CLIMATE COUNCIL

POWERING A 21ST CENTURY ECONOMY: SECURE, CLEAN, AFFORDABLE ELECTRICITY

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Published by the Climate Council of Australia Limited

ISBN: 978-1-925573-32-9 (print)
978-1-925573-33-6 (web)

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Key Findings

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The inevitable closure of Australia's inefficient, ageing coal plants provides a critical opportunity to move to a modern, 21st century electricity system.

- Within a decade, over two thirds of coal plants in Australia's National Electricity Market will be 50 years or older, technically obsolete, unreliable and costly to maintain. Australia must prepare for a major energy transition, which is already underway.
- Ageing coal and gas electricity infrastructure is vulnerable to increasingly severe weather events influenced by climate change.
- Wholesale energy prices are rising due to rising gas prices and on-going national policy uncertainty undermining future energy investments.
- Renewable energy is now the cheapest form of new power.

2

There are five key requirements in building a robust energy system that will meet Australia's needs into the future. All five must be met for Australia to effectively meet its energy needs into the future.

- Clean: Tackling climate change requires a rapid transition away from polluting sources of energy to clean sources.
- Reliable: Balancing demand for electricity (from households, business and industry) with supply from power stations, energy storage and demand flexibility (via demand management).
- Secure: Meeting technical requirements for grid stability (described by terms such as "frequency control" and "inertia"), ensuring the power grid can overcome disturbances.
- Resilient: Delivering reliable power in the face of increasingly severe weather events influenced by climate change.
- Affordable: Lowering electricity costs for households and businesses.

3

A modern grid powered by diverse renewable energy and storage can provide secure, reliable, clean and affordable power for Australians.

› Major authorities, CSIRO, AEMO and the Finkel Review are highly consistent in their findings that there are no technical barriers to Australia achieving secure, reliable power from a very high proportion of renewable electricity.

› Combining low cost wind and solar PV with other renewable energy technologies such as solar thermal, hydro and biomass plants can provide round-the-clock, or on-demand power as well as meeting technical requirements for grid stability.

› Adding energy storage in the form of grid scale batteries, pumped hydro and heat storage (as part of a solar thermal plant) and greater interconnection between states by transmission lines will enhance the security and reliability of power supply and increase competition in the electricity market.

› Major economies like California, Germany, and Spain are already actively transitioning to more flexible, modern grids powered by renewable energy. California is on track to reach 50% renewable power by 2030.

4

A key risk for Australian grids and power stations is worsening extreme weather, particularly extreme, prolonged heat and storms. A distributed, flexible grid using multiple forms of technology will be critical to building a resilient energy system.

› A distributed and diverse electricity system incorporating a wider variety of supplies - wind, solar, biomass, hydro, and energy storage, spread out geographically and less concentrated - is far more resilient to disruption from increasing extreme weather events such as heatwaves, storms and bushfires fuelled by climate change.

Introduction

A modern electricity grid powered by diverse renewable energy and storage can provide secure, clean and affordable power for Australians.

Australia's inefficient, ageing, polluting coal plants will inevitably close. It is simply too expensive to keep them going once they reach around 50 years old. This provides a critical opportunity to move to a modern, 21st century electricity system. In doing so, Australia will tackle multiple policy objectives: affordable electricity for consumers; a secure and reliable electricity system; safeguarding our electricity system from worsening extreme weather; and tackling climate change by reducing Australia's pollution.

With rapidly falling costs of renewable energy and storage technologies, polluting coal and gas power are no longer necessary to provide affordable, reliable power on-demand.

Major economies like California, Germany, and Spain are actively transitioning to more flexible, modern grids powered by renewable energy with storage technologies, plus demand management and an interconnected grid.

The glossary at the back of this report provides details of important terminology used in this publication.

Inevitable coal closures provide a critical opportunity to modernise Australia's electricity system.

1. Challenges to Australia's Electricity System

Australia's electricity sector will undergo a major transition in coming years. Its old, polluting coal fired power stations will inevitably close. Disruptive digital and renewable energy technologies with dramatically lower costs, like solar, wind and storage, coupled with a modern power grid and smart consumers will dominate new supply in Australia (AEMO 2017a).

A modern power grid has infrastructure and operating rules to make the most of new technologies and consumer demands. These technologies are already being adopted globally (IEA 2017). As well as delivering flexible, clean, reliable, lowest cost power, this combination of 21st century technologies will buttress electricity supply against the ravages of escalating extreme weather events (like heatwaves, bushfires and storms) influenced by climate change. In the past year, Australia has seen the impact of extreme weather, such as heatwaves (in New South Wales) and storms (in South Australia) on our electricity system.

Our current electricity system is not fit to meet 21st century requirements. Australia's electricity generation is dominated by old, inflexible and polluting coal-fired power plants. Within a decade, over two thirds of coal plants in Australia's National Electricity Market will be 50 years or older (Finkel 2017), technically obsolete, unreliable and costly to maintain. Faced with climate extremes, these plants could fail, bringing blackouts (AEMO 2017a). Many of these coal plants aged in their 40's, are already failing when needed most, such as during heatwaves (AEMO 2017b). Australia's oldest coal fired power station, Liddell operates at about 35% efficiency - with large amounts of energy lost in heat and in operating the ageing power plant (SMH 2017). It is estimated that keeping the plant open beyond its scheduled closure in 2022 could cost almost $1 billion (SMH 2017). Further, a Climate Council poll found that when respondents were asked what should happen to the power station after its planned closure, 77% said public money should not be used to keep it open. The most popular solution, chosen by 59% of people, was to introduce a Clean Energy Target policy to encourage new renewable energy to replace the power station (Climate Council 2017a).

A long-term climate and energy policy is needed to reduce pollution and limit climate impacts.

Wholesale power prices are rising rapidly. With ongoing policy uncertainty undermining future investments (IGCC 2017), expensive gas sets high power prices most of the time, in part because Australia exports most of its gas overseas, pushing up domestic prices (Australian Industry Group 2017).

As coal plant closures approach, the Australian Energy Market Operator has highlighted the urgent need for Australia to put a stable policy framework in place to bring sufficient new flexible, dispatchable power and storage online in some markets to ensure reliable electricity supply.

In response to these challenges, and in the absence of Federal Government policies on power or pollution, states and territories are leading the transition to a modern, clean renewable powered grid (Climate Council 2017b).

A long-term coherent climate and energy policy for Australia is needed to reduce emissions from the sector and enable the necessary investment in new power supply (IGCC 2017). Policies designed to drive investment in new renewable energy, such as the Clean Energy Target recommended by the Finkel Review, can drive lower power prices (Finkel 2017). Keeping unreliable, expensive and inflexible old coal and gas power plants open past the end of their technical lives will not deliver the modern electricity grid that Australia needs (Engineers Australia 2016).

2. Building a Modern Australian Electricity Grid

Numerous studies have consistently found there are no technical barriers to Australia achieving secure, reliable power from a very high proportion of renewable electricity (AECOM 2012; AEMO 2013; Elliston et al 2013; Lenzen et al 2016; Teske et al 2016; CSIRO 2017; Finkel 2017; Stocks et al 2017).

The CSIRO has shown the transition to a modern power grid is possible and affordable. The CSIRO has laid out a detailed roadmap with key steps to be taken to achieve a zero emissions, reliable and affordable power supply for Australia (CSIRO 2016).

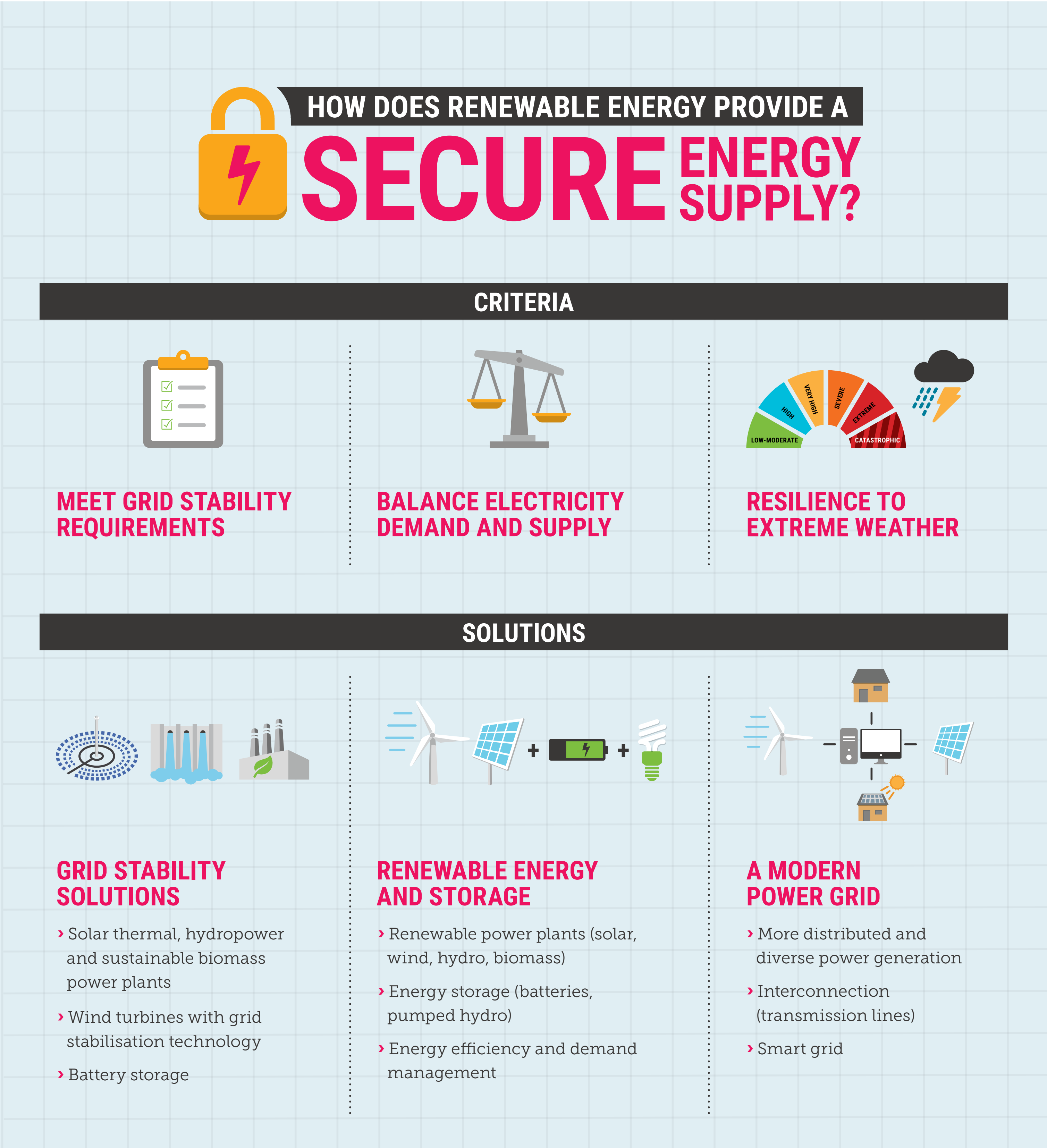
A modern electricity system should be clean, affordable, reliable and secure.

A modern, electricity system needs to meet five criteria:

1. Clean: Tackling climate change requires a rapid transition away from coal and gas to renewable powered electricity (Section 2.1).
2. Reliable: Balancing demand for electricity (from households, business and industry) with supply from power stations, energy storage and demand flexibility (via demand management) (Section 2.2).
3. Secure: Meeting technical requirements for grid stability (described by terms such as "frequency control" and "inertia"), ensuring the power grid can overcome disturbances (Section 2.3).
4. Resilient: Delivering reliable power in the face of increasingly severe weather events influenced by climate change (Section 2.4).
5. Affordable: Lowering electricity costs for households and businesses (Section 2.5).

The following sections detail how a renewable powered electricity system can meet the above criteria without the need for continued or increased reliance on fossil fuels (Figure 1).

Figure 1: How does renewable energy provide secure power?



2.1 Clean: Reducing Electricity Emissions to Combat Climate Change

To tackle worsening climate impacts, such as extreme weather, Australia has agreed with world leaders to limit global temperature rise to well below 2°C, and to pursue efforts to limit temperature rise to only 1.5°C. The Paris Agreement is universal, involving 194 other countries. In practical terms, this means Australia's electricity system needs to reach a minimum of 50% renewable energy by 2030, and zero emissions well before 2050 (ClimateWorks 2014).

Reducing emissions in the electricity sector is relatively easier - with multiple cost competitive solutions available - compared to other sectors such as agriculture (ClimateWorks 2017). Achieving zero emissions from other areas like transport, agriculture and stationary energy, is more challenging. The electricity sector can potentially reduce its emissions by over 60% by 2030 (ClimateWorks 2017). If Australia delays cleaning up the electricity sector, this means we will need to reduce emissions further and faster in other sectors, or we will fail to meet our international commitments.

Today, Australia's fossil fuel dominated electricity sector is the nation's single largest source of greenhouse gas emissions. Electricity accounts for 34% (188 $MtCO_2$¬e in the year to March 2017) of Australia's total emissions (Department of the Environment and Energy 2017a). In addition, the electricity sector has seen the largest total growth in emissions, increasing 45.1% (58.5 $MtCO_2$¬e) between 1990 and the year to March 2017 (Department of the Environment and Energy 2017a).

Major economies like California are already actively transitioning to a renewable powered electricity grid. California is on track to reach 50% renewable power by 2030 (noting that hydroelectricity is not classified as renewable in California, meaning the state is on track to reach around 60% with hydro by 2030) (California Energy Commission 2017). California is now looking to legislate for zero emissions from the electricity sector by 2045 (California Legislative Information 2017).

Major economies like California are actively transitioning to a renewable powered electricity grid.

2.2 Balancing Demand and Supply: Reliable, Round-the-clock Renewable Power

To ensure a reliable supply of power, the electricity system needs to closely balance supply (electricity generation from power plants) and demand (electricity use by households, businesses and industry).

Traditionally, electricity grids have supplied power to meet electricity needs with a mix of inflexible baseload generators (like coal power plants) together with more flexible gas peaking plants able to ramp up and down according to need (California Public Utilities Commission 2015). Increasingly power grids around the world are moving away from inflexible, baseload power to modern, flexible systems which are able to respond quickly to both changes in demand and in generation (REN21 2017). As the amount of low cost, wind and solar generation increases in the grid, the need for baseload power decreases.

Combining diverse renewable energy and storage technologies can provide round-the-clock, on-demand power. A modern power grid with a high proportion of renewable energy balances demand and supply using a varied mix of:

- low cost variable renewables (wind and solar photovoltaic (PV))
- on-demand, or "dispatchable" renewables (solar thermal, biomass and hydro)
- energy storage technologies (like pumped hydro or batteries) store energy when plentiful for use later when needed
- greater grid interconnectivity, and
- smart grids and smart consumers, flexibly adjusting demand.

Existing gas power plants can meet power needs during a transition period as coal closes and while renewables and storage are built-out.

Countries such as Germany, Spain, Ireland and Denmark together with major economies like California have all successfully integrated between 20 - 50% wind and solar PV generation into their electricity grids without compromising reliability (IEA 2017). Australia currently sources around 8% of its power generation from solar PV and wind (Department of the Environment and Energy 2017b). This level of solar PV and wind generation can be "managed quite easily" according to the International Energy Agency (IEA 2017).

In states like South Australia, which have limited connection to other states, and where wind and solar PV provide almost half the state's power, the challenges become more technical. There is a greater need to ensure the grid is stable and capable of overcoming any disturbances (see Section 2.3).

DIVERSE RENEWABLE ENERGY TECHNOLOGIES

While wind and solar PV are the most commonly known forms of renewable energy, there are many other technologies (Box 1).

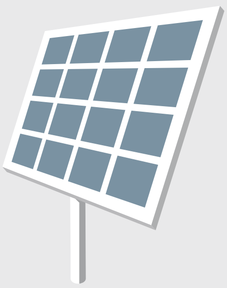
Solar and wind are variable, providing power when the sun shines or wind blows. However, perhaps counter-intuitively, as more wind and solar power is added to an electricity grid, and spread geographically, the variability of the total of wind and solar generation lessens (IEA 2017). This is because weather systems, which bring changing wind and cloud conditions, move across landscapes. Provided there are good levels of grid interconnection, overall output becomes more stable and reliable as more wind and solar are added to the system. Furthermore, electricity grid operators and renewable power producers are able to forecast wind and solar generation with a high degree of accuracy, adding to supply assurance.

BOX 1: RENEWABLE ENERGY TECHNOLOGIES

Renewable Energy Technologies

SOLAR

The sun's energy is converted into heat to drive steam turbines, generating electricity (solar thermal) or converted directly into electricity by solar cells (solar PV).



BIOENERGY

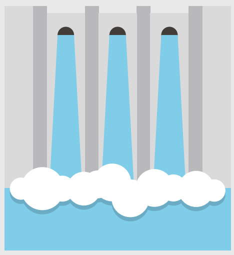
Energy is derived from organic matter (recently living plant or animal material), such as sugarcane waste, landfill gas and algae.

WIND

Wind turns the blades of a wind turbine to generate electricity.

HYDRO

Flowing water turns water turbines to generate electricity.

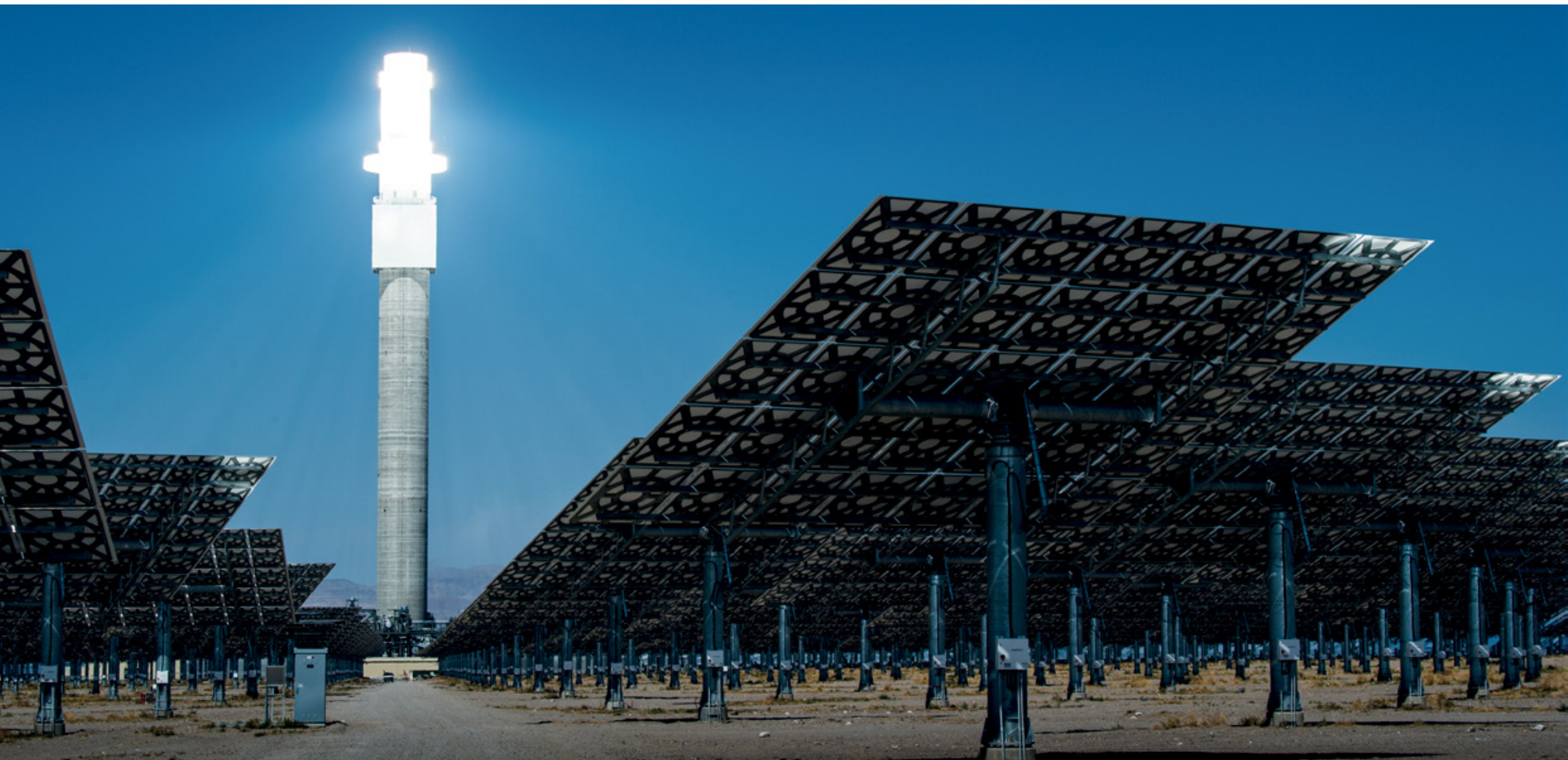


Wind, solar and energy storage together provide reliable power, 24/7.

Other renewable energy technologies provide a constant source of power, or power on-demand (called "dispatchable" power). These technologies include solar thermal power plants able to store energy as heat, for later conversion to electricity (e.g., Figure 2), biomass plants, or existing hydroelectric power plants. These power plants can all generate power for use at the time required. These forms of renewable energy are well placed to complement increasing levels of low cost wind and solar power.

For example, the South Australian Government has announced Solar Reserve successfully tendered to build a 150MW solar thermal power plant in Port Augusta, to be completed in 2020, which will supply power to meet the state government's electricity needs (Government of South Australia 2017a). The solar thermal plant will be capable of storing heat energy. This enables the plant to provide "dispatchable" on-demand power at peak demand times on summer evenings after the sun has set.

Figure 2: Solar Thermal Power Plant in the US.



COMBINING WIND AND SOLAR POWER WITH ENERGY STORAGE

Combining wind and solar together means that much of the time, generation from one form complements the other. For example, it may be very windy on stormy overcast winter days, but often, still winter days are very sunny. Adding geographic diversity of both increases supply assurance.

Complementing wind and solar PV with large-scale energy storage, further improves the ability for reliable renewable power to meet continuous demand. There are a number of projects underway across Australia pursuing a combination of wind, solar PV and storage.

There are a number of projects underway in North Queensland combining solar with wind and/or battery storage, including:

- Lakeland integrated solar and battery storage power plant will be the Southern Hemisphere's first large-scale integrated solar and battery storage facility. The project combines a 13MW solar power station together with 5.3MWh battery storage and will be able to provide reliable power quality and supply (Conergy 2016).
- Kennedy Energy Park combines solar, wind and battery storage (19MW solar PV with 22MW wind and 4MWh of battery storage) with plans in place to scale up to 600MW of solar PV and 600MW of wind power (ARENA 2017).
- The Kidston project (Figure 3) combines up to 330MW of solar PV (phase one 50MW, phase two 270MW) with pumped hydro storage, utilising a former gold mine. The pumped hydro storage stores energy by pumping water from a lower water storage reservoir to an upper reservoir; the water can later be released (generating electricity) at times of high demand. The project will potentially provide up to 330MW of power on-demand into the National Electricity Market (GenexPower 2017).

Figure 3: Kidston solar and pumped hydro project.

California demonstrated battery storage can be quickly deployed to replace gas and enhance reliability.

A number of state governments are actively pursuing energy storage projects. South Australia is investing in the world's largest lithium-ion battery storage facility (100MW/129MWh) provided by Tesla, to be paired with the 315MW Neoen Hornsdale Wind Farm (Government of South Australia 2017b), and a second 30MW battery project is being built on Yorke Peninsula to strengthen the regional network. The Victorian and Queensland Governments have also called for large-scale battery storage tenders.

International experience shows that large-scale battery storage projects can be installed quickly. For example, in response to the worst recorded gas leak in United States history (at the Aliso Canyon gas storage facility from October 2015 to February 2016), and the potential loss of gas power to meet peak electricity demand, California responded with a record-breaking rollout of more than 100MW of battery storage in six months (Scientific American 2017). The rollout included the world's current largest lithium-ion battery - 30MW/120MWh battery storage facility - at Escondido, California (Figure 4). The majority of the large-scale battery systems installed in California are capable of storing wind and solar power from the grid and providing power for four hours.

Figure 4: Escondido, California battery storage facility.

GREATER INTERCONNECTION CAN IMPROVE POWER RELIABILITY AND SECURITY

High voltage transmission lines connect Australia's eastern states and South Australia (referred to as the National Electricity Market, NEM). Some states, like Victoria (which connects to three other states), have higher levels of interconnection than others, such as South Australia and Tasmania. Generally, these interconnectors are of limited capacity relative to the size of electricity demand within the states they connect. As these existing interconnectors are not duplicated, they risk failure during extreme bushfire or storm conditions. This means that even though states may be connected, states also need to have enough locally provided power generation to meet their own peak demand, which may not be the most economic approach.

There are two separate interconnected systems in Western Australia (The North West Interconnected System, NWIS and the South West Interconnected System, SWIS). The Northern Territory has three smaller separate electricity systems (Australian Government 2016).

Interconnections between states are less expensive to build, than single new large coal and gas power stations, and associated fuel supply infrastructure. For example, a new interconnector between South Australia and New South Wales would cost around $500 million and save households about $100 a year off their power bills (AFR 2016). This compares to costs of at least $900 million to keep Liddell Power Station open for ten years (SMH 2017) and minimum $2 billion to build a new coal fired power station (ABC 2017; Minerals Council of Australia 2017).

Multiple interconnections reduce power costs (by adding more supply competition to each state market), increase diversity of supply and system resilience, and improve reliability and security of power supply. Interconnections also open up new areas of low cost untapped renewable power potential (and energy storage opportunities, in the case of Tasmania) to be developed. By enabling increased diversity of renewable supplies across several states, and increasing regional power transfer capacity, interconnectors reduce the need for backup gas or coal power plants. Interconnectors also reduce the risk that renewable energy will be wasted through curtailment (when there is more electricity generation than needed to meet local demand and export capacity) and minimise the risk an individual state will be "islanded" and unable to meet demand.

Interconnections can also help prevent blackouts when one state is facing periods of high power demand during a heatwave, when available power generation within the state is exceeded (Energy Networks Australia 2016). For example, during the February 2017 heatwaves in New South Wales, with near record all-time peak electricity demand, the state narrowly avoided a blackout. In large part the power was kept on in New South Wales, due to electricity imports via three interconnections with Victoria and Queensland, which contributed 12% to meeting peak demand (AEMO 2017b), although the extreme demand coupled with New South Wales fossil fuelled power plant failures overloaded the limited interconnector capacity (AEMO 2017b). Additional interconnections linking South Australia and Tasmania, would make the electricity grid in these states more resilient and robust.

BOX 2: AUSTRALIAN ENERGY MARKET OPERATOR FLAGS SHIFT TO MORE FLEXIBLE, RESPONSIVE GRID IN KEY REPORTS

The independent power grid operator, the Australian Energy Market Operator released two reports in September.

1. Electricity Statement of Opportunities 2017

   This annual report provides a ten-year outlook for electricity supply in the National Electricity Market. This report highlighted the risks for electricity supply posed by Australia's ageing coal and gas fired generators, particularly during extended heatwaves, and if renewable energy cannot be brought online fast enough in advance of coal closures.

   The report states *"The overall responsiveness and resilience of the system is at risk from increased vulnerability to climatic events, such as extended periods of high temperatures, and the risk of loss of, or reduction in output of, major generation units."*

2. Advice to Commonwealth Government on Dispatchable Capacity

   This report was commissioned in response to a request from the Federal Government for advice on the level of "dispatchable" resources (power plants and technology able to provide power on-demand such as gas plants, battery storage) required to maintain the reliability of electricity supply in the National Electricity Market. Dispatchable power technologies are fast responding, flexible power plants (and other technologies) which are able to be turned on and off, or ramped up and down quickly to balance electricity supply and demand. Dispatchable power is significantly different to baseload power plants like coal power plants which run continuously and are very slow to respond to changes in electricity demand.

   The report recommends increasing the level of dispatchable power to make Australia's electricity grid more reliable. There is a wide range of technologies capable of providing dispatchable energy including pumped hydro, solar thermal and peaking gas as well as flexible demand. The report also recommends a short-term strategic reserve mechanism, using diesel generators and demand response to ensure power supply for the 2017/18 summer.

Sources: AEMO 2017a and AEMO 2017d.

2.3 Meeting Technical Requirements for Grid Stability: Renewable Power Plants Can Provide Secure Power

A secure, stable electricity system is one that can rapidly overcome disruptions or major fluctuations in electricity supply or demand. Operating the power grid within certain technical parameters (described by terms such as frequency, voltage, fault current levels) ensures the system maintains a stable operating state.

Traditionally, a stable operating state was maintained by a mix of inflexible baseload generators (like coal power plants) together with more flexible gas peaking plants able to ramp up and down as needed (California Public Utilities Commission 2015). As electricity grids transition away from inflexible, baseload power to modern, flexible systems, these services can be provided in smarter ways (REN21 2017).

Some power plants or energy storage technologies can provide ***inertia*** or ***frequency response*** services to the grid. Inertia and frequency response provide an initial, immediate response to help maintain a stable, operating grid when supply and demand becomes unbalanced over short time periods and help "buy time" while more power is injected (or withdrawn) to bring supply and demand back into balance.

Power plants that generate electricity via large rotating steam or water turbines are sometimes called ***synchronous generators***. These power plants provide ***physical inertia***. Inertia provides an initial, immediate response to keep the electricity system working. Solar thermal, hydropower, and biomass power plants are synchronous generators capable of providing the same inertia (Vithayasrichareon et al 2015).

Frequency response is a service which can be provided to re-balance electricity supply and demand. This service can be provided by a range of technologies including battery storage systems, modern wind turbine technology and solar plants with smart inverter technology. ***Fast frequency response*** substitutes for a portion of physical inertia in the electricity grid, and can be provided by battery storage systems, modern wind turbine technology and solar plants with smart inverter technology.

For example, modern wind turbines can incorporate technology which enables them to provide similar grid stability services to gas power plants. Wind farms in Quebec, Canada (e.g., Figure 5) are required to incorporate this technology, and this technology is being trialled at the Hornsdale 3 Wind Farm in South Australia (AFR 2017).

A recent Californian study on large-scale solar plants demonstrated that these power plants are capable of providing equivalent or better grid reliability services as conventional power plants by using smart inverter technology and by making simple modifications (National Renewable Energy Laboratory 2017).

Frequency response and *operating reserve* are needed if supply and demand are out of balance for longer periods. Frequency response can be provided by technologies such as demand management (where large power users opt to cut their power use for a given time), battery storage systems and large spinning machines called synchronous condensers. For example, the Victorian Government has called for expressions of interest to build large-scale battery storage for the purpose of improving grid stability (RenewEconomy 2017a).

Operating reserve is planned spare capacity in the system that can be called upon when there are unexpected variations in electricity demand, or generation or transmission faults. A range of energy storage technologies as well as dispatchable renewable power plants can provide operating reserve.

Figure 5: Quebec wind farm.

2.4 Energy Security and Extreme Weather: Distributed Power Systems are More Resilient

The Australian Energy Market Operator (2017a) has identified extreme weather as one of the largest risks to secure electricity supply, in particular heatwaves. Australia has experienced the impact of extreme weather on power systems in recent years. In the past year, Australia has seen the impact of extreme weather, such as heatwaves (in New South Wales) and storms (in South Australia) on our electricity system.

Electricity systems that rely on single massive sources of power transported over long distances, from large coal and gas power plants with a long "skinny" grid, are more vulnerable to extreme weather such as bushfires, storms (e.g., Figure 6) and heatwaves.

While renewable output from individual power plants is weather dependent, so too is output from fossil fuelled plants. Large, concentrated energy assets - like huge coal and gas power stations, are particularly vulnerable to extreme weather, increasing supply risks if one or more fail at times of extreme demand. Their operating and cooling systems suffer at high temperatures, and in some cases fail. These power plants are also reliant on the availability of fuel - gas and coal. For example, on 8 February, thousands of South Australian households lost power in part because gas was unavailable to supply the second unit of the Pelican Point gas plant at the time needed (AEMO 2017c).

Figure 6: Severe storms in South Australia brought down transmission towers in 2016.

Ageing coal and gas power stations are vulnerable to extreme weather events.

Coal and backup gas fuelled power plants have a poor record of reliability as recent events in New South Wales, Queensland and South Australia have shown (ABC 2017; AEMO 2017b; AEMO 2017c). Fossil-fuelled power plant failures at times of peak demand on hot days not only lead to high prices, but also blackouts and load shedding which hurt people and industry. In February, during heatwaves which affected the entire east coast of Australia and South Australia, collectively around 4,000MW of coal and gas fired plant were not available as expected when plants under-performed in high temperatures, failed to start, or tripped (Table 1).

A more distributed system where smaller power generation units are spread geographically and utilise a wider variety of supplies - wind, solar, biomass, hydro, storage - is far more resilient to disruption from extreme weather.

Cities that have experienced severe damage to their electricity infrastructure from extreme weather, such as New York, have actively diversified the sources and location of power generation. Generating and storing power closer to where it is needed, for example using solar and storage technologies can reduce risks of grid failure for critical infrastructure.

Table 1: Coal and gas unavailable in heatwaves 8 - 12 February 2017.

Date	State	Coal and gas fired power stations unavailable (MW)
8 February	South Australia	453
10 February	New South Wales	3,050
12 February	Queensland	787

Sources: AEMO 2017b; AEMO 2017c; Australian Energy Regulator 2017a; Australian Energy Regulator 2017b.

2.5 Electricity Prices: More Renewable Energy Leads to Lower Power Bills Than Business As Usual

Renewable energy is the cheapest form of new power generation (Table 2).

Wind is the cheapest form of new power generation in Australia. Recent prices for Australian wind farms, such as Stockyard Hill in Victoria and Coopers Gap in Queensland have set record low prices of under $60/MWh (RenewEconomy 2017b). Large-scale solar PV plants are being built in Queensland for less than $70/MWh. A solar thermal plant in Port Augusta, South Australia, capable of providing round-the-clock power has been contracted for under $78/MWh (Government of South Australia 2017).

Renewable energy is the cheapest form of new power generation.

Table 2: Cost of new build power plants.

Power Technology	Levelised Cost of Energy (LCOE)$ (aus)/MWh
SA Solar Thermal Plant	$78[1]
Wind	$60 - 118[2]
Solar	$78 - 140
Gas Combined cycle	$74 - 90[3]
Coal	$134 - 203
Coal with CCS	$352

Source: BNEF Research 2017.
[1] Government of South Australia 2017.
[2] Note recent prices for wind are “well below” $60/MWh.
[3] Based on gas prices of $8/GJ. Current gas prices are much higher than this, and at peak times can be up to 2-3 times higher.

Total capital and operating costs for new solar PV and wind power plants in Australia are now approaching or cheaper than the operating costs alone for most gas power stations, and even some of the older less efficient coal plants like Liddell (RenewEconomy 2017c).

Companies like Telstra and SunMetals are starting to take advantage of the low, and rapidly falling costs of renewable energy, by signing contracts directly with solar and wind farms (RenewEconomy 2017d).

Costs for wind, solar PV and battery storage have fallen, and continue to fall rapidly, as these technologies have been rolled out at significant scale globally (REN21 2017). Between 2010-2015 the cost of solar PV energy fell 58% and could continue to fall by 57% between 2015-2025. The cost of wind energy has reduced by two-thirds since the 1980s and could continue to fall by 12% between 2015-2025 (IRENA 2016). New lower cost records for these three technologies in real world projects continue to be broken month after month.

Increased levels of renewable electricity generation will reduce power prices in Australia. Modelling for the Finkel Review's recommended Clean Energy Target found this policy (which resulted in 42% renewable power by 2030) would result in lower residential power prices than continuing with "business as usual" (Finkel 2017).

CSIRO (2017) modelling found transitioning to a zero emissions electricity sector by 2050 would result in $414 annual savings for an average household compared to business as usual.

3. Role of Fossil Fuels in the Future Grid

Modelling for the Climate Change Authority shows that for Australia to play its role in keeping temperature rise below 2°C requires the closure of two-thirds of Australia's coal power plants and an increase in renewable power (to 50 – 70% of electricity supply) by 2030 (Jacobs 2016).

In order to ensure reliable electricity supply, and avoid further electricity price rises, sufficient new power generation capacity needs to be brought online well in advance of inevitable coal power station closures.

Recently, companies have begun providing many years notice of coal plant closure. This enables planning to ensure there is sufficient new capacity added before coal plants close. For example, AGL announced plans to close the Liddell Power Station in April 2015, seven years in advance of the proposed closure date in 2022 (AGL 2017).

Governments should support coal workers to transition to new jobs, including in renewable energy.

Advanced noticed of closure has also been recommended by the Finkel Review and accepted by the Federal Government. Such long lead times also allow affected communities and State and Federal Governments, to plan ahead in order that workers and businesses impacted are able to transition to new opportunities. Furthermore, national and state policies are needed to ensure consistent and equitable support for rural and regional communities impacted by coal power closures. Employment modelling has shown that transitioning to 50% renewable energy by 2030 will lead to over 28,000 new jobs nationally, nearly 50% more than would be created under business as usual conditions (Climate Council and EY 2016).

Any new fossil fuelled power plants built in coming years would likely continue operating beyond 2050 when electricity emissions need to reach zero. This brings a range of risks including - carbon pricing risk, higher financing costs, risk of shorter lifetime to achieve a return on investment due to regulatory closure, stranding risk, corporate reputational risk, and potential for legal claims against directors and senior officers (WRI 2015; Actuaries Institute 2016).

Building new coal or gas power plants is clearly inconsistent with action on climate change.

4. Myths and Facts

MYTH 1 - COAL IS ALWAYS RELIABLE

The Australian Energy Market Operator has identified ageing coal power stations as a significant risk to a reliable electricity supply:

"While no generation withdrawals have been announced in Victoria, there are risks of significant failure or outages in scheduled generation, due to the state's aging coal fleet... this risk exists for all coal generators across the NEM" Australian Energy Market Operator (2017a).

Ageing coal power stations are especially vulnerable in the heat. Heatwaves place pressure on electricity systems due to both increased demand for electricity (as everyone turns on their air-conditioners) and also because coal and gas power plants struggle to operate in high temperatures as their cooling systems cannot cope, or station heat loads are limited to avoid destructive impacts on rivers and estuarine environments.

For example, during February 2017 heatwaves in New South Wales, with near record all-time peak electricity demand, over 1,700MW of coal power was unavailable (Table 3). The deficit of 17% of supply was very significant and required industrial assets to have to be closed to prevent large scale blackouts.

During the heatwave, it was electricity imports from Victoria and Queensland, careful use of power by consumers and load shedding at the Tomago aluminium smelter, which allowed New South Wales to avoid widespread blackouts.

Ageing coal power stations are a risk to reliable electricity supply.

Table 3: Coal fired power generation in New South Wales at 5pm 10 February 2017.

Power plant	Registered capacity (MW)	Output at 5pm (MW)	Deficit (MW)
Bayswater	2,640	2,638	2
Eraring	2,880	2,438	442
Liddell	2,000	868	1,132
Mount Piper	1,400	1,292	108
Vales Point	1,320	1,230	90
TOTAL	10,240	8,466	1,774

Source: AEMO 2017b.

MYTH 2 - EXTENDING THE LIFE OF COAL-FIRED POWER PLANTS WILL ENSURE RELIABLE, AFFORDABLE POWER

The average age of Australia's coal power plants is 33 years old (Australian Energy Council 2017). By 2035, 68% of coal power plants in the National Electricity Market will be 50 years old (Finkel 2017). Once power stations reach 40 to 50 years old, it becomes increasingly expensive to continue to run them as they are inefficient to operate and costly to maintain.

Extending the life of old, inefficient coal power plants, even for a short period, beyond their technical life is hugely expensive. For example, the cost of extending the life of the Liddell Power Station for ten years beyond its planned closure date (2022) is estimated to be at least $900 million (Jotzo and Anjum 2017; SMH 2017). The costs of refurbishment will be passed onto consumers through increased power bills or taxes. Furthermore there will be an ongoing risk of failure or outages due to continued reliance on these ageing power plants.

MYTH 3 - WE NEED "BASELOAD" POWER

"Baseload" power refers to large, inflexible coal and nuclear plants which generate power continuously at full output. Such baseload power stations cannot easily or quickly adjust their power output up or down when needed.

On the other hand, demand for electricity has always been variable with changing electricity needs throughout the day, week and year.

Increasingly, power grids around the world are moving away from inflexible, baseload power to modern, flexible systems which are able to respond quickly to both changes in demand and in generation (REN21 2017). As the amount of low cost, wind and solar generation increases in the grid, the need for baseload power decreases. For example, in California, which reached 36% renewable power in 2016 (California Energy Commission 2017), the need for baseload resources like coal and nuclear is waning, and the need for system flexibility is increasing (California Public Utilities Commission 2015; AEMO 2017d).

Ageing coal fired power plants are unreliable and inflexible.

MYTH 4 - YOU CAN'T RUN AN ELECTRICITY SYSTEM ON RENEWABLE ENERGY

Numerous studies have consistently found there are no technical barriers to Australia achieving secure power from a very high proportion of renewable electricity (AECOM 2012; AEMO 2013; Elliston et al 2013; Lenzen et al 2016; Teske et al 2016; CSIRO 2017; Finkel 2017; Stocks et al 2017).

A high renewable powered grid can balance demand and supply for electricity through a mix of variable renewables (wind and solar PV), on-demand, or "dispatchable" renewables (such as solar thermal, biomass or established hydro power), energy storage technologies (such as pumped hydro or batteries) together with energy efficiency and demand response. There is enormous potential for pumped hydro energy storage and battery storage. For example, a recent study identified 22,000 potential pumped hydro energy storage sites across Australia (Blakers et al 2017)

A mix of renewable energy and storage can power Australia.

Figure 7: Lakeland solar and battery storage project.

Conclusion

Australia can transition directly to a secure, reliable and affordable power system which dramatically cuts electricity sector emissions within a decade.

Importantly, while we may use some existing gas plants during this transition, we do not need new gas or coal plants built. Persisting with existing coal plants beyond their technical design lives will lead to unreliable power and higher electricity prices and continued high levels of pollution from Australia's electricity sector.

This transition requires shifting away from obsolete "baseload" concepts and inflexible old coal power generators to a modern, flexible, 21st Century grid powered by a diverse mix of renewable energy and storage technologies.

Glossary

Baseload power

Baseload power plants, like coal and nuclear power plants, run continuously, producing a constant output of electricity. These power plants are very inflexible, and slow to respond to changes in electricity demand.

Dispatchable power

Dispatchable power technologies are fast responding, flexible power plants (and other technologies) which are able to be turned on and off, or ramped up and down quickly to balance electricity supply and demand. There is a wide range of technologies capable of providing dispatchable power including pumped hydro, solar thermal, batteries, peaking gas as well as demand management.

Energy storage

Energy storage technologies, like batteries and pumped hydro, store energy to produce power later when needed.

Frequency response, Fast frequency response

Frequency is a measure that enables operators to know if electricity supply and demand is in balance. Frequency response is a service which can be provided to re-balance electricity supply and demand. This service can be provided by a range of technologies including battery storage systems, modern wind turbine technology and solar plants with smart inverter technology.

Inertia

Power plants that generate electricity via large rotating steam or water turbines are sometimes called synchronous generators. These power plants provide physical inertia. These power plants provide physical inertia. Inertia provides an initial, immediate response to keep the electricity system working when supply and demand are out of balance. Solar thermal, hydropower, and biomass power plants are synchronous generators capable of providing physical inertia.

Interconnections

High voltage transmission (power) lines connecting states and/or regions.

Modern grid

A modern power grid has infrastructure and operating rules and is able make the most of new technologies such as solar, wind and battery storage and meet changing consumer demands.

Operating reserve

Operating reserve is planned spare capacity in the system that can be called upon when there are unexpected variations in electricity demand, or generation or transmission faults.

Reliability

Balancing demand for electricity (from households, business and industry) with supply from power stations, energy storage and demand flexibility.

Resilience

Delivering reliable power in the face of increasingly severe weather events influenced by climate change.

Security

Meeting technical requirements for grid stability (described by terms such as “frequency control” and “inertia”), ensuring the power grid can overcome disturbances. These are characteristics which help to maintain a stable, operating grid when supply and demand becomes unbalanced over short time periods.

Solar thermal power

A concentrating solar thermal power plant, concentrates solar energy to heat up a storage material, such as salt. The heat stored is then used to produce steam to drive a turbine and generate electricity. Some concentrating solar thermal power plants can store this heat energy to generate electricity when needed.

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