Is liquid air the missing link in energy storage?

The role of the electricity distribution network and its flexibility is an essential component in the delivery and overall cost and viability of any storage scheme.

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I have never quite got to the bottom of why greater value is not placed on the latent energy assets that Australia has in its solar and nuclear resources.

Australia is not alone in coming to experience that there is a vital missing link – the inability to store energy – that keeps a divide between the aspirations of being able to use renewable resources and the practicalities of renewables' use in future energy generation and supply systems.

The concept of electrical and thermal storage is mentioned in the 2012 Energy White Paper 2012, however it is somewhat surprising that the issue is not highlighted as an area needing strategic intervention alongside the demand and supply management measures.

With renewable sources, energy is often created in the wrong place at the wrong time and it becomes difficult to utilise it. Examples would be wind, wave and solar energy. A key question is what technologies are available to capture the energy in a form that can be used and to do this in a highly cost-efficient manner?

In the UK efforts have been made to raise government's understanding of where the value of electrical and thermal energy storage may lie in a marketplace that is deregulated with separate bodies for generation, transmission and distribution. The situation in Australia has some resemblance, to the extent that Australian Climate Change legislation is driving de-carbonisation and this will shift the energy provision and create new markets. The public mind however is on cost, energy poverty, accessibility and security of supply.

However, the opportunities in the UK and Australia are very different, just as the energy generation mix is very different. In November the UK Chancellor announced that energy storage technology was indeed critical to the future UK economy and valued at £10 billion a year by 2050. This value comes from understanding where the different energy storage technologies fit into the grid at generation, transmission and distribution segments. It's not simply a matter of providing storage capacity but seeing how a robust system can be configured to suit the changing energy mix and so minimise the cost of transmission investment as the demand for electrical power grows, due to electrification. UK Ministers have subsequently emphasised the need for energy storage research.

So what might energy storage mean for Australia – or perhaps, first, what it doesn't mean.

In my view it certainly should not mean filling the country with batteries for storing renewable energy. Batteries are vastly resource-intensive and demand re-use in ways that business models have not been able yet to accommodate. While there have been some extensive battery park trials for regional storage in China, the US and other energy constrained countries (for example, Chile) this does not appear to be a widespread option suited for Australia.

A range of energy storage methods is currently available and most of these have been reviewed recently. Figure 1 shows a summary based upon the scale of power rating and the call-down time, expressed here as a discharge time at rated power.

Clearly, different applications demand appropriate storage characteristics and a range of technologies are needed to suit the specific needs. Technologically speaking, energy can be stored in mechanical, electrical or chemical devices and in the form of heat. All are probably needed but, other than hydro-storage dams, there have been few examples at a significant scale. The need for flexibility in supply means that it is likely that several different types of storage may be needed since some can be switched

Figure 1 Energy storage methods

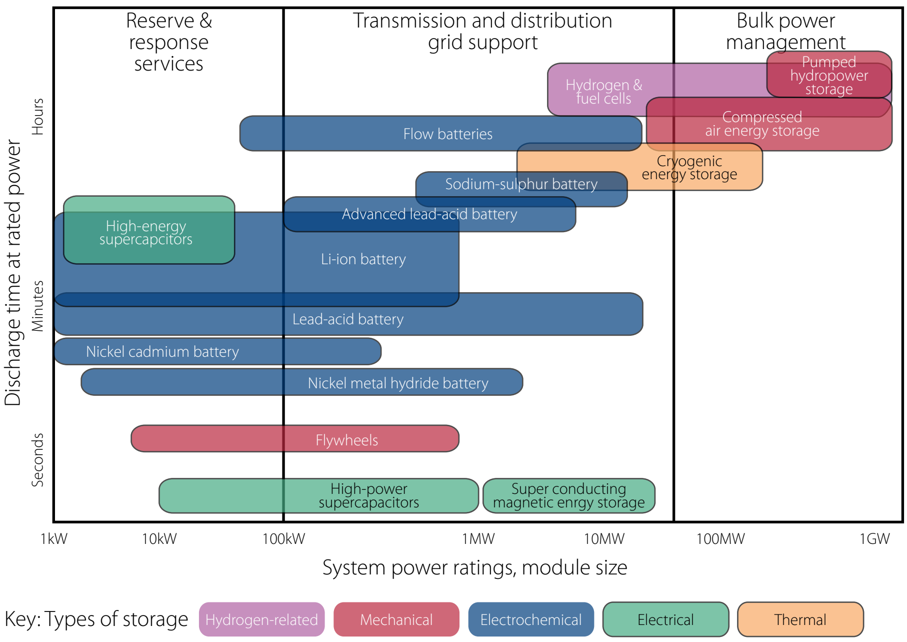

Table 1 Comparative energy storage cost estimates

Technology	Size range (MW)	Capital cost ($/kW)	Capital cost ($/kWh)	Efficiency (% round trip)	Geographical requirements	Use of advanced chemicals
Pumped hydro	280-530	2500-4300	420-430	76-85	Requires mountains	No
CAES (with gas firing)	180	960-1150	60-120	46-48	Requires caverns	No
NaS battery	< 50	3100-3300	520-550	68	None	Yes
Flow batteries	< 50	1450-1750	290-350	60	None	Yes
Highview Cryo Energy System	10-200	900-1900*	260-530*	50-80+	None	No

* Depending on cycling.

on quickly (batteries), whereas others require a few minutes before providing an energy supply (heat, hydroelectric).

The place of deployment of different technologies is likely to be at city, region, home and personal/domestic device level. Very large-scale storage capacity is likely to be associated with industrial operations or at points of generation and distribution. The role of the electricity distribution network and its flexibility is an essential component in the delivery and overall cost and viability of any storage scheme. Clearly, the point of deployment affects the grid demand and methods through which it may be controlled.

Conventional batteries of different types have their place but the societal need is pressing strongly for an alternative to batteries. This is not only driven by realisation of the cost, resource wastefulness, environmental impact and scarcity associated with rare earth components but also a growing public misgiving about safety. The number of battery-related safety incidents has been growing rapidly over the past few years, relating to vehicular and air transportation, computers, large-scale battery parks and wind/solar on-site storage locations.

There are alternatives. For example, in the UK there is a growing interest in the notion of cryogenic liquids. These are reported to be at a lower cost point and more likely to be suitable where solar energy can be used to drive compressors to compress air to liquid air (as cryogenic fluids). Liquid air is potentially an energy vector in itself and vaporisation of the liquid using low-grade waste heat makes for a very efficient system that then drives a generator.

The round-trip efficiency of these systems rivals batteries. These have now been demonstrated at a small scale – with 350kW/2.5MWh scale for on-grid electrical storage and further developments to scale out to beyond 10MW underway. Systems of 100MW or more with GWhs of storage are deliverable using existing supply chains and components Some comparisons of estimated costs for comparative storage systems have been mooted (Table 1).

Such systems offer a means for low-cost off-grid generation, to smooth power requirements (as demonstrated in arbitrage benefits in UK) and to provide security of supply by creating a national reserve.

Liquid air is also useable directly as a fuel and the first 'cars that run on air' are currently being evaluated and attracting significant attention. The concept of liquid air as an energy vector is based on the fact that Australia, as the UK, has an existing infrastructure to support early adoption. The technology derives from mature supply chain/components with proven long life whose costs are known. Liquid air storage is at low or atmospheric pressure, resulting in low-cost, above-ground, safe bulk tanks. There is no fuel combustion risk. There are no geological/geographical constraints to location of stores or distribution pathways. The energy density of liquid air compares favourably to other low-carbon competitors.

Finally, there is great synergy with other industrial processes, including use of waste heat and provision of cold. Further, there is the option of using liquid air as an energy vector to transport this stored energy around by road (as is currently done) or ship (as with LNG).

A major review of this opportunity is underway and this may have profound application in Australia if it turns out that liquid air can be used as a fuel. Meanwhile, the UK Energy and Climate Change Minister John

Cryogenic on-grid energy storage 2.5MW demonstration plant in Slough, UK.

Hayes believes that liquid air may offer some radical solution with real economic stimulus to the economy.

Putting a value on energy storage is difficult. The value lies in different places for different applications. A key reflection in approaching this with regard to solar is that the business model has a feedstock (sun) that is free and this means that arguments based purely on technical process efficiency and cross-comparisons to other process are not germane. Rather it is the benefit that needs to be quantified.

Australia will need to grasp these emerging concepts as new opportunities emerge to better utilise renewable energy and mitigate escalating infrastructure costs associated with energy supply and security. I am increasingly confident that the de-carbonisation drivers may open up significant new economic opportunities ahead.

This article is based on Professor Williams' presention to an ATSE Energy Forum meeting in November 2012.

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Funding boost for CSIRO UltraBattery

Cost-effective battery storage for residential and commercial renewable energy systems is a step closer following an Australian Government investment of $480,000 to test a world-leading battery technology.

The Australian Renewable Energy Agency's (ARENA) Emerging Renewables Program will put nearly $500,000 in project funding into Ecoult, a CSIRO spin-off company, to optimise CSIRO's UltraBattery technology.

The $1.16 million project aims to optimise the UltraBattery technology for use in a range of settings, including residential locations with a high number of household solar installations; in remote areas not connected to the national electricity grid; and in hybrid diesel systems.

Applying the technology to hybrid diesel systems will help to improve fuel efficiencies, while in remote areas it will help provide electricity to communities when renewable energy sources are not available.

"In residential areas with a large volume of rooftop solar photovoltaics, or in off-grid and remote communities that are trying to displace diesel through renewables, battery technology will be crucial to maximising electricity from renewable energy resources," said former Resources and Energy Minister Martin Ferguson.

"One of the benefits of CSIRO's UltraBattery technology is its suitability for managing energy intermittencies, smoothing power from irregular sources and shifting energy availability over time to ensure more regular availability.

"That's why the Australian Government, through ARENA, will be investing in a 30-month project using the UltraBattery technology to determine whether it can lower operating and storage costs by conducting testing on a storage pilot at CSIRO's Newcastle facilities.

"Testing the UltraBattery technology for both off-grid and distributed technology environments will allow us to learn how we can reduce power fluctuations, which can otherwise act as a barrier to connecting additional solar installations to the electricity grid."

SOLAR COUPLE WIN INNOVATION AWARD

A solar 'power' couple who trained at the University of NSW have been honoured with an award recognising visionary Australian citizens living and working abroad.

Dr Jianhua Zhao and his wife Dr Aihua Wang were joint recipients of an Advance Global Australia Award for contributions to the field of clean technology. The pair also won a special Australia in the Asian Century Honour.

"Jianhua and Aihua were excellent students and staff members here at UNSW, and prolific researchers," said Scientia Professor Martin Green AM FAA FTSE, Director of the ARC Photovoltaics Centre of Excellence.

"They took us to the position where we can now make the most efficient cells in the world and nobody yet has been able to catch up. They are both well respected internationally and have played an influential role in establishing China as a major producer of solar power and PV technology."

Dr Zhao, who completed his PhD in electrical engineering at UNSW under Professor Green in 1989, was affiliated with the university as a lecturer, researcher and associate professor until 2006. In 2004, he co-founded the Chinese solar cell manufacturing company China Sunergy, where he is now Chief Technology Officer and Director. Dr Wang, who also completed her PhD and worked at UNSW for more than a decade, is the company's Vice-President of R&D.

In 1999 the pair developed the high-efficiency crystallised Silicon PERL cell and set a new record, demonstrating 25 per cent energy conversion efficiency – one of several records they set while at UNSW.

Martin Green (centre) with Jianhua Zhao and Aihua Wang.