CLIMATE COUNCIL

POWERFUL POTENTIAL: BATTERY STORAGE FOR RENEWABLE ENERGY AND ELECTRIC CARS

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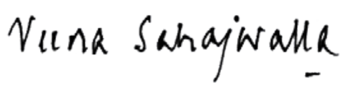

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Contents

Key Findings

1 Battery storage is expected to grow very quickly and will promote increased uptake of renewable energy and electric cars.

- Battery storage is a solution to the intermittency of some renewable energy sources such as solar and wind.
- Battery storage capacity is expected to grow 50-fold in less than a decade.
- Battery costs have fallen by 14% on average every year between 2007 and 2014 and more dramatic cost reductions for lithium ion batteries are expected as several companies rapidly scale up production.
- The rapidly falling cost of batteries is expected to make electric cars cost-competitive with conventional cars within the next twenty years, leading to much greater uptake.

2 Australia is expected to be one of the largest markets for battery storage due to the high cost of electricity, the large number of households with solar panels and Australia's excellent solar resources.

- Together with rooftop solar, battery storage presents an opportunity for Australian households to use a much greater proportion of the solar photovoltaic (PV) electricity they generate and minimise the need to purchase expensive electricity from the grid.
- In Australia, battery storage in 'behind-the-meter' applications (such as paired with residential or commercial solar PV) is expected to undergo a similar rapid expansion to solar PV - which has grown one-hundred-fold in capacity in six years.
- Half of all households in Australia are predicted to adopt solar systems with battery storage on the basis of $10,000 battery system with a payback of 10 years, with the market potentially growing to $24 billion.

3 Battery storage can reduce electricity costs for households in several ways.

- Home battery systems can allow a household to store electricity from the grid when prices are lowest (during off-peak periods) and then rely on their battery for power (rather than the grid) during the most expensive peak time, thereby minimising their overall electricity costs.

- A battery storage system can almost double a household's self-consumption of solar PV. Adding a 4 kWh battery to a 5 kWh solar system can increase the amount of self-generated solar electricity a household consumes from 30 to 60%.

- By 2018, going off-grid by installing battery storage could be cost-competitive with staying connected as the price of battery storage falls and grid electricity remains expensive.

- As feed-in tariffs are phased out and households receive far less for the solar electricity they put into the grid and electricity prices remain high (particularly at peak times), solar PV systems with added battery storage will become the most economical solution to provide electricity.

- Battery storage will reduce energy costs and boost reliance on renewable energy for the vast areas of Australia that are not connected to the grid and therefore rely on expensive imported fuels. For example, King Island in Tasmania has halved its diesel consumption after switching to renewable energy and battery storage.

4 Battery storage technology has the potential to reduce the two biggest contributors to the cost of electricity bills in Australia – network and wholesale energy costs.

- Ergon Energy estimates battery storage deployed at the grid level could avoid costs associated with building and upgrading the network, potentially reducing costs by 35%.

- Battery storage can also reduce the cost of energy, by providing retailers with an alternative, more cost-effective means of meeting peak demand than purchasing power from expensive gas "peaking plants" (which run only at times of peak demand).

- Other benefits of battery storage at the network level include enabling greater levels of generation from renewable energy without negatively affecting the electricity network.

1. Introduction

The renewable energy sector is booming globally. Technological advances and rapidly falling costs – such as a 75% drop in the price of solar PV modules in the past five years – are driving record-breaking capacity additions, and growth in global clean energy investment and jobs (REN21 2015).

Using batteries to store surplus electricity for use later on is not a new technology. However in recent years, battery storage technology has received greater attention as a means to support higher levels of electricity generation from renewable energy, especially from variable sources such as wind and solar photovoltaic (PV) power (IRENA 2015).

Recent developments in battery storage technology have already achieved (and are expected to continue to deliver) dramatic cost reductions through technology improvements and by massively scaling-up manufacturing (REN21 2015).

As battery costs continue to fall, battery storage will become an increasingly attractive option for storing renewable electricity at the household, business and community level. This is particularly true for Australia, which is projected to be one of the largest markets for battery storage due to the high cost of electricity, the huge numbers of households with solar panels and excellent solar resources. Electric and hybrid vehicles will become increasingly cost competitive with conventional cars (powered by internal combustion engines), which will drive increased uptake of these lower emissions vehicles.

As battery costs continue to fall, battery storage will become an increasingly attractive option for storing renewable electricity at the household, business and community level.

1.1. How Battery Storage Works

Battery technology has been around for more than 200 years. Most Australians are familiar with the small-to-medium sized batteries used in applications such as toys, watches, appliances, phones, computers and cars (Alarco and Talbot 2015; Figure 1).

Larger batteries are commonly used in industrial applications such as farming, construction and mining machinery, to power electric vehicles such as mobility scooters, hybrid and electric cars, as well as to provide standby emergency power (Warnken 2010).

There were almost 500 million batteries in use in Australia in 2010. While the vast majority of these were smaller batteries for handheld devices, around 15 million were conventional (lead-acid) car batteries and 7 million larger batteries (Warnken 2010).

Batteries are usually made up of a number of electrochemical cells. Each cell uses chemical reactions to store energy, and convert this energy into electricity for use later on when needed. The chemical reaction in a cell usually involves two different types of metals or compounds reacting together and releasing electrons. These electrons create electricity as they move from one electrode in the cell to the other, for example, along a wire. By linking individual cells together, higher voltages, larger currents and greater electrical energy storage can be achieved. Rechargeable batteries use electricity provided from outside to reverse the chemical reactions and so store energy (Alarco and Talbot 2015).

Figure 1: Commonly used batteries.

A battery's capacity is usually measured in power or electricity produced over a period of time - kilowatt hours (kWh) or megawatt hours (MWh). A battery's power capability is measured in kW or MW.

There are many different types of batteries:

- Ranging in size from batteries for watches to electric cars (85 kWh) to even larger batteries providing emergency back up power.
- Single-use (such as the alkali batteries purchased at the supermarket) or rechargeable.
- Low temperature (lithium-ion, lead-acid, nickel-cadmium), high temperature (sodium nickel chloride, sodium sulphur) or redox-flow batteries (vanadium, zinc bromide).

While there are a wide range of advanced, rechargeable low cost and efficient batteries that can be used by the electricity sector – including advanced lead acid, redox-flow, sodium sulphur and lithium ion – there has been a recent shift in the market, which has seen a much greater focus on lithium-ion batteries (IRENA 2015). Figure 2 shows the global estimated installed capacity of battery storage used by the electricity sector.

The lithium-ion battery has seen rapid cost decreases (Figure 3), and is considered to have a range of technical and performance advantages over other battery types (energy and power density, usable life). However other batteries, such as advanced lead-acid batteries and redox-flow batteries are suited to specific purposes – such as stabilising the electricity grid, for longer-term storage or larger energy capacity (IRENA 2015).

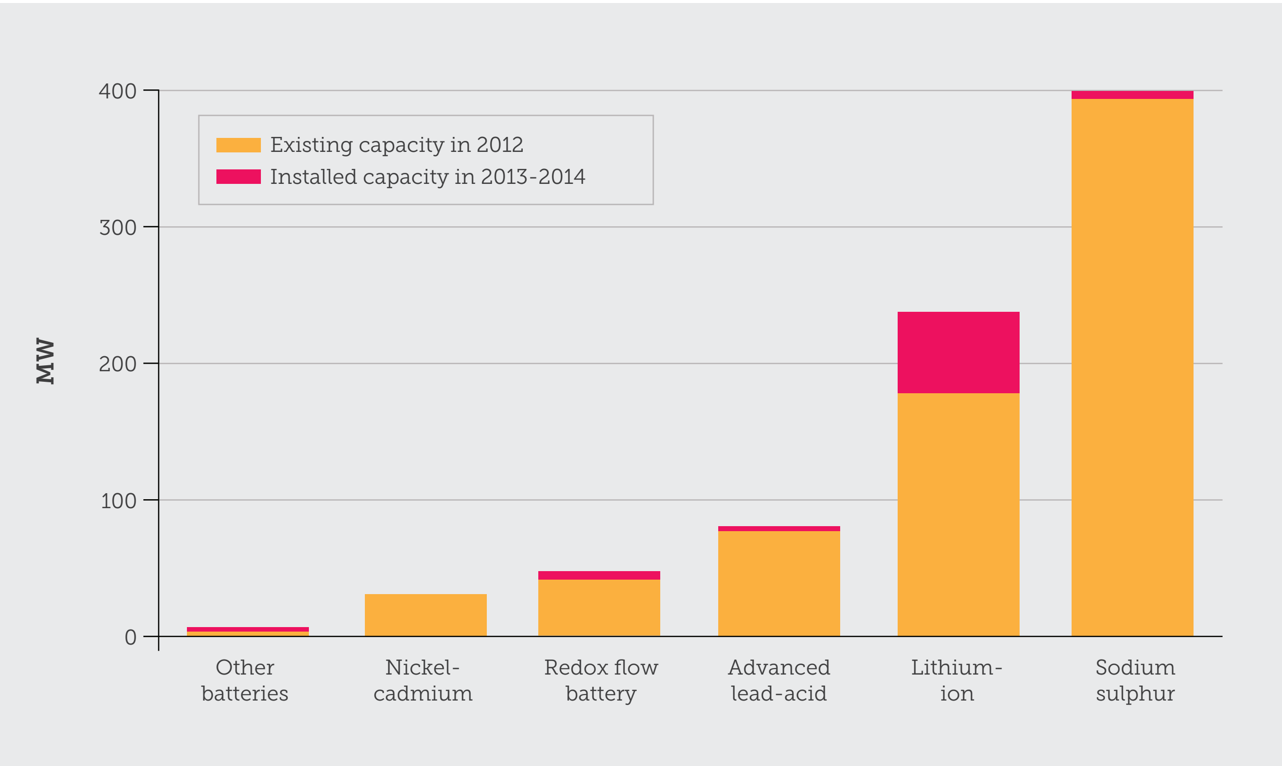
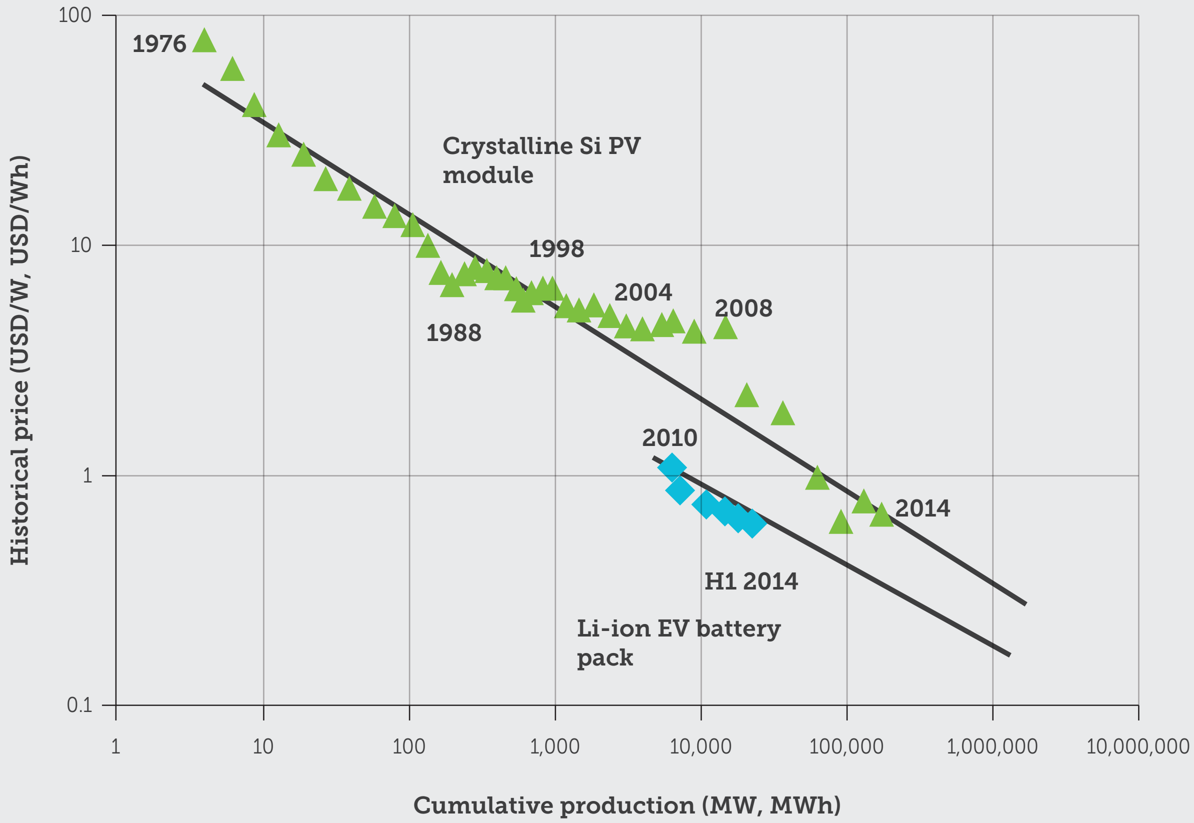


Figure 2: Estimated installed global battery capacity by type for the electricity sector. **Source:** Navigant Research 2014; IRENA 2015.

LITHIUM-ION EV BATTERY EXPERIENCE CURVE COMPARED WITH SOLAR PV EXPERIENCE CURVE



Note: Prices are in real (2014) USD

Source: Adapted from Liebreich 2015

Figure 3: Lithium-ion batteries and solar PV modules are on very similar learning curves for cost reductions.

Battery technology can be used at the point of demand such as the home or business, by utility companies at the grid level enabling a greater proportion of renewable energy (most commonly for off-grid or island applications) or to improve the stability of the grid – ensuring a secure electricity supply without power failures or blackouts (IRENA 2015).

1.2. The Changing Face of Battery Storage

Large, low cost, high capacity batteries are important for enabling increased uptake of renewable electricity (particularly from wind and solar) and of low emissions vehicles such as hybrid and plug-in electric vehicles (see, for example, Figure 4). Both are important solutions to climate change (IEA 2015).

Battery storage for the electricity sector has grown significantly in recent years, and is expected to ramp-up further in a short time period (IRENA 2015; REN21 2015).

Last year, a number of companies have sought to achieve dramatic cost reductions for large batteries through rapidly scaling-up production. New massive lithium-ion battery-manufacturing plants were announced in both China and the US (REN21 2015).

Figure 4: Plugged in electric cars.

Figure 5: Tesla's "Gigafactory" under construction.

One much-publicised example is Tesla's "Gigafactory", currently under construction near Sparks, Nevada in the United States (Figure 5). Tesla, which makes electric cars, has recently launched a home and commercial battery storage system. Tesla's new factory will manufacture batteries for cars, home and commercial storage. The Gigafactory will begin producing batteries in 2017, reaching full capacity by 2020. By 2020, the factory is expected to produce 35 GWh of lithium-ion battery storage per year – more than the entire worldwide production of lithium-ion batteries in 2013 (Tesla 2015).

Costs of battery storage for solar PV and electric vehicles are already falling much faster than expected. Between 2007 and 2014, battery costs fell by 14% on average every year, from USD 1,000/kWh down to USD 410/kWh (Figure 6). Market leaders, like Tesla achieved even lower prices than the average at around USD 300/kWh (Nykvist and Nilsson 2014).

By 2020, lithium-ion batteries are predicted to reach prices of USD 200/kWh even without further technological improvements (Nykvist and Nilsson 2014).

These rapid cost reductions will enable:

- Households, communities or whole electricity grids to store renewable electricity more cheaply.
- Battery electric cars to compete on cost with conventional petrol or diesel-fuelled cars.

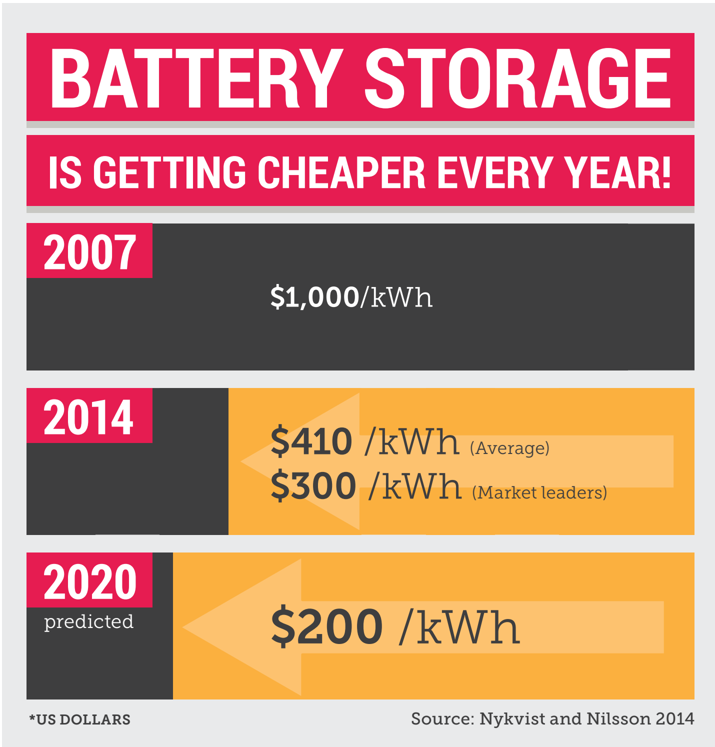


Figure 6: Falling costs of battery storage.

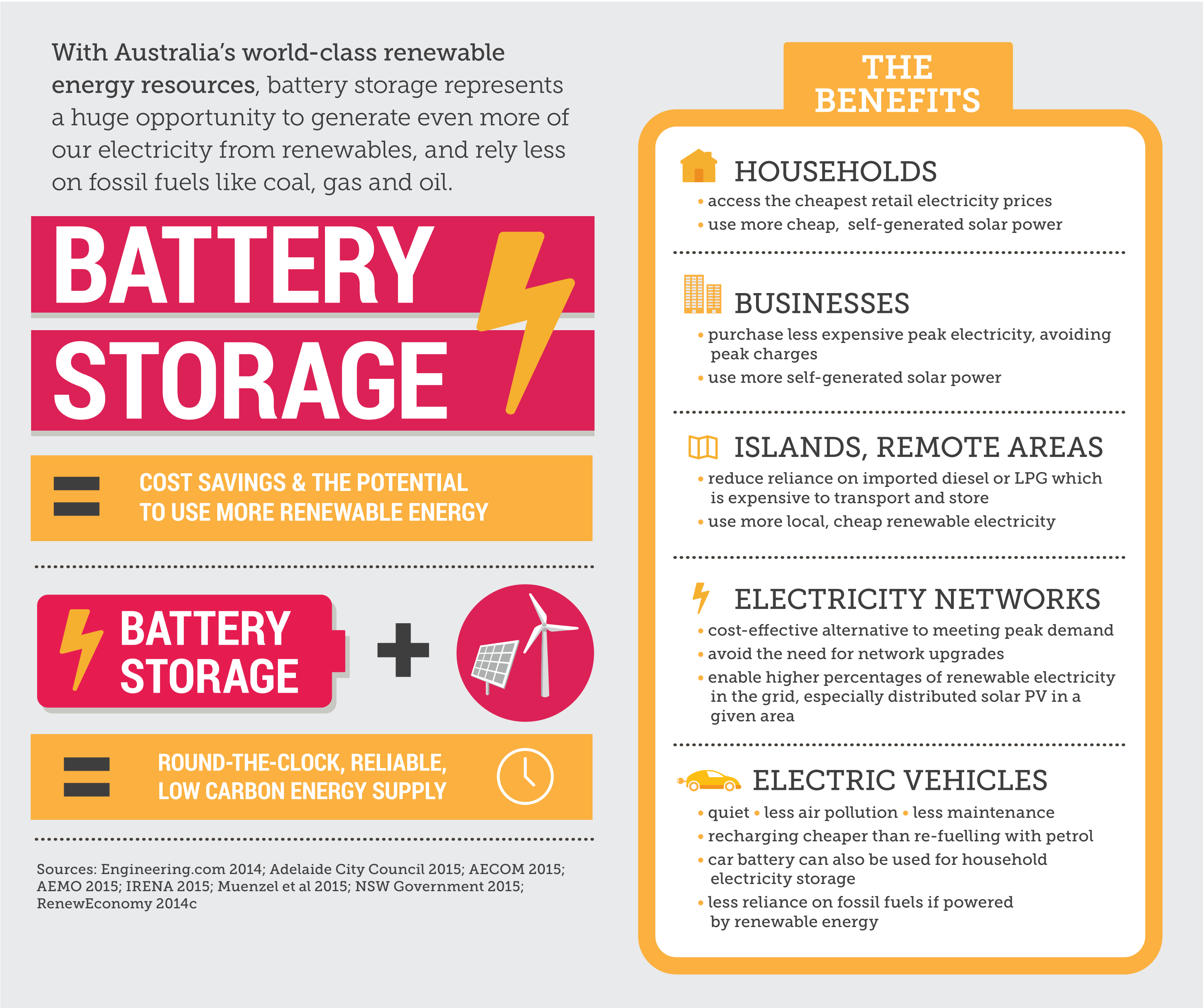


Figure 7: The benefits of battery storage.

Rapid cost reductions for battery storage are expected to drive wide-scale deployment, growing revenue and jobs.

Much like for renewable energy, rapid cost reductions for battery storage are expected to drive wide-scale deployment, growing revenue and jobs.

Recent research estimates that global annual battery storage capacity will grow from:

- 0.36 GW in 2014 to 14 GW in 2023 for utility scale applications.
- 0.17 GW in 2014 to 12 GW in 2024 for residential and commercial applications (Navigant Research 2014; IRENA 2015).

In Australia, battery storage in 'behind-the-meter' applications (such as paired with residential or commercial solar PV) is expected to undergo a similar rapid expansion to solar PV - which has grown one-hundred-fold in capacity in six years, from 39 MW in 2008 to 4 GW in 2014 (AECOM 2015).

While there is limited data available on global employment in battery storage technologies, in California – an early leader in battery storage technology – more than 4,500 people are already employed in the battery storage sector. Businesses range from start-ups to large-scale companies like SolarCity and Tesla (AEE Institute 2014).

Australia is already home to battery developer RedFlow. RedFlow's flow battery energy storage system was originally developed at the University of Queensland. Flow batteries differ from other battery types, in that the electrolyte is stored externally (in tanks) and then pumped through a central unit where the reaction takes place (IRENA 2015).

RedFlow's products are now used for a wide range of applications such as providing renewable energy storage (for example, together with household or business solar PV systems), on and off-grid remote power, telecommunications, smart grids and peak demand management. The company is based in Brisbane, Queensland and employs nearly 50 staff across its offices (also located in the United States and Europe) (Nanalyse 2014). While research and development is done locally in Brisbane, manufacturing of the flow batteries is outsourced to a facility in North America (RedFlow 2015).

The Victorian Government has identified energy storage as an area with significant potential for widespread uptake, as well as the creation of local business opportunities and jobs – in manufacturing, sales and energy management services. Victoria's Renewable Energy Roadmap (Victorian Government 2015) identifies reducing barriers to distributed generation (like solar PV) and energy storage as one of four priority areas to drive renewable energy in the state. The Victorian Government has also allocated $20 million dollars to a New Energy Jobs Fund with a specific focus on renewable energy storage technologies (Victorian Government 2015).

Nearly 5,000 people are employed in California's battery storage sector.

1.3. Batteries for Renewable Energy Storage

One of the criticisms of wind and solar PV has been that they are intermittent generators of electricity – only producing power when the sun is shining or the wind is blowing.

While pumped hydropower storage has existed for more than a century and some large scale solar thermal plants now incorporate heat storage, other renewables such as wind and solar PV often rely on the electricity grid (and other generators such as coal or gas power plants) to provide back-up power or active demand management to reduce the need for electricity at key times.

Figure 8: An example of a household solar pv battery storage system.

The intermittency of renewables is not an issue at low percentages of renewable electricity generation. However as international action on climate change demands deeper decarbonisation of the electricity supply in all countries, less reliance will be able to be placed on fossil fuel generators, like natural gas peaking plants and coal fired stations (without carbon capture and storage), to provide this backup (ClimateWorks 2015).

Renewable energy storage, like batteries (see, for example, Figure 8), provides an answer to the intermittency of renewable electricity generators addressing fluctuations in renewable energy generation over both seconds and hours. As well as pumped hydropower, heat storage and batteries, there are many other storage technologies including flywheels, fuel cells and compressed air storage (IRENA 2015). These technologies have different characteristics and applications for the electricity grid (Centre for Low Carbon Futures 2012; Figure 9).

Renewable energy storage technologies are important as they can enable households, communities and electricity grids to reach higher proportions of renewable electricity and reduce the need for reliance on back-up power from the grid powered by fossil fuels such as gas, or from imported LPG or diesel.

Battery storage is a solution to the intermittency of some renewable energy sources such as solar and wind.

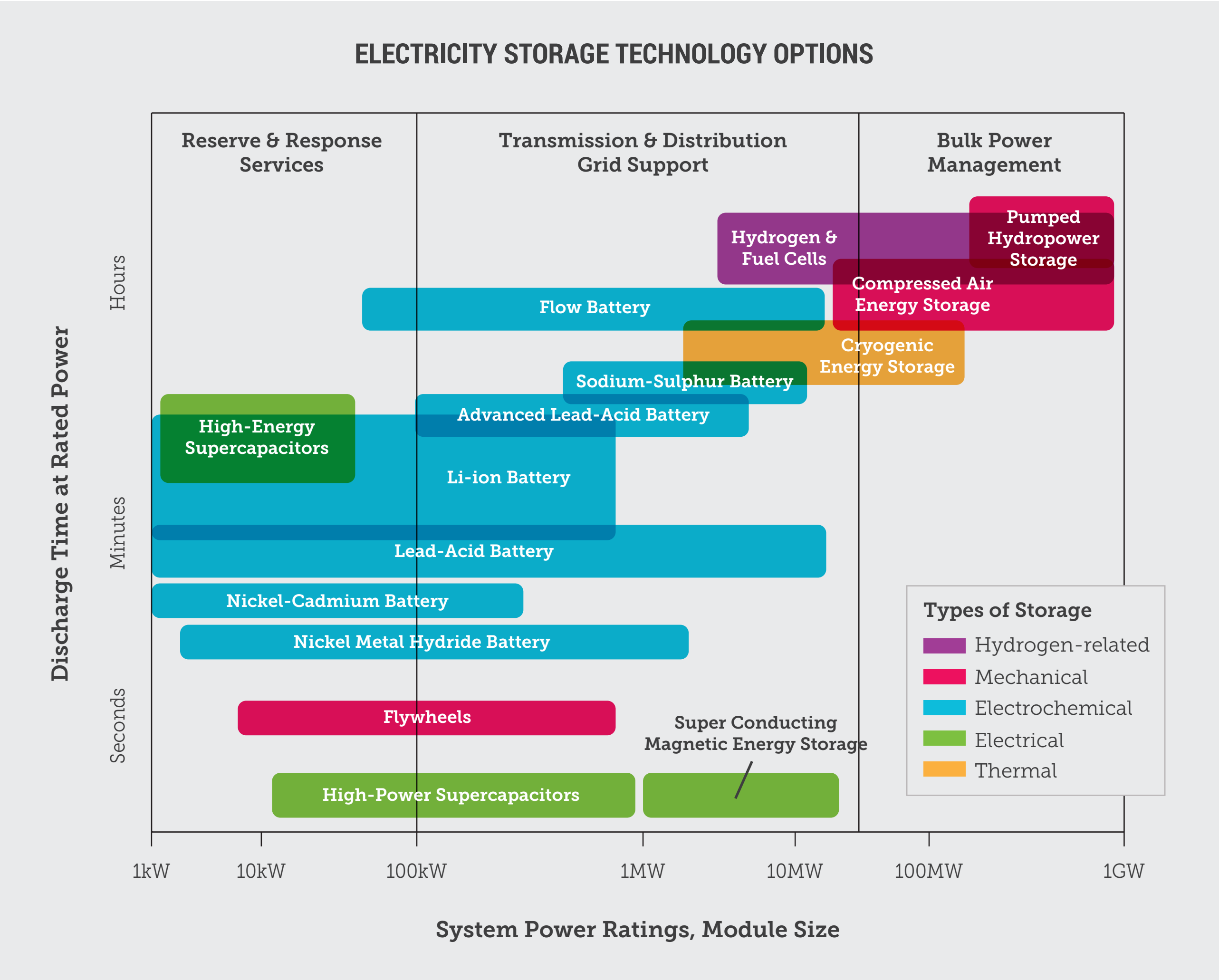


Figure 9: Characteristics of different energy storage technologies. **Source:** Centre for Low Carbon Futures 2012.

2. International Leaders in Battery Storage

China, Germany, Japan and the United States are leading the way on battery storage development (IRENA 2015).

Germany, like California, has long been a global leader in renewable energy (see, for example, Figure 10). In 2013, the German government introduced a number of incentives targeted at households, companies, local authorities and community organisations to encourage both utility and smaller-scale battery storage uptake (AECOM 2015). Under one incentive scheme, German households and businesses are able to access grants for 30% of the upfront installation costs (and loans with favourable conditions) to install new solar PV and storage systems or to retrofit storage to an existing solar PV system (CitiResearch 2013).

Figure 10: Wind power is one type of renewable energy that has seen a rapid uptake in Germany.

Like Germany, California has a history of progressive energy policies. The state's Renewables Portfolio Standard requires 33% of electricity to come from renewable sources by 2020 and 50% by 2030 (California Senate 2015). California has recently introduced energy storage support programs and targets to support its renewable energy targets, including:

- An Energy Storage Mandate with a target requiring Network Service Providers to install 1.3 GW of energy storage by 2020.
- The Self-Generation Incentive Program providing rebates for a range of electricity users to install a variety of clean energy technologies, including advanced energy storage systems (AECOM 2015).

Hawaii, New York and Texas have also implemented programs for rapid deployment of utility-scale energy storage and incentives for households to adopt battery storage (AECOM 2015).

China already has some of the world's largest energy storage in the form of pumped hydroelectric and has installed 57 MW of battery storage. A number of major battery manufacturing plants are under construction. China aims to have 100 cities with high levels of solar and storage uptake, and reach 5 million (hybrid and plug-in) electric vehicles by 2020 (AECOM 2015).

Japan subsidises more than half of the price for businesses and households installing lithium-ion battery storage. The subsidy program has an overall budget of USD 98 million (AECOM 2015).

BOX 1: RECENT DEVELOPMENTS IN BATTERY STORAGE TECHNOLOGY

Research – *lithium-ion batteries*

Lithium-ion batteries are an important component of modern technology, powering phones, laptops, tablets and other portable devices when they are not plugged in. They even power electric vehicles. But to make batteries that last longer, provide more power, and are more energy efficient, scientists must find battery materials that perform better than those currently in use.

At the United States Department of Energy's Brookhaven National Laboratory, a team of researchers has studied one member of a class of materials, called transition metal fluorides that are potential cathodes for future lithium-ion batteries. The researchers discovered that adding copper atoms to one member of this class iron fluoride produces a group of new fluoride materials that can reversibly store lithium-ions, and can store three times as many as conventional cathode materials. Measurements indicate that these new materials could yield a cathode that is extremely energy efficient.

Research – *Nickel metal hydride batteries*

Recently scientists at chemical company BASF are exploring the possibilities of an older type of battery, nickel-metal hydride, now used in hybrid vehicles. The researchers recently doubled the amount of energy that these batteries can store, making them comparable to lithium-ion batteries. Changing the microstructure of the batteries helped make them more durable, which in turn allowed changes to the cell design that saved considerable weight, enabling storage of 140 watt-hours per kilogram. Nickel metal hydride batteries are durable, and inherently safer than lithium-ion batteries.

Sources: Wang et al 2012; Bullis 2015.

3. Battery Storage Potential in Australia

Currently in Australia, the most relevant, and highest value opportunities for battery storage are:

- 'Behind-the-meter' applications such as for households and businesses together with rooftop solar.
- Off-grid areas (remote locations) and on the fringes of electricity grids (regional areas, e.g. Figure 11) where the costs of back-up power from connecting to the grid or by importing diesel and LPG are high (AECOM 2015).

Figure 11: Off grid house in regional NSW.

3.1. Battery Storage for Households

Australia is already home to some of the most affordable solar PV systems in the world, but also some of the highest retail electricity prices (Business Spectator 2015). Together with rooftop PV, battery storage presents an opportunity for Australian households to use a much greater proportion of the solar PV electricity they generate and minimise the need to purchase increasingly expensive electricity from the grid (AECOM 2015).

Other key drivers for households taking up solar PV and battery storage are the excellent solar resources, the growing affordability of batteries, the phasing out of premium feed-in tariffs for solar PV and the introduction of demand-based tariffs, as well as the desire by many households to be more energy self-sufficient (AECOM 2015; AEMO 2015).

Electricity prices in Australia are higher than in Japan, the European Union, the United States and Canada. Four Australian states (South Australia, New South Wales, Victoria and Western Australia) are among the top six places with the highest electricity prices when compared with 91 other countries, states and provinces worldwide (Carbon and Energy Markets 2012).

Over 1.4 million Australian households are already using solar to control their electricity bills. Nearly 15% of all Australian households have solar panels on their rooftops (see, for example, Figure 12) with an average system size of 4.5kW and rising (ESAA 2015). Furthermore, Australia's solar PV systems are among the most affordable in the world (Business Spectator 2015). These economic benefits are a key reason why solar panels are primarily taken up by lower and middle-income earners (Green Energy Trading 2014).

Figure 12: Solar rooftop in Adelaide.

High electricity prices, increasingly affordable solar PV and battery systems and the desire to be more energy self-sufficient will drive many Australian households to take up battery storage.

In Australia, most solar PV systems 'pay for themselves' in less than a decade. A Choice (2015) survey of 700 households with solar PV found the average payback period was 3 years and two months. Other studies (Commonwealth of Australia 2014; ESAA 2015) have estimated solar PV systems pay for themselves between 4 to 12 years, with the shortest payback periods in the Northern Territory or South Australia.

Further, in all Australian capital cities except Canberra, solar PV systems have already reached "grid parity". This means that the cost of energy (per kWh) for installing a solar PV system is equal to or below the standard cost of electricity from the grid (ESAA 2015).

Initially in Australia, incentives such as feed-in tariffs encouraged households with solar PV to feed as much electricity into the grid as possible by offering a premium price for the electricity. However, most of these feed-in tariff schemes have been scaled back or stopped in recent years (Muenzel et al 2015).

Households with solar PV which are no longer eligible for premium feed-in tariffs are now receiving a relatively low price for their solar power (a typical house in Victoria earns 6.2c/kWh for solar power fed into the grid, dropping to 5c/kWh in 2016), but are paying a much higher price to purchase electricity from the grid (typically around 33c/kWh) at other times when the sun is not shining (Muenzel et al 2014; Essential Services Commission 2015).

The Australian Energy Market Commission has made a ruling requiring electricity network companies to introduce cost-reflective tariffs. This means that customers such as households and businesses will pay a price for the electricity they use which reflects the cost to the networks for supplying the electricity. In general, this means that electricity used during peak times will cost more, and networks will also charge households based on their demand for electricity over short high usage periods, creating an incentive to use less electricity during those times (AEMC 2014). The Australian Energy Regulator is currently considering applications from network companies for these new peak demand based tariff structures.

As feed-in tariffs are phased out, cost-reflective tariffs are brought in and electricity prices increase over time (particularly at peak times), solar PV systems with added battery storage will become the most economical solution to meet household electricity needs (Ratnam et al 2013; Weniger et al 2014; Grattan Institute 2015). Under these conditions, households will get the most benefit out of their solar PV systems by maximising their use of electricity generated by their own solar panels and minimising the amount of electricity they purchase from the grid (Muenzel et al 2015).

The current payback period for battery systems and solar PV is estimated between 6 and 12 years in NSW (AEMO 2015). A 5 to 8 kWh battery system would already pay for itself in less than 12 years if electricity prices stay at current levels (Muenzel et al 2015). If battery system prices continue to fall as expected, the payback is expected to drop to 8 years in 2020 and 6 years in 2030.

The Adelaide City Council is providing an additional incentive for households to take up battery storage. The council is the first government in Australia to offer a rebate of up to $5,000 for residents, businesses, schools and community groups for installing batteries for energy storage.

The rebate for batteries is part of the Sustainable City Incentives Scheme, designed to encourage early and widespread adoption of emerging energy technologies.

The scheme provides up to:

- $5,000 for solar PV.
- $5,000 for energy storage.
- $500 per electric vehicle charging controller.
- $5,000 for apartment building energy efficiency upgrades.
- $1,000 for replacing halogen lights with LEDs (Adelaide City Council 2015).

The South Australian Government has also announced it will install battery storage systems at a number of high profile public buildings (with existing solar PV systems) located along North Terrace including the Museum, the State Library, the Art Gallery of South Australia (Government of South Australia 2015).

As storage systems become more affordable, households may benefit from installing a battery system, regardless of whether or not they have a rooftop solar PV system.

Home battery systems (Figure 13) can allow a household to store electricity from the grid when prices are lowest (during off-peak periods) and then rely on their battery for power (rather than the grid) during the most expensive peak times, thereby minimising their overall electricity costs (Grattan Institute 2015).

Figure 13: Household battery storage.

3.2. Commercial Potential for Battery Storage Systems

In Australia, there is already evidence of growth in the commercial solar PV market. An average sized (27.6 kW) commercial-scale solar PV system pays for itself in under six years in South Australia and Queensland, and under ten years in all states (ESAA 2015). Likewise, battery storage used in commercial settings pays for itself in a much shorter timeframe than residential systems (IHS 2015; NSW Government 2015).

Energy usually accounts for less than 5% of the cost of doing business in Australia. However, for some businesses such as liquor, grocery and hardware stores and supermarkets the costs are more significant and have been increasing in recent years by more than the consumer price index (Productivity Commission 2014).

Together with a solar PV system, battery storage can enable businesses to maximise their use of self-generated cheap solar electricity. Even without solar PV, adding a battery storage system can enable businesses to access cheaper electricity from the grid and store it for use at more expensive, peak periods as well as reduce peak demand charges typically applicable to business users (NSW Government 2015).

In the United States, commercial take-up of solar PV and battery storage is expected to grow significantly in only a few years. It is expected that rising energy prices will drive rapid take-up of commercial battery storage systems. In North America, commercial applications already represent around half of all solar PV installations paired with energy storage. And commercial installations are expected to dominate the battery storage market in 2017 and 2018 (IHS 2015).

The growth in commercial use is being driven by a number of solar PV and battery storage suppliers in the United States now offering solar PV and storage systems to commercial users at no upfront cost, as well as passing on a proportion of the electricity bill savings to the owner/user (IHS 2015).

Even without solar PV, adding a battery storage system can enable businesses to access cheaper electricity from the grid and store it for use at more expensive times.

3.3. Battery Storage for Off-grid Areas and Remote Locations

Islands and off-grid areas are an important market for battery storage (see, for example, Figure 14) as many of these locations rely on expensive imported fuels to meet their power needs (IRENA 2015).

Outside of the major capital cities, and the southern and eastern seaboards, Australia has vast areas that are "off-grid" – not connected to a larger electricity grid – as well as many island communities (AECOM 2015).

Islands and off-grid areas are an important market for battery storage as many of these locations rely on expensive imported fuels to meet their power needs.

Figure 14: Off-grid battery bank for solar PV in Western Australia.

King Island has halved its diesel consumption thanks to renewable energy and battery storage.

These areas generally rely on imported diesel or liquefied petroleum gas (LPG) to provide their electricity. These fuels are expensive and have the added cost of transportation and storage. In off-grid areas, renewable energy can generally provide more affordable electricity. However, for wind and solar PV, diesel and LPG are still relied on for back-up power.

Batteries are an alternative way to increase the supply of renewable electricity to these off-grid and island areas while ensuring a reliable supply of electricity. For off-grid and island applications, the payback period for battery storage is generally less than four years for a range of battery technologies (lithium-ion, lead acid, sodium metal halide, advanced flow) (IRENA 2015).

King Island in Tasmania is an example of an off-grid, island community using battery storage to boost its reliance on renewable energy (Hydro Tasmania 2015). Previously relying entirely on diesel for its electricity, King Island is now powered mainly by wind, solar and biodiesel together with one of the largest battery storage systems in Australia. The island's 3 MW / 1.6 MWh advanced lead acid battery system is designed to enable wind power to provide up to 70% of the Island's electricity demand (at times providing 100% renewable energy) while maintaining a stable grid. Since installing the renewable energy and storage system, King Island has halved its diesel consumption from 4.5 to 2.6 million litres per year (AECOM 2015).

As well as regional, remote and island communities, renewable energy and battery storage also provides an economically attractive option for powering remote mines and infrastructure facilities. For example, construction is currently underway on a 10.6 MW solar PV and a 6 MW battery storage system for the DeGrussa copper mine in Western Australia, located 900 kilometres northeast of Perth. The solar and battery storage system supported by the Clean Energy Finance Corporation (CEFC) and the Australian Renewable Energy Agency is expected to reduce the mine's reliance on diesel, saving about 5 million litres each year (CEFC 2015; Engineers Australia 2015).

3.4. Projected Uptake in Australia

Globally, the market for solar PV panels and battery storage is expected to grow tenfold in less than five years – from 90 MW in 2014 to 900 MW in 2018 (Clean Energy Council 2015).

Currently there are about 500 residential battery storage and solar power systems installed across Australia (AEMO 2015). Current large-scale battery storage capacity in Australia is around 0.5 GW, made up of – 70 MW lead acid, 100 MW lithium ion, 27 MW nickel cadmium, 304 MW sodium sulphur (AECOM 2015).

While there are varying predictions about the potential size of the local market in coming years, most agree that Australia will be an attractive market for battery storage and there is potential for a "megashift" with wide-scale adoption of battery systems over a relatively short period of time (AECOM 2015; AEMO 2015).

The Australian Energy Market Operator (2015) has predicted a potential market of 0.5 GW in 2017-18, 3.4 GW in 2024-25 and 8 GW in 2034-35. However these projections only considered new rooftop solar PV plus battery storage and did not consider the key market opportunity of households and businesses with existing solar PV retrofitting battery storage (AECOM 2015; AEMO 2015).

Market research by Morgan Stanley (RenewEconomy 2015) estimated half of all households in Australia would adopt solar systems with battery storage on the basis of a $10,000 battery system (based on a Tesla 7 kWh daily cycle battery) with a payback of 10 years, with the market potentially growing to $24 billion.

Globally, the market for solar PV panels and battery storage is expected to grow tenfold in less than five years.

3.5. Battery Storage - Going Off-grid and Using More Rooftop Solar Power

The phrase "going off-grid" implies households or sometimes communities with enough renewable power and storage to provide for their own requirements, and therefore able to disconnect from the grid.

Yet, even with solar and battery storage prices becoming more affordable and grid electricity prices rising, there are two barriers likely to prevent most households going completely off-grid: upfront system costs and roof space (Grattan Institute 2015).

Grattan Institute (2015) estimated that to achieve 95% reliability for an average household would require a 7 kW solar PV system and a 35 kWh battery storage pack. According to Grattan Institute, a system this size would require an upfront investment of $34,000 and 60m^2 of clear roof space, ideally facing north. Achieving 99% reliability (reliability comparable to the electricity grid) would require more roof space, ruling out most households and an upfront investment of $52,000 to purchase and install 10 kW solar PV and 60 kWh battery storage (Grattan Institute 2015).

Global investment bank UBS (RenewEconomy 2014a) came up with a similar figure to go off-grid - around $39,000, but expects that with falling battery storage prices by 2018 going off-grid will be cost competitive with staying connected.

However, for households and communities at the fringes of the grid or in off-grid areas, the substantial cost of connecting to the grid may encourage households to invest in solar and battery storage. For example, Melbourne writer Emma Sutcliffe (The Age 2014) was quoted $30,000 in 2012 to connect to the electricity grid (only one kilometre away), but instead installed solar and storage systems sufficient to power her household requirements for $60,000 (with no foreseeable future power bills).

Off-grid housing estates with centralised battery storage are beginning to be developed in Australia. A new estate in Alkimos Beach, Western Australia will trial more than 100 solar PV systems together with a centralised 1.1 MWh lithium-ion battery storage system (ARENA 2015). The White Gum Valley estate, also located in Western Australia will incorporate solar PV on north facing homes and domestic battery systems – with residents expected to save over $1,000 a year on their electricity bills (ABC 2015a).

Other communities, such as Uralla in New South Wales and Newstead in Victoria, are hoping to become entirely self-sufficient by meeting all their electricity needs from local renewable energy generation and storage. These towns have set a goal of being completely energy self-sufficient and off the electricity grid within a decade (RenewEconomy 2014b).

Battery storage can increase the uptake of solar PV (see, for example, Figure 15) in a given area, increasing the overall amount of electricity generated from solar while maintaining a stable electricity grid (IRENA 2015).

Potential benefits include:

- Almost 70% more solar PV can be installed in a given area if households and businesses are using battery storage to restrict the amount of solar feeding into the grid (IRENA 2015).
- A battery storage system can almost double a household's self-consumption of solar PV. Adding a 4 kWh battery to a 5 kWh solar system, for example, can increase the amount of self-generated solar electricity a household consumes from 30 to 60% (IRENA 2015).

Figure 15: Household solar pv in Armidale, NSW.

4. Battery Storage and Electric Cars

Plug-in electric cars run entirely on electricity, powered by rechargeable batteries. Electric vehicles are more efficient, emit less air pollutants, are quieter, have stronger acceleration and require less maintenance than conventional cars (with internal combustion engines) (US Department of Energy 2015). The electric vehicle industry has led much of the recent investment and technological development in battery technology (CitiResearch 2013).

Hybrid vehicles combine an electric engine and battery able to be charged by an internal combustion engine. In the case of plug-in hybrid vehicles (see, for example, Figure 16), the battery can also be charged from the grid (ESAA 2013).

The market for electric cars (for both hybrid and plug-in electric vehicles) remains only a tiny proportion of the global car market, although there has been significant growth in recent years - about 50% from 2013 to 2014 (IEA 2015).

From almost no cars on the road in 2009, there are now about 665,000 electric vehicles worldwide. In leading countries such as the Netherlands, Norway, Sweden and the United States, electric vehicles have achieved more than 1% of car sales (IEA 2015).

In Australia, sales of hybrid and electric vehicles doubled in the three years from 3,312 in 2009 to 6,095 in 2012 (Joule Logic 2014). Sales doubled again between 2012 and 2014 to 13,080 – made up of 1,130 electric vehicles and 11,950 hybrids (CarsGuide 2015).

Figure 16: Electric cars at a public charging station at San Francisco City Hall.

Projections for electric vehicle uptake in Australia by 2020 (based on no government support policies or incentives) are wide-ranging:

- AECOM (2011) predicts electric vehicles to be a "significant presence" representing 20% of new car sales.
- PwC (2010) expects hybrid electric vehicles to comprise 7%, battery electric vehicles around 3%.
- ABMARC (2012) anticipates hybrid cars will be a "vehicle of choice" for many Australians making up 6.4% of the market, battery electric vehicles just 0.4%.

High battery costs currently represent the key cost difference between conventional cars and battery electric vehicles. When battery prices reach USD 150/kWh then battery electric vehicles will become directly cost competitive with conventional cars (Nykvist and Nilsson 2014). Cost-parity is not far off given batteries are expected to reach USD 200/kWh by 2020 even without further technological improvements (Nykvist and Nilsson 2014). Cost-parity will lead to much greater uptake.

Households choosing an electric car will benefit from reduced transport costs as the cost of electricity for charging an electric vehicle (even using 100% GreenPower from the grid) are substantially lower than the cost of fuel for an equivalent petrol car (AECOM 2015).

Households with electric cars will also benefit, by being able to use their vehicle as a form of household battery storage. These households will be able to use their car's battery to store excess solar power at peak times for use later - maximising their use of solar PV generation if they have a rooftop system - or to manage their electricity demand from the grid (AECOM 2015).

Households with electric cars will also benefit, by being able to use their vehicle as a form of household battery storage.

The Tasmanian Government (2015) anticipates electric vehicles becoming competitive on both cost and performance (with conventional vehicles) within the next twenty years. With imported transport fuels being a major cost for Tasmanian households and businesses, the wider adoption of electric vehicles is viewed by the State Government as a way of improving competition with petroleum-based fuels and reducing Tasmanians' vulnerability to oil price rises. A key action outlined in the Tasmanian Energy Strategy is to establish a demonstration program for electric vehicles in both government and private vehicle fleets to encourage uptake, build awareness and confidence in electric vehicles, and to develop the necessary charging infrastructure.

The Royal Automobile Club (RAC) of Western Australia supported by local councils is building an "electric highway" of car charging stations along the southwest coast between Perth and Augusta. Even though most electric cars can travel about 150 kilometres on one charge, the charging stations are designed to tackle "range anxiety" perceptions by giving people confidence they will be able to recharge their vehicles if travelling far from home (ESAA 2013; ABC 2015b). Four stations have already been built in Mandurah, Bunbury, Busselton and Margaret River with eight to come (RAC 2015). Electric car users will be able to plug their vehicle in and charge from a flat battery to 80% in twenty minutes (RAC 2015).

5. Electricity Generation and Network Benefits of Battery Storage

Significantly, in addition to household and commercial savings from battery storage located 'behind-the-meter', battery storage technology also has the potential to reduce the two biggest contributors to the cost of electricity bills in Australia – the cost of building and maintaining the electricity distribution network and purchasing wholesale energy (AEMC 2013).

Network costs are the largest contributor to electricity prices in Australia – making up around half of the average electricity bill and have also been the main reason for energy prices rising in recent years (ACCC 2012). Most of the recent large increases in network costs have been due to the cost of meeting forecast future peak demand - replacing and upgrading poles, wires and pipelines – which may occur for only a few hours a year. Batteries (and other energy storage technologies) provide an alternative to expanding and upgrading the network, by instead evening out the demand on the network at peak times, and making more effective local use of surplus distributed generation. As a result, battery storage can potentially reduce the need for investment in expanding the network, and facilitate greater uptake of distributed power (like solar PV). Ergon Energy estimates grid based battery storage could reduce network costs by 35% (RenewEconomy 2014c).

In North Queensland, Ergon Energy (2014) is currently trialing a number of different battery storage systems and sizes in a group of ten Townsville homes. The trial will test whether battery technology can be used to provide cheaper power to consumers while also reducing pressure on the electricity network. The trial is aimed at finding an alternative to continually upgrading and expanding the network to cope with peak demand.

Battery storage technology has the potential to reduce the two biggest contributors to the cost of electricity bills in Australia – network and wholesale energy costs.

Figure 17: Large battery for network use.

After network costs, wholesale energy (the cost of electricity purchased from power plants) is the next largest contributor to electricity prices in Australia – contributing about a third to the cost of the average electricity bill (ACCC 2012). Battery storage has the potential to reduce the cost of wholesale energy by providing an alternative, more cost-effective means of meeting peak electricity demand than by relying on expensive gas peaking plants (McConnell 2015). For example, in California last year, a large battery bank won a competitive tender to provide 100 MW peaking capacity – as the most cost-effective and reliable solution out of 1,800 bids (Engineering.com 2014). For electricity retailers, managing peak demand by installing batteries (or encouraging their customers to) can reduce the need for the retailer to buy as much expensive 'peaking' power, thereby reducing the cost of the wholesale energy component of the bill.

In Thomastown, Victoria AusNet Services is trialing the use of a 1 MW utility-scale battery storage system to help the grid cope with peak demand periods (in the afternoon and on hot days). By recharging at off-peak times, the battery can supply around 300 homes for an hour at full capacity. The two-year trial is designed to test whether the network battery system is a cost-efficient solution for meeting peak demand (AusNet Services 2015).

Other benefits of battery storage at the network level (see, for example, Figure 7) include providing grid stability, reducing substation overloading, and managing reverse power flow (an issue associated with high concentrations of distributed generation).

High levels of variable renewable energy can cause instability in the electricity grid if the generation is not adjusted to match demand. Solar PV generates maximum power in the middle of the day. As solar take-up grows over time, the maximum solar PV generation in the middle of the day (12 noon to 2 pm) could eventually exceed demand leading to an unstable grid. Battery storage provides a solution – enabling the excess local generation to be stored and spread across the day (CitiResearch 2013).

Battery storage can allow higher levels of household and commercial solar PV in a given area while also ensuring the grid is stable by smoothing out the demand and supply peaks. Battery storage can also be used at the utility level to smooth output from large-scale solar PV and wind generators and also store electricity for later export to the grid (IRENA 2015).

Energy storage can also be used to improve power quality and reliability, particularly in areas where there are network constraints or high levels of renewable generation (AECOM 2015).

6. The Future of Battery Storage

High electricity prices, increasingly affordable solar PV and battery systems and the desire to be more energy self-sufficient will drive many Australian households and businesses to take up battery storage in coming years. Most analysts predict widespread adoption of solar PV and battery storage in Australia as systems become increasingly cost effective in 'behind-the-meter' applications and two battery storage companies, Enphase and Tesla, have recently announced they will launch their home battery systems in Australia (Sydney Morning Herald 2015).

While other countries such as Germany, the United States, China and Japan are driving the uptake of battery storage with incentives, policy support and targets, in Australia consumers (households, businesses and communities) seeking cheaper electricity or transport are most likely to propel the local market.

To date, there have been some initiatives at the state and local government level encouraging take-up of battery storage and electric vehicles. However, the Federal Government has recently indicated battery storage and improving the utilisation of solar power will be a focus of new initiatives designed to meet the proposed 2030 emissions reduction target (Australian Government 2015). Future deployment of battery storage in Australia - whether these technologies are encouraged or hindered - will also depend on tariff and regulatory decisions and the actions of governments, electricity networks and retailers and other competitors.

As prices continue to fall, battery storage will deliver cost savings to households and businesses by enabling them to use more of their own solar electricity and also by accessing and storing electricity from the grid when it is cheapest. Islands and remote areas will benefit through relying more on local renewable energy and reducing their need to import expensive diesel or LPG. For electricity network companies, battery storage has the potential to provide a more cost-effective alternative to meeting peak demand and can be used to enable higher percentages of renewable electricity, particularly of distributed solar power. As battery prices fall, so too will electric car prices. People choosing electric cars will benefit from reduced transport costs, with 're-charging' cheaper than 're-fuelling', and will be able to use their vehicles for household electricity storage.

Both in Australia and globally, rapid deployment of battery (and other energy storage technologies) for stationary energy and electric vehicles will be important elements in addressing climate change by enabling even greater levels of reliance on renewable energy – both by households and businesses from rooftop PV, and from solar and wind at the grid level. Plug-in electric vehicles with rechargeable batteries also provide an alternative to continued reliance on fossil fuels for transportation, especially when charged by renewable electricity.

Significantly, by enabling an increase in the uptake of renewable energy and electric vehicle use, battery storage can support efforts to reduce global greenhouse gas emissions and help tackle climate change.

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