?

The value derived by contracting or owning a PHES asset comes through a number of avenues:

- Utilising the plant as a trading asset to take advantage of the incidence of significant price events.
- Being able to firm other intermittent generation such as solar PV and wind.
- Australia has a potential of more than 358 GWh new storage capacity with potential new pumping capacity of 3 GW.

**Benefits**

<table>
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<th>Multiple revenue options</th>
<th>High-power capacity solution</th>
<th>Ability to lock in long term PPAs</th>
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<tbody>
<tr>
<td>Long life span</td>
<td>Large scale and easily scalable in power rating</td>
<td>Mature technology</td>
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<td>Limited / low OPEX</td>
<td>Government support</td>
<td>Attractive IRR range (typically 8% to 12%)</td>
</tr>
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**Considerations**

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<th>High CAPEX</th>
<th>Limited sites with appropriate supporting infrastructure</th>
<th>Long lead times</th>
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<tr>
<td>Cycling generally limited to once per day</td>
<td>Environmental approvals</td>
<td>Social approvals</td>
</tr>
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**Benefits**

- Writing derivative contracts to provide price protection for other retailers.
- Providing a range of ancillary services critical to grid stability and proper function of the network, such as inertia, voltage control, frequency support, and system restart capabilities.

*Source: ARENA*  
The key players in the market

We have strong global connections within the energy industry, hydro developers, contractors, debt financiers and equity financiers. The below provides the key technology and contractors in the market and examples of our global financier connections.
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- Gas will provide peaking facility
- Uncertainty on batteries makes their future in the market hard to call
- Batteries will most likely be used in less continuous applications
- Renewable firming can be provided by PHES for continuous applications using proven technologies

Near term | Long term
Our multi-disciplinary team can assist across all strategic, commercial, financial and legal work streams

We can provide integrated services across all stages of a hydro project’s development. Our flexible offering allows us to tailor our services to meet your needs and ensure value for money. Involvement of our teams is as required, but they are always available to you.

- **Strategy**
  - Setting clear goals and direction
  - Identifying opportunities among key market segments and participants

- **Government advisory and relations**
  - Establishing early communication with government and specific government agencies

- **Stakeholder engagement**
  - Detailed stakeholder and community engagement plan
  - Local and Indigenous economic and social benefits
  - PwC’s Indigenous Consulting

- **Financial Advisory & Valuation**
  - Valuation/commercial modelling
  - Analysis of key risks
  - Analysis of value drivers for investment case

- **Structuring**
  - Identify optimal deal structure
  - Advice on key commercial terms
  - Financial, Tax, Legal and Commercial Advisory
  - Deal sheets & target confirmation

- **Market Sounding**
  - Using PwC’s strong industry connections to establish the market appetite for various aspects of the project
  - PPA market sounding
  - EPC market sounding
  - O&M market sounding

- **EPC and O&M procurement**
  - Develop a specific procurement process for the project
  - Understand key risks and negotiating terms through EPC and O&M procurement

- **PPA negotiations**
  - Understand impact of additional generation in the current market
  - Approaching key off-take parties
  - Negotiate electricity and renewable certificates pricing

- **Debt and Equity (if needed) raising**
  - Understanding the debt markets and specific financial services available
  - Establishing the optimal debt syndicate for the project
  - Undertake a debt and equity tender process with international and domestic investors

- **Transaction services**
  - Establishing clear documentation structures
  - Key documents and data rooms

- **Commercial and financial close**
  - Prepare and negotiate
  - Legal and financial agreements finalisation
  - Completion mechanics
  - Debt hedging

- **Post completion**
  - Post-deal filings and lodgements
  - Assisting with separation and transition
  - Assistance across construction and operations
Thank you

Sally.Torgoman@pwc.com