D4.4(ii): (Output 5) A comparison of STORES with other energy storage technologies and gas and biomass generation

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In this report we compare STORES with alternatives for short and long term storage.

Short term storage (hours to days)

There are currently two leading candidates for short to medium term (hours to days) energy storage being deployed in Australia – batteries and pumped hydro storage. Other candidates, that are not currently deployed in Australia beyond pilot scale, are concentrated solar thermal power (CSP) with thermal storage and open-cycle gas turbines (OCGTs) using renewable fuels.

The technologies are often compared on the basis of a single cost per kWh for the entire storage. However, this is misleading, and the reality is more complex. There are two primary components to an energy storage system – those associated with delivery of power (units Watts) and those associated with the storage of electrical energy (Watt-hours).

Examples of the contributors to the power component are the inverters for batteries that convert the DC storage to AC power; and the pumps, turbine, penstocks/tunnel in a pumped hydro system. For the energy storage component, the costs are the Li-ion cells in a Li-ion battery or the water reservoirs in a PHES system.

Typically, batteries have lower costs for the power component with the battery inverter components being less expensive than the power generation for pumped hydro. The reverse is true for the energy storage, where the cost per MWh of the reservoirs is much lower than the cost of the batteries. This leads to different storage regimes where the capital cost of one system is lower than the other. The equation below reflects the capital costs

Capital costs = {Power (MW) * power costs ($/MW)} + {energy costs ($/MWh) * hours (h)}

The relative capital cost can be seen in Figure 1 below. It is important to note that this takes no account of the much longer lifetime of pumped hydro. In this example, the capital cost for the battery are assumed to be $200/kW for power and $209/kWh for storage while for the pumped hydro these are $800/kW and $70/kWh respectively. The battery storage cost is from Bloomberg]1] in late 2017 while the pumped hydro costs are in line with our 100% renewable study [2].

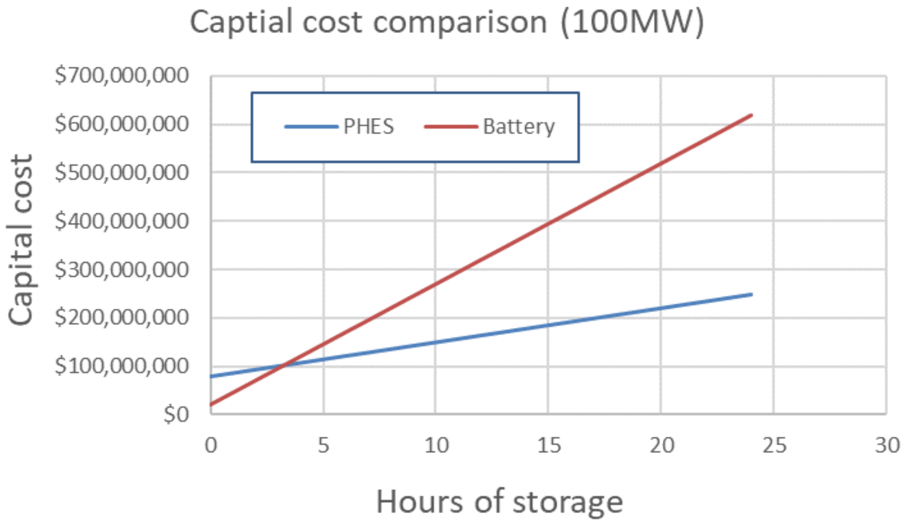

Figure 1. Capital cost for 100MW battery and PHES storage

Looking purely at capital costs, the cross over point is at 4 hours of storage. For longer term storage, pumped hydro has lower capital costs due to the lower storage costs while for shorter periods batteries are lower due to the lower power costs.

This balance shifts towards much shorter periods of time when lifetime and financial costs are considered. Lifetimes for batteries are heavily dependent on the number of charge cycles with the batteries degrading slightly with each cycle. For this comparison, 10 year battery life is assumed with no degradation. Powerwall2 is guaranteed to maintain 70% power at 10 years [3]. Pumped hydro systems are generally assumed to have a life of 50-100 years with the lower 50 year life assumed. The US Department of Energy Storage Database [4] shows many operational systems at this age. Australia's Tumut 3 pumping station is already greater than 45 years old [5] with no retirement date planned.

The annualized capital costs (ACC) for these systems is then given by

$$ACC = \text{capital cost} * [r/(1-1/(1+r)^t)]$$

where r is the real discount rate and t is the lifetime of the system in years.

The relative annualized costs for batteries and pumped hydro are then shown for 5% and 10% real discount rates in Figure II below. The real weighted cost of capital is typically around 5% for current wind and PV developments according to communications with the CEFC.

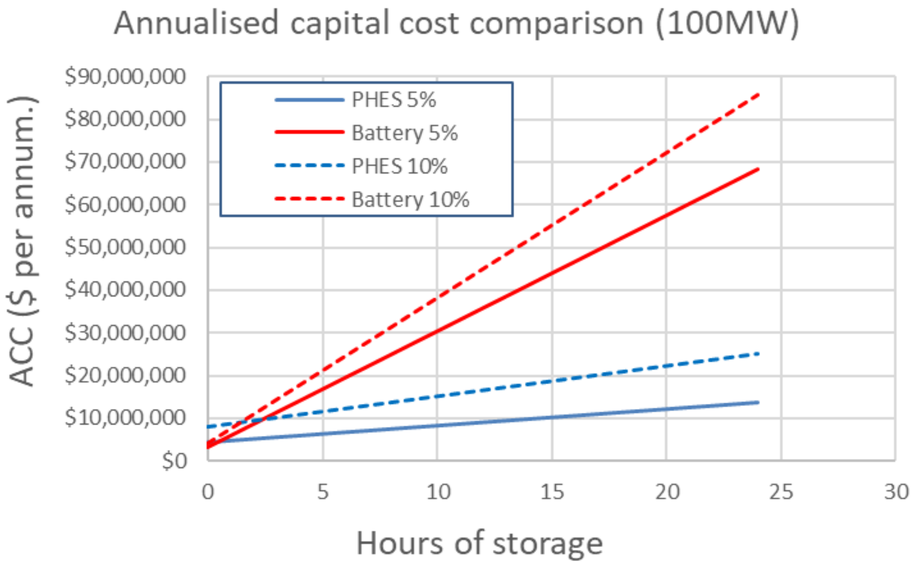

Figure II. Annualised capital cost of batteries and PHES for 5% (solid) and 10% (dashed) real discount rates.

The different effects of lifetime and discount rate can be seen in this figure. Battery costs are dominated by the cost of short operational lifetime while pumped hydro storage is dominated by finance costs. The annualized cost of batteries changes relatively little with a doubling in discount rate.

This financial analysis shifts the cross-over point for batteries down to 30 minutes with 5% discount rate to 1.5 hours with a 10% discount rate. Batteries therefore have an advantage when short term power is the service required, say for managing peaks, short term (e.g. 5min) firming of wind or solar farm output or very fast frequency response ancillary services. Medium term storage (greater than a few hours) is better suited to pumped hydro storage. Batteries can provide power very quickly when required (sub-second time frame) while pumped hydro requires tens of seconds (if the turbines are spinning in air). Thus batteries have an advantage in the short-term balancing of supply and demand, and in frequency control and ancillary services (FCAS).

The situation does not change significantly, even if battery storage costs drop to $100/kWh as forecast for around 2030 [6] due to the shorter battery lifetime. At a 5% real discount rate, the cross-over point is still 1.25 hours increasing to 4 hours at the much higher 10% real discount rate.

Batteries do have a number of non-financial advantages relative to pumped hydro storage. They are scalable, so can be deployed at a household level and aggregated to provide scale benefits for both distribution and wholesale markets. They are not dependent on geography so can be deployed anywhere within the network where a storage needs arises.

CSP

Very few concentrating solar thermal power plants are being built around the world. There is not sufficient information on molten salt thermal energy storage for us to make an informed comparison of molten salt storage with the alternatives.

OCGT

Biofuels are being trialled in jet engines (which are OCGTs) of several major airlines. However, at present, environmentally sound sources of biofuel production in Australia are too small in quantity to provide for OCGT power stations as well as supplements to motor vehicle and air transport fuel.

In the medium-term future, renewable electricity may be used to produce renewable hydrogen and ammonia, although at present that approach would be expensive.

Long term storage (weeks to months)

Long term storage is critical for managing extended energy deficits in the system. This is particularly important for regions that have substantial season variation. Australia has moderate latitude and lacks the cold winter experienced in northern latitude countries, but still has substantial seasonality in the south.

Our 100% renewable simulations [2] for high wind and PV penetration identified that extended periods of low generation (cloudy, windless week in winter) were critical for determining the amount of pumped hydro storage required to balance supply and demand. 17TWh of seasonal storage was assumed based on historic generation from hydro and biomass in Australia. This implies an average capacity factor for the existing long-term hydro storage of less than 10%. OCGTs utilising renewable fuels could possibly contribute in future.

Hydro

Conventional hydro is expected to continue to play the dominant role in long term storage. Existing water storage is cheap and capable of storing significant amounts of energy with relatively minor losses due to evaporation. Availability is affected by rainfall, with lower availability in drought years. Changing rainfall patterns with climate change will have to be considered. There are some constraints, relating to the need to store water for irrigation in the summer.

Biomass

Biomass for primary energy production is significant in Europe. There are several key differences for biomass use for storage. In Europe, there is significant demand for heat in winter, and direct thermal energy delivery can be more efficient than electrical delivery (heat pumps are less effective in a cold winter). In addition, agriculture is more intensive which reduces the transport distances and increases waste availability.

Resource availability is a constraint in Australia. Bioenergy competes with food production and ecosystems for access to land, water, fertilisers and pesticides. In Australia there is around 2 TWh of biomass generation today, primarily in the form of sugar cane bagasse and landfill methane. For comparison, about 14 TWh of hydro energy is generated in Australia each year.

Bioenergy Australia [7] looked at the potential for biomass in Australia and identified that there was 70 TWh per year of potential resource. Despite this, it is difficult to see biomass having a major role in seasonal storage in Australia due to the combined challenges of low capacity factor, transport and storage leading to significant costs.

Current biomass electricity in Australia is predominantly associated with waste streams. Bagasse (sugar cane waste) and black liquor/pulp (paper making waste) are converted on site to provide both electricity and process heat for plant operations. The feedstock is brought to site as part of the process so additional transport costs are not required and the waste stream would otherwise need to be disposed of, improving the economics. Similarly landfill and sewerage waste is brought to site for processing. None of these approaches involve seasonal storage - the fuel source is processed as it is produced.

The largest identified biomass source in Australia is straw stubble estimate at 24 million tonnes per annum with potential to deliver 47 TWh of electricity. The West Australian Department of Agriculture undertook a biomass scoping study [8] in 2014. Considering a seventy kilometer radius for collection, they estimate 155 to 1087 thousand tonnes of straw per annum would be available for collection (leaving some material for soils maintenance) depending on growth conditions, primarily affected by rainfall. This should be capable of delivering 0.2 TWh of power in a poor year.

The economics does not look promising for biomass for seasonal storage. Acciona have built straw burning [9] plants in Spain. Based on their capital costs (5% real discount rate) and estimated Australian wheat straw costs ($95/tonne), a plant operating continuously would cost produce electricity at ~$125/MWh, decreasing to $108/MWh if plant costs halved through learning or scale. This is not competitive with wind or PV for bulk energy delivery. However, these costs increase dramatically if the plant is predominantly used for storage (i.e. idle for much of the time). At 10% capacity factor, cost increase to $280/MWh which is not competitive with electrical storage. Converting to ethanol results in additional processing costs and higher losses [10], further increasing costs.

Gas

Our simulations for meeting the entire Paris emissions targets in the electrical sector [11] indicate that gas is not competitive with renewable energy and pumped storage at gas prices above $5/GJ. Gas prices in 20017 averaged $9/GJ [12].The continued decrease in energy costs of renewables along with the moderate amount of storage required with 50% wind and PV penetration make gas increasingly uncompetitive. Detailed calculations and assumptions are in that report.

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