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TAKING CHARGE: THE ENERGY STORAGE OPPORTUNITY FOR AUSTRALIA

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INTRODUCTION

Life today for most Australians would be very different without personal electronic devices like mobile phones and laptop computers.

These are power hungry devices whose ability to get through the day is made possible by small but powerful lithium-ion batteries.

The challenge for policymakers is to replicate that small battery flexibility and reliability at scale: to put storage at the heart of a smarter electricity grid.

Today, batteries, pumped hydro and other energy storage technologies make up a fraction of the installed capacity of global energy networks. Tomorrow, energy analysts expect to see energy storage deployed on a grand scale: supporting the transition to renewable generation sources, helping to match energy supply to energy demand, and empowering consumers to manage their costs.

At a glance

- Energy storage will be crucial in the transformation of the Australian electricity network.
- In 2017, Australia was the world leader in the installation of residential battery storage in terms of power capacity.
- Lithium-ion batteries and pumped hydro are the two most mature energy storage technologies in Australia.
- The price of home battery systems is falling.
- There is an opportunity for Australia to expand mineral exports, especially lithium used in batteries.
- Australia is well placed to be a leader in the production and export of renewable hydrogen.

In that transition, Australia has much to gain.

Grid-scale batteries are entering the Australian electricity market, and consumer interest in home and business-scale battery systems is rising. Ambitious pumped hydro projects, including an expansion of the iconic Snowy Mountains Hydro Scheme, are planned or in construction. Demonstration projects using hydrogen as an energy storage medium have been announced. At the same time, Australian companies are positioning themselves to supply raw materials and technology expertise for the global storage boom ahead.

This paper summarises the evidence gathered by an expert working group of the Australian Council of Learned Academies (ACOLA) on the energy storage horizon of opportunity, commissioned by the Commonwealth Science Council and presented in 2017.[1]

Box 1: How to describe energy storage

Primary energy sources such as wind, solar, coal, gas, oil, uranium and catchment hydroelectricity can generate electricity for hundreds of years or indefinitely and the generation equipment can be maintained for 30 years or more. The generation capacity of these systems is best described as a single number – electrical power, given in units such as megawatts.

Stored energy sources such as batteries, pumped hydro, renewable hydrogen or heat packs are different in two important ways. First, they have to be 'charged' from other energy sources. Second, they only store enough energy to supply electricity for a few hours or days. Following on from this, two numbers are required to describe the generation capacity for stored energy sources – electrical power and the stored energy. The standard engineering term for the stored energy is a multiple of watt-hours, such as megawatt-hours.

Watt or watt-hour? Because of their similar nomenclature, watts and watt-hours are frequently confused. An easier approach is to specify the duration. A 150 megawatt pumped hydro facility that stores 900 megawatt hours will for most readers be easier to comprehend as a 150 megawatt facility that can run for six hours. Either way, journalists and engineers will communicate more clearly by always using two numbers to describe stored energy facilities. Describing a battery as 100 megawatts is as incomplete as describing the weather by temperature without mentioning the precipitation. In this paper, we will consistently use power and duration.

Tumut 3 generating station, Snowy Mountains Hydro Scheme

Image credit: Colin Henein/Wikimedia Commons/CC-BY-SA-3.0

STORAGE IN THE TWENTY-FIRST CENTURY GRID

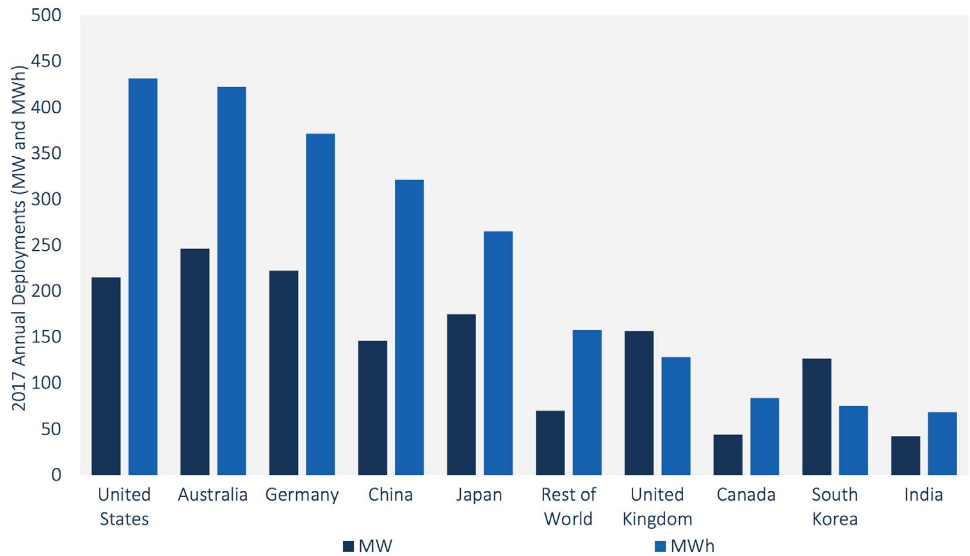
In 2017, the number of residential battery systems installed in Australia trebled from the previous year. Almost 21,000 systems were installed in Australian homes during 2017.[2]

The appetite for storage systems has meant that Australia has become a leader for new energy storage products. Out of a worldwide total of 1.4 gigawatts of battery storage capacity providing on average 1.6 hours of supply in 2017, Australia led the way on the installation of power capacity, with 246 megawatts for 1.7 hours (See Figure 1).[3]

The Australian take-up of energy storage systems follows the high penetration rates of renewable energy generation. Australia is ideal for solar and wind generation, with abundant sunshine, strong winds and available land. These conditions, combined with financial incentives and continuing falls in the cost of wind and solar electricity generation technologies, have supported a rapid expansion of renewable energy generation.

Wind and solar generation have the advantage of producing no emissions when operating. But their availability is not constant; and unlike coal, hydro or gas-fired power stations, they cannot produce electricity on demand.

Figure 1: Annual Battery Storage Deployments by market, 2017



Source: GTM Research

The widespread uptake of solar rooftop generation is having a major impact on the Australian electricity grid that a few decades ago maintained a simple, one-way flow of electricity from central generators to customers. Today's electricity grids are much more complex, requiring operators to manage a system that has two-way electricity flow and greater fluctuations in supply and demand than historically anticipated.

Energy storage can play a key role by smoothing out the peaks and troughs of renewable energy generation. When a wind or solar farm is producing more electricity than can be instantly consumed in the grid, it can be stored for later use. The same is true for rooftop solar generation.

The two most mature energy storage technologies in Australia are pumped hydro and lithium-ion batteries. There are other emerging storage technologies, such as renewable hydrogen and flow batteries.

Pumped hydro is a well-established technology that currently accounts for 97% of electricity storage worldwide. It is today's most cost-effective technology for long-duration, grid-scale energy storage to help meet peak demand, such as during heatwave conditions. However, no large scale pumped hydro storage has been developed in Australia in the past 30 years.

That could be about to change. In north Queensland, Genex Power is constructing a solar farm with an associated 250 megawatt pumped hydro storage facility that will operate for 6 hours at full power. It uses the discontinued Kidston gold mine's pits as water reservoirs. Feasibility studies are underway for at least another seven pumped hydro projects in South Australia alone.

On a larger scale, in late 2017, Snowy Hydro Limited released a feasibility study for a contemplated expansion of the Snowy Mountains Hydro Scheme through pumped hydro.[4]

If implemented, Snowy 2.0 will add 2000 megawatts of storage power capacity with the ability to run continuously at full power for 7 days. It would augment the Scheme's current catchment hydro primary power capacity of 5500 megawatts, at an estimated cost of A$4.5 billion, plus further costs for new transmission lines.

Thousands of additional potential sites for pumped hydro in Australia have been identified through the Atlas of Pumped Energy Storage developed by the Australian National University (ANU) and commissioned by the Australian Renewable Energy Agency (ARENA).[5]

Batteries are a rapidly emerging technology that can be used to provide back-up electricity if there is insufficient power generation to meet demand. In addition, they play a crucial role in ensuring the stability of the grid by helping to maintain a constant frequency.

For example, in the event of a major equipment failure or lightning strike, a large battery system can deliver an almost instantaneous injection of energy to help stabilise the network frequency.

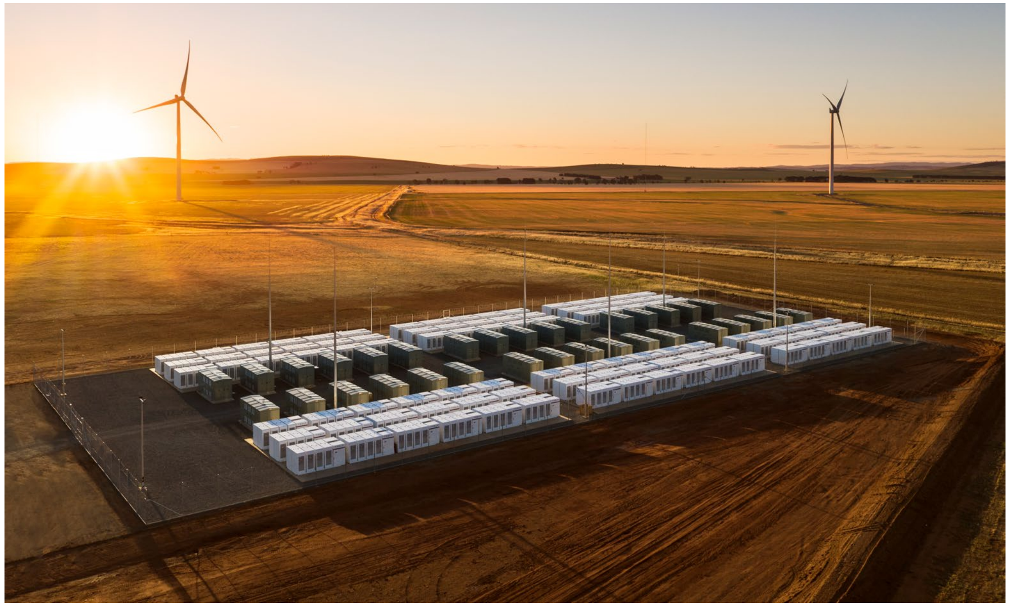
One advantage of batteries is that they can be initially installed as small units then scaled up as needs and funds arise. Further, they can be installed close to where they are needed, making the transmission costs either small or non-existent. In some cases, batteries can save investment costs by avoiding the need to upgrade distribution lines in cities.

For example, if a large office building needs to increase its peak electricity draw but the distribution lines to the site have reached their limit, instead of upgrading or building new distribution lines it might be more economical to install a battery system in the building basement that would be charged at night and discharged during the day to supply part of the peak demand. This usage is known as 'peak shaving'.

South Australia is home to the world's largest lithium-ion battery, supplied by Tesla and owned by Neoen, which started operating at the Hornsdale wind farm in December 2017.

The project can, in theory, dispatch 100 megawatts of electricity for almost an hour and a half at full power. However, the battery is usually constrained to 30 megawatts for back-up electricity and the remaining 70 megawatts is reserved to ensure grid security by helping maintain a constant frequency.

This battery system has captured 50% of South Australia's frequency control ancillary services.[6] It is an important step in demonstrating the potential for batteries to add both stability and dispatchable power to the grid.



Hornsdale Power Reserve, South Australia
Image supplied by Neoen

Most interest today is in lithium ion batteries, which in recent years have experienced dramatic price drops with multiple economic forecasts predicting continuing price declines over the next 15 years.

The demand for lithium-ion batteries, initially for mobile phones and computers, led to improvements in energy density and reliability. The demand for larger batteries in electric vehicles led to further improvements and set the stage for lithium-ion batteries to be used for energy storage in grids and buildings.

Other battery types such as those based on sodium rather than lithium, or using liquid electrolytes, are in production and being further developed.

Other means of storing energy include hydrogen storage, solar thermal storage and electrical thermal storage (See box 2).

Box 2: Energy storage technologies

Currently, pumped hydro and lithium-ion batteries are considered the most mature global energy storage technologies with renewable hydrogen rapidly emerging as another important technology.

Pumped Hydro

During times of high energy availability, water is pumped uphill into a large reservoir. During times of energy scarcity or peak demand, the water is allowed to run back downhill, driving a generator. The difference between catchment hydro and pumped hydro is that in catchment hydro, rain is collected over hundreds of square kilometres to fill dams from which electricity can be generated. In pumped hydro, electricity generated from a primary energy source is used to pump water uphill to a dam and later let it run downhill to generate electricity.

Batteries

Lithium-ion batteries are the most common rechargeable battery technologies, used in applications from household devices to large grid-scale batteries. The focus of research is on extending the lifetime of lithium-ion batteries. Flow batteries, unlike conventional batteries, rely on liquid electrolytes that are stored in external tanks and pumped through electrochemical cells.

Hydrogen

Renewable hydrogen is produced by splitting water molecules to produce hydrogen gas and oxygen in a process called electrolysis, usually powered by excess electricity from hydroelectric, wind and solar generation. Renewable hydrogen is a rapidly emerging technology but not as mature as lithium-ion batteries and pumped hydro.

Thermal

Usually built in conjunction with a concentrated solar plant, molten salt storage uses concentrated sunlight to directly heat mineral salts to very high temperatures. Another thermal storage system uses electricity to melt silicon. The heat energy is used when needed to generate electricity.

EMPOWERING CONSUMERS

A decade ago, almost all Australian householders received their electricity from the grid and paid for it like any other household expense.

Today more than 1.8 million buildings in Australia are fitted with rooftop solar panels, and the majority are residential. The owners are installing these systems to reduce their electricity costs and at the same time reduce carbon dioxide emissions. The addition of a home battery system is a logical next step.

The financial equation is straightforward, driven by the difference in the high price to purchase electricity compared with the low price to sell it to the grid.

Without a battery system, a solar-equipped household that is not normally occupied during the day will sell the electricity generated at the feed-in price of, say, 8 cents per kilowatt hour.

In the evening, when the occupants are home using their lights and appliances, electricity will be purchased at the retail price of, say, 30 cents per kilowatt-hour. This is the classic buy expensive, sell cheap dilemma. By installing a battery, this predicament can be overcome because the solar electricity generated during the day can be stored for evening use.

The main barrier to the take-up of home battery systems in Australia has been the up-front cost. However, prices are on a downward trajectory globally making widespread adoption feasible.[7]

Another barrier to the widespread take-up of batteries is the lack of information. A survey of more than 1,000 people commissioned by ACOLA found just 12 per cent of respondents thought they were moderately or very familiar with home battery storage.

Greater public awareness of home battery systems is likely to occur with the emergence of new business models that assist consumers to install and finance quality products.

Australia's strong safety record with batteries is set to be further strengthened with a nationwide battery storage installation standard currently under development.[8] It will be important that the final version of the standard facilitates the emerging industry while ensuring safety for owners and installers.

ECONOMIC OPPORTUNITIES

Mineral exports

Australia is a leader in advanced and sustainable mining technologies. Our top export commodity is iron ore, which accounts for almost 17 per cent of our export revenue[9].

Australia has managed to expand its market share in the global iron ore market by adopting smart, high-tech, cost-effective mining practices that push down the price of extraction.

Using this innovation expertise, Australia is very well placed to build new export streams.

With an expected world-wide boom in battery production, particularly for lithium-ion batteries used in electric cars and grid storage, Australia could dramatically increase its lithium exports. Australia is already the leading producer and exporter of lithium (see Box 3).

Cobalt is another mineral export opportunity, because it is commonly used in the cathode in lithium-ion batteries. Australia has 15 per cent of the world's cobalt reserves.

Shipping sunshine

Some countries, notably Japan and Korea, lack the land or climatic conditions to support large scale renewable energy and are searching for a lower-emission energy alternative.

Renewable hydrogen made by using solar or wind electricity to split water into hydrogen and oxygen is a logical choice. The only by-product in production is oxygen. During use, the exact same quantity of oxygen is consumed to produce heat or electricity, and the only by-product is water vapour. Japan has made hydrogen a national priority to power heavy industry and drive the hydrogen fuel-cell cars produced by its carmakers such as Toyota and Honda.

Australia is well positioned to be 'shipping sunshine' in the form of exported hydrogen. Hydrogen gas can be cooled to a liquid state or converted to ammonia for shipment by sea.

Box 3: Lithium in Australia

Australia is the world's biggest exporter of lithium, supplying about 40% of the global market.[10]

Australian lithium is mainly sourced from spodumene mineral deposits in Western Australia, which include the largest, highest-grade spodumene deposit worldwide.

Global demand for lithium is growing due to the prevalence of lithium-ion battery technologies. Currently, the global lithium value chain is US $165 billion, and forecast to increase to US $2 trillion by 2025. It is estimated Australia will secure US $10 billion of the total value of the lithium market in this time through mining, but this share could dramatically increase if Australia also began processing lithium.[11]

Technology Development

Australia is one of the fastest growing energy storage markets in the world. Technologies for the Australian market will be required to perform under Australia's extreme weather conditions, and to demonstrate financial viability in an electricity network in rapid transition.

Projects now underway capitalise on Australia's breadth and depth of expertise, coupled with strong international links and advanced research facilities. No fewer than 12 Australian universities are actively pursuing energy storage projects, in addition to the leading public research agencies CSIRO and the Australian Nuclear Science and Technology Organisation (ANSTO).

- At Monash University, the spinout company SupraG Energy has commercialised graphene super-capacitors that allow a three-fold increase in energy storage density.
- CSIRO and Deakin University have combined to create the BatTRI-Hub aiming to develop the next generation of battery technologies for manufacture in Australia.

Australian and international firms are looking to commercialise Australian-developed technologies, with several projects at an advanced stage of commercialisation.

The Brisbane-based company Redflow has developed the world's smallest zinc bromine flow battery in commercial production.

For grid scale electricity and industrial heat storage, the South Australian company *1414 Degrees* has opened a new factory in Adelaide that will manufacture an energy storage system based on heating and melting containers of silicon.

Waste management

Australia could consolidate its lead in the responsible management of battery waste. More than 90 per cent of Australia's traditional lead-acid batteries are recycled. With the shift to lithium-ion batteries, Australia could develop recycling technologies and whole-of-life management approaches that would be a model for the rest of the world.

CONCLUSION

The global electricity sector is undergoing unprecedented change as policymakers strive to develop systems that deliver affordable, reliable and low-emissions supply.

Energy storage will be a key factor in a successful transformation, and a catalyst for growth in the Australian economy.

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