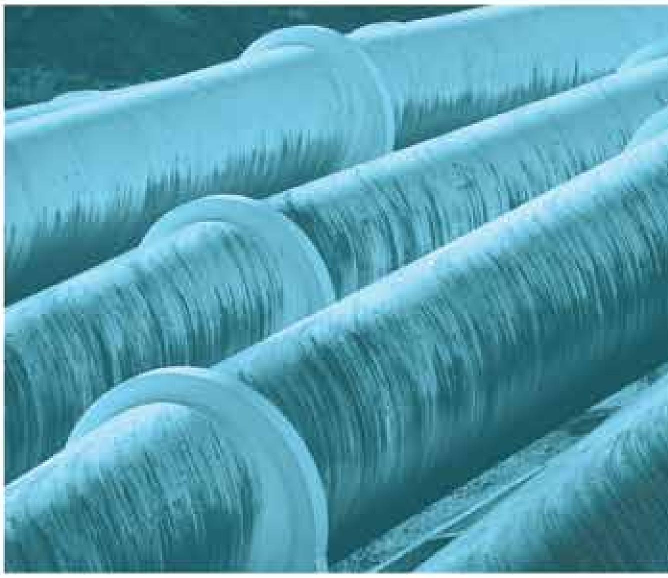
APPENDIX H

STRATEGIC CONTEXT AND THE NEED FOR SNOWY 2.0


Strategic context and the need for Snowy 2.0

Snowy 2.0 Main Works

Prepared for Snowy Hydro Limited
September 2019

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Strategic context and the need for Snowy 2.0

Snowy 2.0 Main Works

Report Number

J123456 RP#38

Client

Snowy Hydro Limited

Date

13 September 2019

Version

Final

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1 Introduction

1.1 Overview

The New South Wales (NSW) energy system and broader National Electricity Market (NEM) is facing major and unprecedented challenges through rising energy costs, deterioration in energy system security and reliability, and a transition in the generation mix away from coal-fired, dispatchable, base-load power to intermittent renewable wind and solar power.

For the most part, the NEM's current energy mix has been able to cope with the increasing level and uncertain variations in the delivery of the intermittent renewable wind and solar power. However, this will change as these intermittent sources become a larger proportion of the total generation as the NEM energy mix transition continues. As the amount of the variable renewable energy increases in response to economics and retiring coal-fired power stations, energy storage and dispatchable generation will play an increasingly vital role in ensuring the continued provision of reliable and cost efficient energy generation.

Snowy 2.0 will increase pumped hydro-electric generating capacity of the existing Snowy Scheme by almost 50%, providing an additional 2,000 megawatts (MW) generating capacity, and making approximately 350,000 megawatt hours (MWh) of storage available to the NEM. This is equivalent to 175 hours of large-scale energy storage.

Snowy 2.0 is an effective way to provide large-scale storage and quick start energy generation and as the NEM moves to an energy mix with a higher penetration of intermittent renewables and retiring thermal generation, Snowy 2.0 will underpin its reliability and stability. Snowy 2.0 (and the capabilities of the existing Snowy Scheme) will provide a significant contribution to ensure an orderly transition as the economy decarbonises.

The project will be operated primarily within Kosciuszko National Park (KNP), under a lease agreement given effect by the *Snowy Hydro Corporatisation Act 1997*. Other land required (for construction only) is outside of KNP (known as Rock Forest), with use of the land secured through a private lease agreement with the landowner. A separate application has been lodged for use of a site in Polo Flat, an industrial area east of Cooma, as a proposed segment factory which would produce tunnel segments for the project.

Snowy Hydro has undertaken a number of critical activities to develop the business case for the project. These include the procurement of an experienced contractors to deliver the Main Works under an appropriate form of contract, development of a detailed capital and operating cost estimate and schedule, evaluation of tax and treasury effects of the project, investigation and modelling of the NEM, the assessment of risk and uncertainty in the future NEM, internal valuation of the project and modelling of alternative market and corporate scenarios.

1.2 Purpose of this report

During the Feasibility Study for Snowy 2.0 and in the lead up to its Final Investment Decision (FID), Marsden Jacob Associates (MJA) carried out independent market modelling to understand upcoming trends and the future NEM that Snowy 2.0 will operate in. This report has been prepared with consideration of MJA's modelling and other market sources and independent studies relating to the strategic need for Snowy 2.0.

Further detail is provided in the following MJA reports (available on Snowy Hydro's website):

- NEM Outlook and Snowy 2.0 (MJA 2018a); and
- Modelling Snowy 2.0 in the NEM (MJA 2018b).

While the MJA modelling in the lead up to FID in late 2018 is still very relevant and underpins the strong economic case for the project - since this time, the energy market has evolved and changed much more quickly

than originally anticipated even just a year ago. The likelihood of coal-fired generators closing earlier than previously anticipated is increasing (Aurora Energy Research 2019) and concurrently, the rapid uptake of intermittent renewables due to favourable economics is changing the energy market landscape. For example, investment in large-scale renewable energy projects doubled in 2018 compared to a previous record-breaking 2017, increasing from $10 billion to $20 billion (Clean Energy Council 2019).

This report has been prepared to detail the strategic context relevant to Snowy 2.0 having regard to its critical significance for NSW and the broader NEM, relevant State and Commonwealth government plans and policies relating to energy security and reliability, and economic, social and environmental trends driving change in the energy market. On this basis it also identifies the strategic need and potential benefits of the project.

1.3 Energy concepts and definitions

The key principle of storage value provided by Snowy 2.0 is to purchase energy at low prices for pumping (generally during periods when available energy supply is greater than system demand), store the energy as potential energy of water at higher elevations, then sell the energy when supply-demand is constrained or at times of peak energy demand. In other words, the project's storage value is analogous to a battery.

'Firming' matches intermittent solar or wind (supply) with a load (demand). The difference between demand (load) and the supply of energy from wind and solar is a supply deficit. Firming acts to cover this deficit. Hydro-electricity is an excellent source for firming wind and solar.

To assist in reading this report, the following energy concepts and definitions are provided for reference in Table 1.1, with further definitions provided in the linked Australian Energy Market Operator (AEMO) glossary document below.

Table 1.1 Energy terms and definitions

Term	Definition
General terms	https://www.aemo.com.au/media/Files/Other/planning/ntndp/NTNDP2011_CD/documents/glossary%20pdf.pdf
AEMO	The Australian Energy Market Operator (AEMO) is responsible for operating Australia's largest gas and electricity markets and power systems including the NEM in Australia's eastern and south eastern seaboard and the Wholesale Electricity Market (WEM) in Western Australia.
Base load	A generating system designed to run almost constantly at near maximum capacity levels, usually at lower cost than intermediate or peaking generating systems.
Capacity	This refers to the ability of a power plant to produce a given output of electric energy at an instant in time.
Capacity for reliability	The allocated installed capacity required to meet a region's minimum reserve level (MRL). When met, sufficient supplies are available to the region to meet the Reliability Standard. Capacity for reliability = 10% Probability of Exceedence (POE) scheduled and semi-scheduled maximum demand + minimum reserve level – committed demand-side participation.
Consumer or customer	A person who engages in the activity of purchasing electricity supplied through a transmission or distribution system to a connection point.
Demand	The electrical power requirement met by generating units. The Electricity Statement of Opportunities (ESOO) reports demand on a generator-terminal basis, which includes the following: • The electrical power consumed by the consumer load. • Distribution and transmission losses. • Power station transformer losses and auxiliary loads. The ESOO reports demand as half-hourly averages

Table 1.1 Energy terms and definitions

Term	Definition
Diversity	The lack of coincidence of peak demand across several sources of demand, such as residential, industrial, and gas powered generation.
Firming	Power or power-producing capacity covered by a commitment to be available at all times during the period
Generation	The production of electrical power by converting another form of energy in a generating unit.
Intermittent	A description of a generating unit whose output is not readily predictable, including, without limitation, solar generators, wave turbine generators, wind turbine generators and hydro-generators without any material storage capability
Load	A connection point or defined set of connection points at which electrical power is delivered to a person or to another network or the amount of electrical power delivered at a defined instant at a connection point, or aggregated over a defined set of connection points.
National Electricity Market (NEM)	The wholesale exchange of electricity operated by AEMO under the National Electricity Rules (NER). It is the wholesale market for the supply of electricity in all states of Australia except Western Australia and the Northern Territory. The output of all electricity generators is aggregated in a pool and supplied as needed to meet demand according to rules set by the AEMC. It is the world's longest interconnected power system, from north Queensland to South Australia.
National Electricity Rules (NER)	The National Electricity Rules (NER) describes the day-to-day operations of the NEM and the framework for network regulations.
Network	The apparatus, equipment, plant and buildings used to convey, and control the conveyance of, electricity to customers (whether wholesale or retail) excluding any connection assets. In relation to a network service provider, a network owned, operated or controlled by that network service provider.
Network capability	The capability of the network or part of the network to transfer electricity from one location to another.
Peak load or peak demand	Terms which are used interchangeably to denote the maximum power requirement of a system at a given time; or the amount of power required to supply customers at times when need is greatest. They can refer either to the load at a given moment or to averaged load over a given period of time.
Peaking capacity	Generating equipment normally operated only during the hours of highest daily, weekly, or seasonal loads; this equipment is usually designed to meet the portion of load that is above base load.
Peaking generating system	A generating system that typically runs only when demand (and spot market price) is high. These systems usually have lower efficiency, higher operating costs, and very fast start up and shutdown times compared with base load and intermediate systems.
Power system	The National Electricity Market's (NEM) entire electricity infrastructure (including associated generation, transmission, and distribution networks) for the supply of electricity, operated as an integrated arrangement
Reliability	Reliability is the extent to which customers have a continuous electricity supply. Interruptions to continuous supply can be of varying duration from fractions of a second to several hours, depending on the cause and what has to be done to restore supply. Reliability in the power system means there is enough capacity (generation and network poles and wires) to supply customer demand.
Reliability of supply	The likelihood of having sufficient capacity (generation or demand-side participation (DSP)) to meet demand
Security	Security in the power system relates to the physical stability of the system. The power system is secure when technical parameters such as voltage and frequency are maintained within defined limits. To maintain frequency the power system has to instantaneously balance electricity supply against demand.
Supply	The delivery of electricity.

Table 1.1 Energy terms and definitions

Term	Definition
Supply-demand outlook	The future state of supply's ability to meet projected demand.
Transmission network	A network within any participating jurisdiction operating at nominal voltages of 220 kV and above plus: any part of a network operating at nominal voltages between 66 kV and 220 kV that operates in parallel to and provides support to the higher voltage transmission network, any part of a network operating at nominal voltages between 66 kV and 220 kV that is not referred to in paragraph (a) but is deemed by the Australian Energy Regulator (AER) to be part of the transmission network.
Variable renewable energy	VRE is a renewable energy source that is non-dispatchable due to its fluctuating nature, such as wind and solar power.

2 Energy context

2.1 National electricity market

The NEM involves the wholesale generation of electricity from coal, gas and renewable sources that is transported via high voltage transmission lines from generators to local distributors. From the distributors, it is converted to low voltage electricity and delivered to almost 10 million homes and businesses across the Australian eastern and south eastern seaboard. The NEM delivers around 80% of all electricity consumption in Australia.

The NEM operates on one of the world's longest interconnected power systems and connects five regional market jurisdictions – Queensland, NSW (including the Australian Capital Territory), Victoria, South Australia, and Tasmania (as shown in Figure 2.1). The NEM has over 300 registered industry participants which include market generators, transmission network service providers, distribution network service providers and market customers.

The NEM comprises around 40,000 km of transmission lines and cables across all jurisdictions and within NSW, four companies are responsible for the transport of electricity. TransGrid manages the high voltage transmission power lines and towers, cables and substations, while three electricity distributors, Ausgrid, Endeavour Energy and Essential Energy, deliver the electricity to consumers in their network regions.

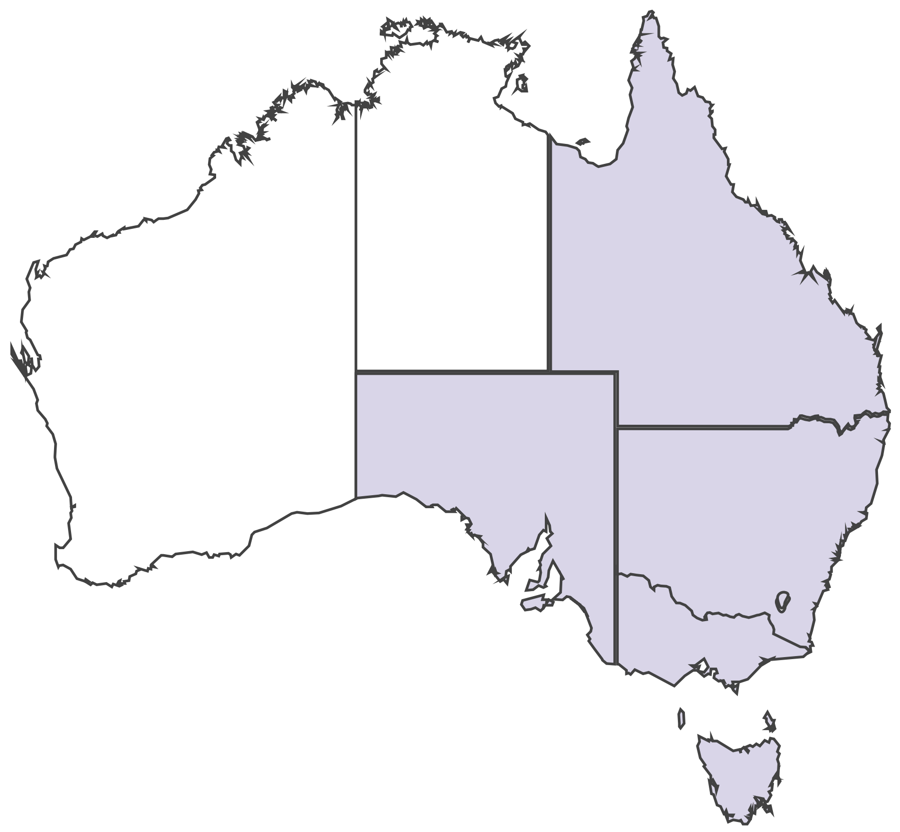
The NEM is a wholesale commodity exchange for electricity across the five regional markets. As electricity cannot currently be stored easily, the NEM works as a "pool", or spot market, where power supply and demand across all jurisdictions is matched instantaneously in real time through a centrally coordinated dispatch process.

The "pool" is not a physical thing, but a set of procedures that is managed on a day to day basis by the Australian Energy Market Operator (AEMO), where generators offer to supply the market with specified amounts of electricity and AEMO decides which generators will be deployed to produce electricity, with the cheapest generator put into operation first. NEM operation is designed to meet electricity demand (or consumption) in the most cost-efficient way.

Currently, coal powered generation accounts for approximately 77% of the annual generation of electricity within the NEM, with gas (9%), water (8%) and wind (5%) contributing the majority of the remainder. Solar and other generators (including biomass generators) currently account for approximately 1% of generation within the NEM (https://www.aemo.com.au/).

The NEM is operated in line with the National Electricity Law (NEL) and the National Electricity Rules (NER) that are developed and governed by the Australian Energy Market Commission (AEMC) and enforced by the Australian Energy Regulator (AER). In the development and government of NER, AEMC is also required by law to apply the National Energy Objective (NEO), which is aimed at looking after the long term interests of electricity consumers with respect to, amongst other things, security and reliability of the national electricity system.

The NEM and how it works



There are over **300** registred participants such as generators, retailers & distributors in the NEM

States/Territories that form the NEM

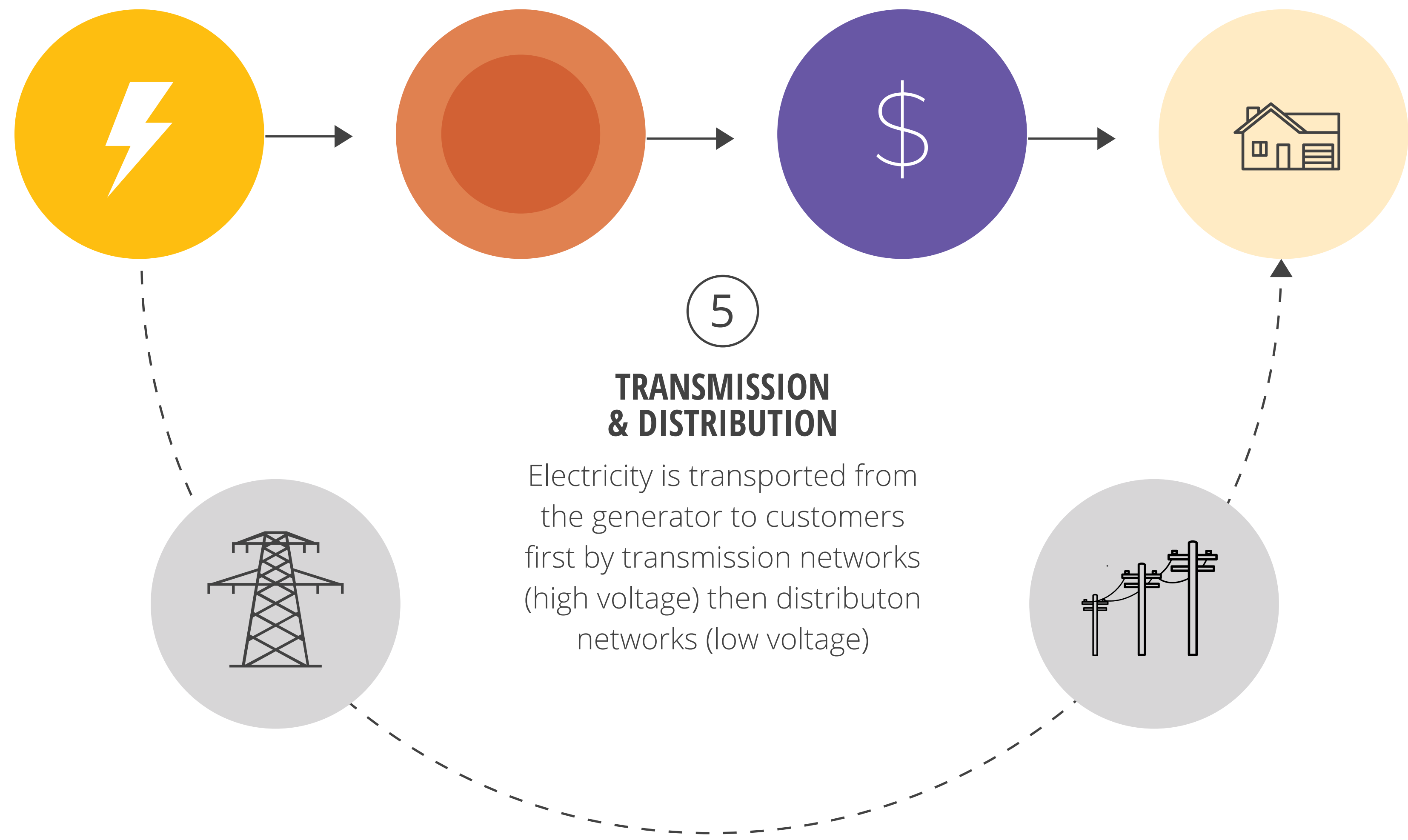
40,000 km	80%	9 million
of transmission lines and cables.	of all electricity used in Australia is deleivered via the NEM	customers

1. **GENERATORS**
   Generators within Qld, NSW, ACT, Vic, Tas & SA produce electricty from fuels, as well as via wind, solar and hydro.

2. **'THE POOL'**
   Generators offer to supply the market with set amounts of electricity at set prices for set periods. All power available at any given time is reffered to as 'the 'pool'

3. **RETAILERS**
   Retailers buy electricty produced by generators from the pool and sell it to customers

4. **CUSTOMERS**
   Customers (both business and residential) use the power



5. **TRANSMISSION & DISTRIBUTION**
   Electricity is transported from the generator to customers first by transmission networks (high voltage) then distributon networks (low voltage)

2.2 Planning policies driving energy change and regulation

Under Australian constitutional arrangements, the regulation of energy is the responsibility of the various states and territories. In NSW, the minister with responsibility for general matters relating to electricity is the Minister for Energy and Environment with the electricity system, comprising generation, transmission and distribution through to retail business spread across separate operators.

The NSW energy system (and broader NEM) is facing several challenges through rising energy costs, deterioration in energy system security and reliability, and a transition in the generation mix away from coal-fired, dispatchable, baseload power to renewable wind and solar power characterised by intermittency.

This energy transition towards renewables is driven by legislation and several strategic plans and policies set out by the Australian and NSW governments, including:

- Commonwealth Renewable Energy (Electricity) Act 2000;
- Australian Renewable Energy Target scheme;
- the Paris Agreement – a global agreement signed by the Commonwealth Government that sets in place a durable and dynamic framework for all countries to take climate action from 2020;
- NSW Renewable Energy Action Plan (2014); and
- NSW Energy Security Taskforce and Energy Zones.

This legislation and planning policies are described in the following sections.

2.2.1 Australia's commitment to renewable energy

Since 2000, when the Commonwealth *Renewable Energy (Electricity) Act 2000* (the REE Act) was enacted, Australia has demonstrated a commitment to increasing the use of renewable energy sources for electricity generation. For both economic and social reasons, new and replacement coal-fired power stations are not favoured compared with gas-fired and hydro-electric power to provide the balancing required by such a transition to a power system that is increasingly dominated by renewable energy.

The objects of the REE Act are to encourage additional generation of electricity from renewable sources, to reduce emissions of greenhouse gases in the electricity sector and to ensure that renewable energy sources are ecologically sustainable.

The Commonwealth Government has also established the Australian Renewable Energy Target scheme, intended to reduce emissions of greenhouse gases in the electricity sector and encourage additional generation of electricity through investment in sustainable and renewable sources. In 2015, the target for large-scale renewable generation was set at 33,000 GWh to be achieved by 2020. In January 2019, the Clean Energy Regulator (CER) confirmed that this target would be met – a significant milestone for the industry (Clean Energy Council 2019).

It should also be noted that, in late 2015, the Commonwealth Government signed the Paris Agreement – a global agreement that sets in place a durable and dynamic framework for all countries to take climate action from 2020. As part of this agreement, the Commonwealth Government has agreed to reduce greenhouse gas emissions by 26-28% from levels in 2005, by 2030.

2.2.2 NSW commitment to renewable energy

The NSW Government's support for the renewable energy sector is set out in the NSW Renewable Energy Action Plan (2014). This plan positions NSW to increase the use of energy from renewable sources at least cost to the energy customer and with maximum benefits to NSW.

Renewable energy provides a pathway to lasting economic prosperity that does not take resources away from future generations and reduces the impact of our activities on the natural environment. Reducing environmental impacts through increased use of renewable energy is a key objective of the NSW Renewable Energy Action Plan which, along with specific economic and community drivers to benefit NSW, has been designed to support broader environmental objectives to reduce carbon emissions.

The implementation of the Plan will also support Australia's commitments under the Paris Agreement. This commitment is also supported by the NSW Climate Change Policy Framework which aims to achieve net-zero emissions by 2050 and to make NSW more resilient to a changing climate. However, it should be noted that unlike some states and territories, NSW does not have a legislative state-based renewable energy target.

The Plan also forms part of the NSW Government's initiatives to develop a transmission strategy that supports a transition to a reliable, affordable and modern energy system for the state and support the planning for additional transmission infrastructure that may be needed to connect new power generators to the grid.

In 2018, the government announced that all 24 goals set out as part of its Renewable Energy Action Plan had been completed (Energy NSW 2018).

2.2.3 NSW Energy Security Taskforce and Energy Zones

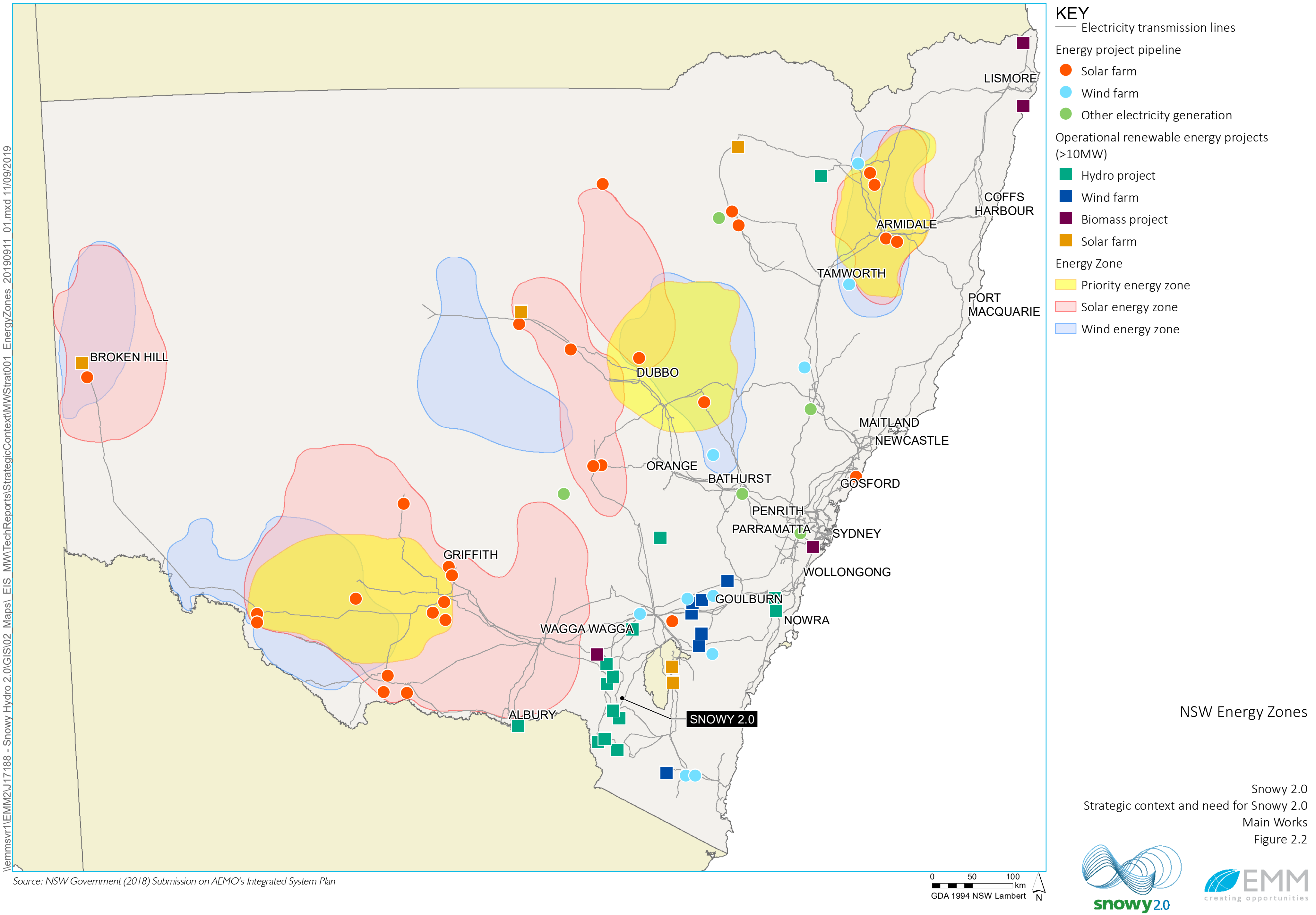
The NSW Government has stated it is committed to a secure, affordable and clean energy future for households and businesses and supports an orderly, private-sector led transition to a modern energy system (NSW Government 2018).

In February 2017, the former NSW Minister for Energy and Utilities established the NSW Energy Security Taskforce to investigate how the State manages its energy security and resilience. The Taskforce released their final report in December 2017, with a number of recommendations to improve energy security in NSW over the long-term. One of these recommendations focussed on the identification and development of Energy Zones, which was a key recommendation in the Finkel review (Recommendation 5.1).

In its submission to AEMO's Integrated System Plan consultation phase (NSW Government 2018), the NSW Government stated that developing Energy Zones in NSW would provide opportunities to better match energy supply and demand across the NEM, due to:

- its central location within the NEM;
- its high connectivity to the other states; and
- it having the highest energy demand.

Energy Zones were proposed to help unlock the pipeline of generation projects, support more competition in the energy market and help deliver low-cost energy for NSW consumers. These zones are across the state, as shown in Figure 2.2, covering renewable energy sources of wind, solar, hydro and biomass.



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Source: NSW Government (2018) Submission on AEMO's Integrated System Plan

NSW Energy Zones

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Figure 2.2

2.3 Technological, social and economic trends

2.3.1 The changing nature of electricity generation

As with many electricity markets around the world, the NEM is undergoing a paradigm transformation that has been brought about through significant shifts in energy efficiency, rapidly decreasing costs of wind and solar generation (known as variable renewable energy or VRE), coal power station retirements, and Australia's participation in global commitments to reduce carbon emissions.

AEMO has sought to highlight where security and reliability needs may be shifting across the NEM on the back of changes in supply mix, electricity demand, and impact of weather. The table below summarises key changes and the key operational challenges AEMO, as system and market operator, is now seeing in relation to those changes.

Table 2.1 Key system changes and operational challenges

Issue	Trend/ changes in the NEM	Operational implications for the NEM
Changing supply mix	• More variable renewable energy • Less dispatchable generation • Older resources	• Increased variability and uncertainty in the resource mix • Increased reliance on directions
Changing electricity demand	• Higher ramps for peaks • Lower minimum demand • More active consumers • More distributed energy resources (DER)	• Increased variability and uncertainty in demand • Erosion of baseload • Increasing ramping requirement
Changing impact of weather	• Temperature changes • Extremity of weather events	• Increased demand • Increased stress on system over prolonged heat periods • Increased risk of disruption • Increased uncertainty

Source: AEMO (2018)

The traditional electricity supply chain model is where electricity is produced by large generators (suppliers) and transported through transmission and distribution systems to industrial, commercial, and residential customers who purchase the electricity. To respond to changing energy trends, the NEM is advancing to a more dynamic and flexible supply model. This includes using 'storage' to optimise the integration of VRE and an increase in consumers installing devices such as rooftop solar and batteries. This changing energy system is depicted in Figure 2.3.

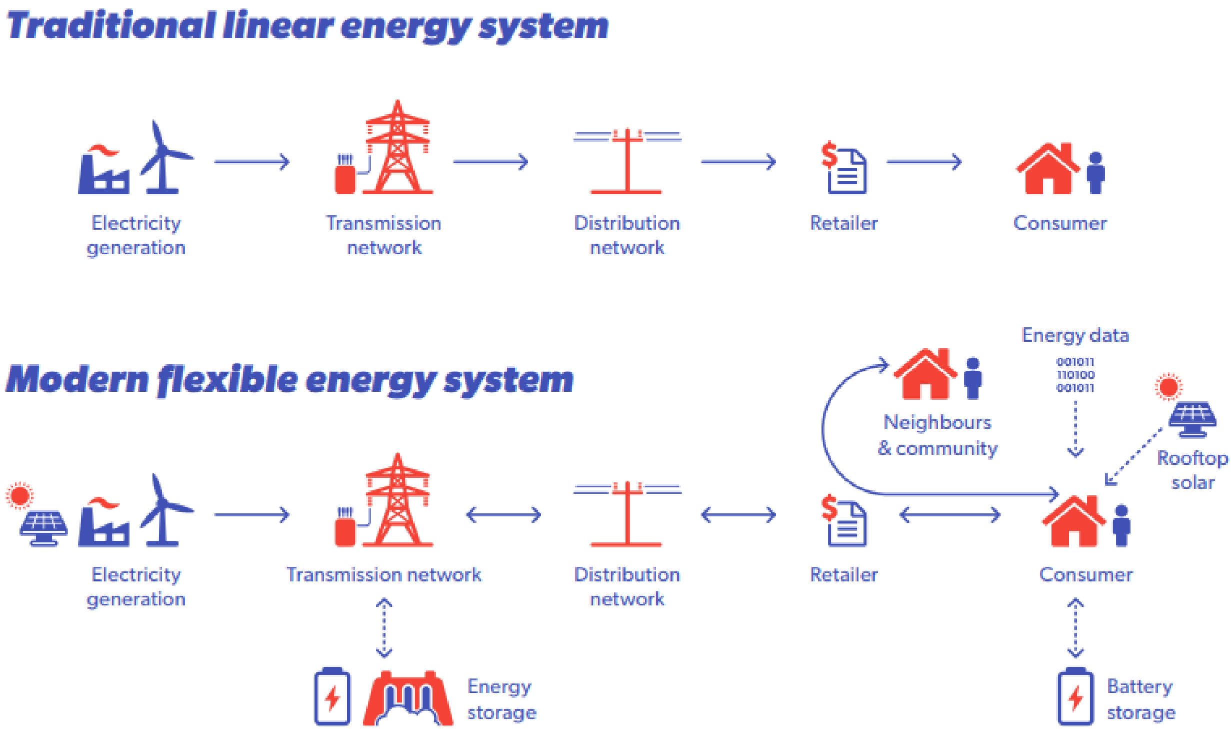


Figure 2.3 Australia's changing energy system

Source: NSW Government Pumped Hydro Roadmap – December 2018

i Retirement of coal-fired power

Following on from Australia's commitment to the Paris Agreement and combined with factors such as the ageing state and expected life span of Australia's coal-fired power plants, a number of these plants will be retired over the coming decades. The retirement of these plants will reduce the energy and capacity in the network from this sector, which currently provide over 75% of electricity generated across the NEM.

Specifically:

- retirement of coal-fired power plants will start with the closing of 2,000 MW in 2023 (recently revised closure date for Liddell Power Station);
- by 2032 a further 5,000 MW of coal plant is likely to be retired (Vales Point, Yallourn, Eraring); and
- by 2037 (five years later) a further 10,000 MW of coal plant is anticipated to be retired.

Approximately one third of coal power stations within the NEM will close over the next 15 years and over two thirds will close by 2040. As can be seen in Figure 2.4 (Integrated System Plan, AEMO 2018) these closures, due to reaching operational lifespans or announced retirements, will reduce the generation capacity of coal powered stations from over 22,000 MW to approximately 9,000 MW. The likelihood for new market-driven private sector coal power stations being developed is low due to comparative costs and the risk associated with carbon emissions.

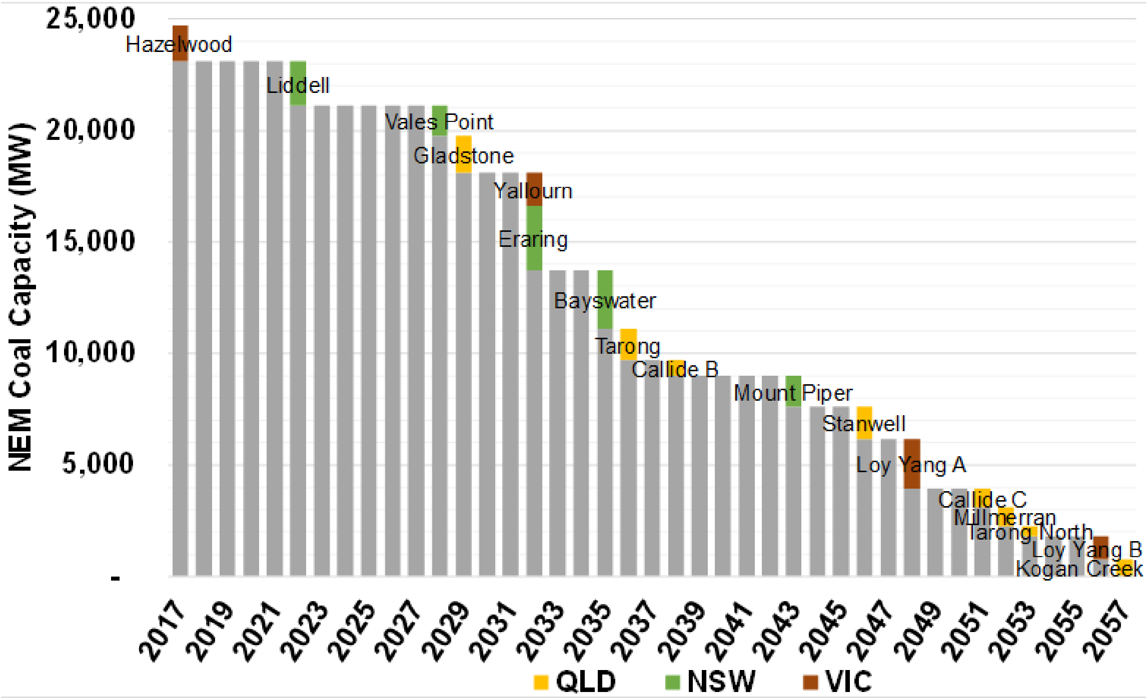


Figure 2.4 NEM coal-fired generation fleet operating life to 2057

Source: AEMO ISP (2018)

As demonstrated in Figure 2.4, as the majority of the coal plants already confirmed to be retired will occur in NSW pre- to mid-2030s, NSW is likely to have the greatest requirement for energy replacement and capacity. As the likelihood of new coal fired power stations is low, much of the replacement of coal powered generation will be from renewable sources.

ii Renewables and storage

The Integrated System Plan (ISP) for the NEM was released by AEMO in July 2018 and evaluates the likely changes to the NEM over the next 20 years. The ISP Insights development plan was later released by AEMO in July 2019 to provide better understanding of proposed pumped hydro developments and their associated transmission infrastructure, based on updated data and improved modelling. Figure 2.5 shows the projected evolution of the generation mix in the NEM, demonstrating both the increase in forecast generating capacity within the NEM and the shift from coal to renewable energy.

Figure 1 Forecast NEM generation capacity in the ISP Insights development plan, Neutral scenario

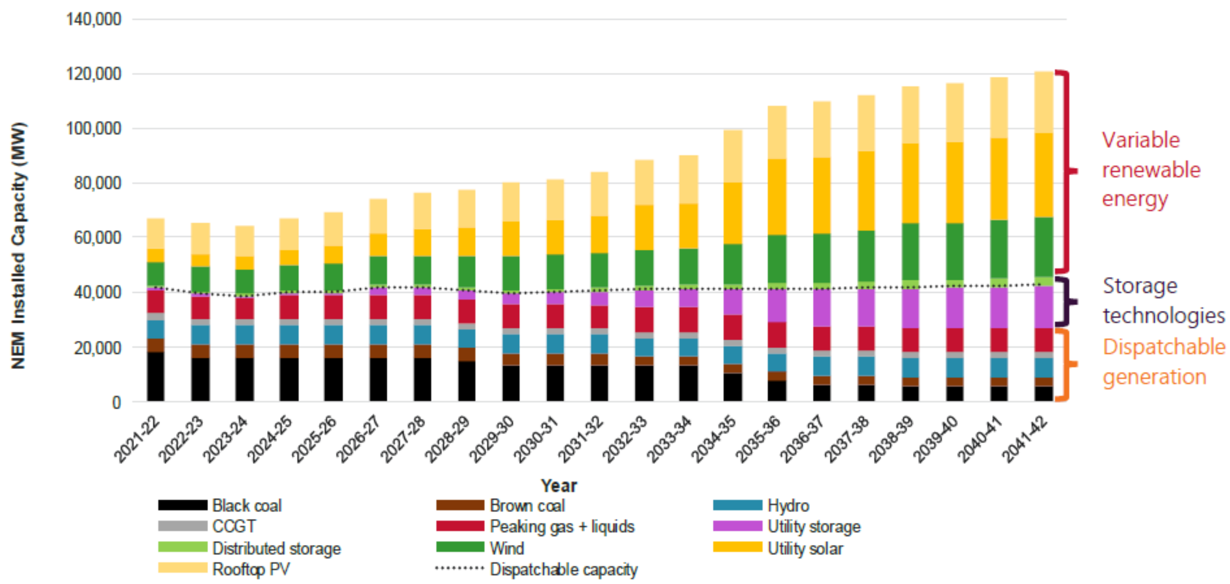


Figure 2.5 Forecast NEM generation capacity

Source: AEMO 2019

A key driver for change in energy mix is also related to the changing economic viability of renewable energy projects, ie the economics of large and small-scale power generation has been transformed due to the low and reducing costs of VRE generation compared to coal and gas generation. Wind generation is now being offered lower than $55 per MWh and solar generation lower than $50 per MWh, and these costs are projected to continue to decrease in the future. This compares favourably to the cost of coal generation estimated at $65 per MWh and the cost of gas generators at over $90 per MWh. High gas costs are now meaning that gas generation will be most suited to short duration operation when needed. In 2018, 21% of total electricity generation across the nation was from renewable sources, the highest proportion of energy generation ever (Clean Energy Council 2019).

iii Emerging technologies

In 2018, the NSW government launched the NSW Emerging Energy Program to support the transition in NSW to a clean energy system as coal-fired power plants are retired. The program is designed to encourage private sector investment in emerging, dispatchable technology to support large-scale electricity and storage projects in NSW. The program enables investors to seek government funding to support emerging technology projects (at least 5MW in size) that will provide clean, dispatchable energy to the network.

It is expected that over the next few decades, emerging low-emissions technologies will enter and erode the competitive market share of traditional generators. The future energy generation mix is therefore expected to be technologically diverse. This technology mix may diversify further in the future than current projections, if forecast technology cost reductions in emerging and maturing technologies increase more rapidly than current expectations.

2.3.2 Building security and reliability into the NEM

i Firming capacity

While technology has improved the efficiency and reduced the costs of VRE generation in recent years, supporting energy generation is required to ensure electricity demand is met when VRE sources are not operating (ie due to low wind or low sunlight). This supporting generation is known as 'firming'.

The amount of VRE generation operating to date has been such that in all states including NSW but excluding South Australia, the flexibility of the current energy generation fleet has been able to 'absorb' the increasing level and uncertain variations in VRE output.

However, this will change as VRE becomes a larger proportion of the total generation, by virtue of the new-build renewables, and retirement of aging coal-fired and sub-economic gas-fired power stations. Energy storage (including battery and pumped hydro storage) and peaking gas generation will therefore increasingly be needed to provide this firming capacity (Finkel et al 2017, AEMO 2018).

While peaking gas generation is and will play an important role in firming when VRE is not available, it does not address periods of excess VRE generation in the way that energy storage can. In addition, gas generation is likely to become increasingly non-cost competitive with energy storage.

ii Energy storage

Energy storage involves the use a chemical process (ie a battery) or a pumped hydro system to store energy (as electrical or potential energy) so that electricity is either available or can be produced on demand.

As the amount of the VRE increases in response to economics and retiring coal-fired power stations, energy storage will play a vital role in ensuring the continued provision of reliable and cost efficient energy generation whilst accommodating the variability and intermittency of VRE generation and having energy generation capacity available when needed.

Battery storage, such as South Australia's Hornsdale Power Reserve which contains the largest lithium-ion battery in the world (129 MWh of energy storage), is able to store energy produced from associated VRE generators, including wind and solar. The battery then stores this energy when VRE is being generated (and when the demand for electricity is low) and can then dispatch it as required when the demand is high, even when the associated VRE is not being generated due to low wind or low sunlight.

Pumped hydro systems also store energy, but instead of storing electrical energy that has already been produced by a generator (ie a traditional battery), hydro systems store potential energy in the form of large masses of water in elevated reservoirs, that can be transferred by gravity at speed through a series of tunnels and turbines to produce electrical energy.

A large pumped hydro system such as Snowy 2.0 (with 350,000 MWh of energy storage, or the equivalent of about 2,700 Hornsdale sized batteries) can therefore provide significant energy storage capable of delivering large-scale generation on-demand and within minutes in times when VRE output is low. Following generation, pumped hydro systems can then transfer the water used for generation from the lower reservoir back to the higher reservoir in non-peak periods (ie periods of low electricity demand), effectively recharging the system.

Energy storage can therefore play an important role in the firming capacity for an electricity market such as the NEM, particular storage systems with very large capacities such as large pumped hydro systems.

2.3.3 Building resilience with pumped hydro

In the NEM, changes in technology, costs, policy and customer preferences are occurring at a rapid rate.

As energy generation needs to balance with customer demand in real time, the integration of intermittent generation will require increased peaking generation and energy storage solutions to provide a sufficiently fast response capacity and to 'time shift' non-dispatchable renewable generation to those periods when it is needed. The requirements for the NEM include storage that can provide energy for consecutive days (MJA 2018a).

Conceptually large-scale renewable generation in targeted zones can be part of future power system development. However, the concern with these zones which may only contain wind and solar generation is the impact of prolonged wind and solar droughts. Without adequate large-scale energy storage the effectiveness of these renewable energy zones would be greatly diminished.

Energy storage helps build power system resilience to weather events (including wind and solar intermittency) by storing surplus renewable generation for use at times when these resources are scarce and allowing more constant operation of less flexible existing generation. This, in turn, creates a more dispatchable and reliable power system, while helping to keep prices down for consumers.

A large pumped hydro generator would pump and store energy at times of high intermittent generation and generate at times of low intermittent generation thereby balancing the supply/demand in the NEM. The large storage capability of Snowy 2.0 would allow the NEM to reliably and securely function in the plausible scenario of prolonged multiple days of low wind and solar generation. This concept is shown in Figure 2.6.

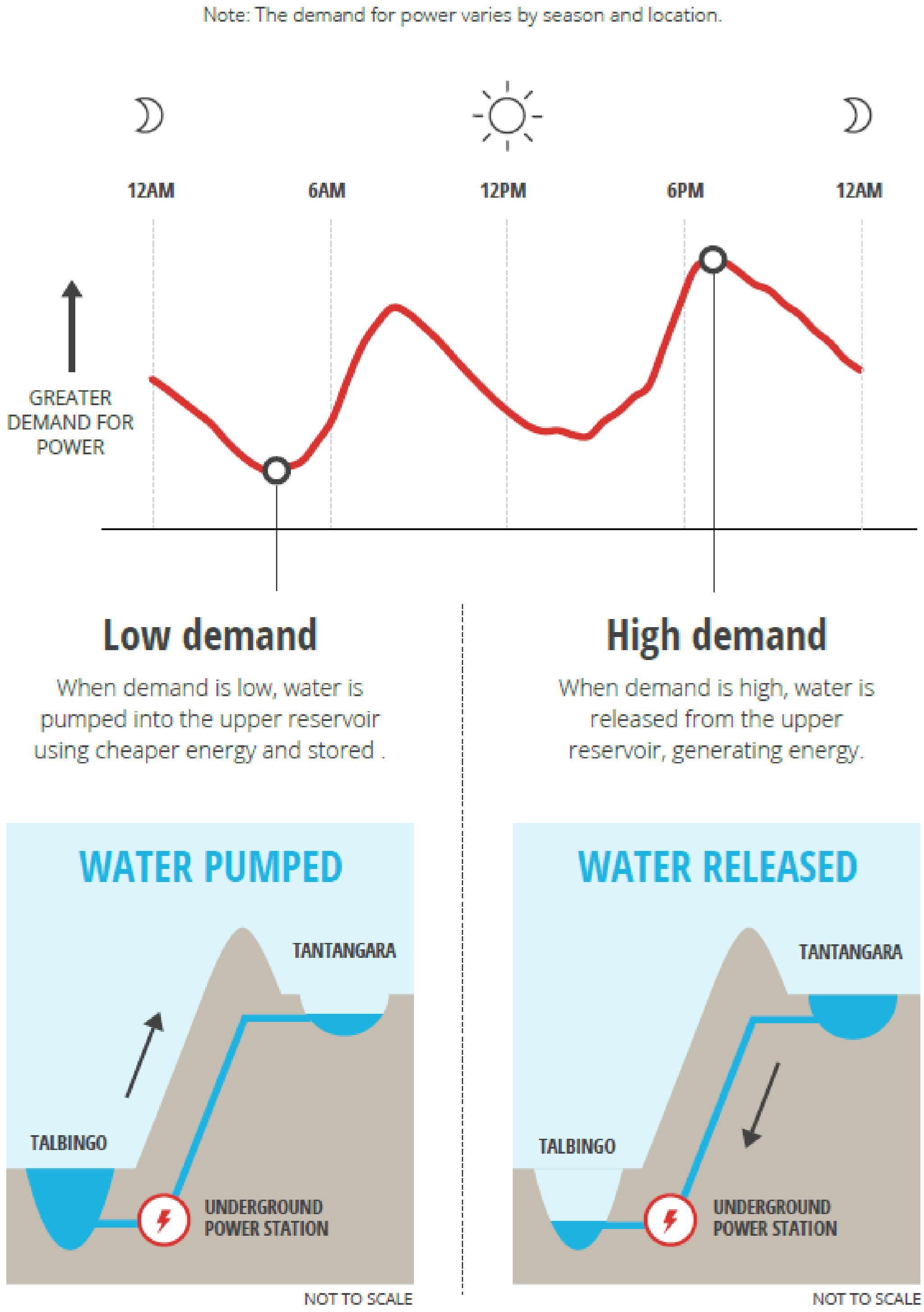


Figure 2.6 How pumped hydro can shift energy to meet demand needs

2.3.4 Community views

There is great support from the broader community to increase the development and use of renewable energy and invest in more renewable energy projects. This is reflected nationally by an increase in households and businesses with rooftop solar, with 45% growth in commercial solar installations throughout 2018 (Clean Energy Council 2019).

Community views have been gathered through Snowy Hydro's consultation program for Snowy 2.0, which with respect to the current energy context, generally suggest the following is considered important to the community:

- reliability in the electricity network;
- lower energy prices;
- increase and expand sources of reliable, renewable energy;
- minimise reliance on traditional fossil fuels (cleaner energy);
- minimise environmental impacts; and
- economic benefits to the local communities.

3 Land use context

3.1 Snowy 2.0 and Kosciuszko National Park

The KNP PoM (NPWS 2006) recognises the Snowy Scheme with various references including to the Park Zoning provisions. The Park Zoning covers the whole of the KNP and is intended to:

- protect the values of the park, as set out in the PoM under the categories of Natural Values, Cultural Values and Recreational Values;
- optimise opportunities for a wide range of recreational activities and visitor experiences; and
- minimise land use conflict between participants in different recreational activities, and between visitors, management operations and other authorised users.

The KNP PoM incorporates the Snowy Management Plan. Both plans will be reviewed and amended as required under a transitional program. Chapter 4 also explains the current arrangements for Snowy Hydro's existing and ongoing occupation and use of land within KNP.

One site is beyond the boundaries of KNP and on land zoned for rural uses (RU1 Primary Production) under the *Snowy River Local Environmental Plan 2013*. The Rock Forest site has been secured by Snowy Hydro under a private lease agreement with the landowner.

3.1.1 Elements of the site that could be impacted

The existing environment of the project area has been generally summarised in Table 3.1. Each of the key features are further described in the relevant section in the EIS, including how they might be impacted by the project. The project interacts with a number of environmental and social values of the project area which include:

- landscape and natural heritage values of KNP, including its management by NPWS and use by the public;
- terrestrial and aquatic biodiversity, including endangered and critically endangered species identified throughout the project area;
- surface and groundwater features and their interaction, including groundwater levels and overlying watercourses and respective water quality of these resources;
- Aboriginal cultural heritage values and sites and historic heritage items; and
- recreational uses of Lobs Hole, Talbingo and Tantangara reservoirs.

Snowy 2.0 Main Works through its design has considered the interactions with these environmental and social values and where possible sought to avoid and minimise impacts. The maximum disturbance area is about 1,680 hectares (ha) which is approximately 0.25% of the KNP.

Table 3.1 Snowy 2.0 site surrounds – key features requiring consideration

Attributes	Talbingo Reservoir	Lobs Hole	Marica	Plateau	Tantangara Reservoir	Rock Forest
Natural environment						
Geology	The Ravine area is within a geologic domain referred to as the Tumut Block which extends west of the Long Plain Fault (LPF) (Figure 6.3) to the east of Talbingo Reservoir. The area is dominated by Silurian to Devonian sedimentary and igneous rocks. The Silurian Ravine Beds, composed of stratified altered siltstone, sandstone and limestone, provide the structural framework and topographic control for this area. The Ravine Beds are overlain in areas, typically along the escarpment, by younger volcanic rock (Boraig Group and Byron Range Group) deposited in the Devonian during a period of explosive felsic volcanism.			The plateau area is within a geologic domain referred to as the Tantangara Block which extends from the Tantangara Fault (TF) in the east to the LPF in the west. The geological units within the plateau area generally grade from youngest to oldest in an east to west direction, reflecting the compression and tilt placed on the structural block. Igneous intrusions within the plateau area include the Ordovician Shaw Hill Gabbro, Devonian Boggy Plain Suite and Tertiary basalt.		The Rock Forest area is also within the Tantangara Block. The area, which is largely characterised by the steeply dipping metasediments of the Ordovician Bolton Beds and Kiandra Beds, has been significantly intruded by Devonian undifferentiated granites.
Hydrogeology	In the Ravine area, groundwater levels are monitored in the Ravine Beds and the Boraig Group. Groundwater levels within the Ravine area are influenced by the steep relief that exists across the area. Groundwater levels generally mirror the topography. Groundwater levels within the Ravine Beds vary from approximately 1325 m AHD in the topographically elevated terrain adjacent to the LPF towards the east; to approximately 545 m AHD in the topographically lower terrain adjacent to Talbingo Reservoir towards the west. Overall, groundwater levels indicate that groundwater flow within the Ravine Beds is towards the west from the direction of the LPF.			In the plateau area, groundwater levels are monitored in the Tertiary basalt, Gooandra Volcanics, Tantangara Formation, Temperance Formation, Boraig Group, Kelly Plains Volcanics, Boggy Plains Suite and within several bog and fen areas.		N/A
Watercourses	Tumut River and Middle Creek.	Yarrangobilly River, Wallaces Creek, Lick Hole Gully, Sheep Station Creek.	Highground Creek tributaries, Stable Creek tributaries.	Eucumbene River, Murrumbidgee River, Tantangara Creek, Gooandra Creek and unnamed tributaries, Nungar Creek, Kellys Plain Creek, Boggy Plain Creek.		Camerons Creek, unnamed watercourse.
Biodiversity	Aquatic habitat comprises submerged trees and the reservoir is considered habitat for Murray Crayfish (threatened species).	Areas of habitat for threatened species such as Booroolong Frog (recorded and mapped Yarrangobilly River) and Smoky Mouse (recorded and mapped along Lobs Hole Ravine Road).	Areas of habitat for threatened species such as Smoky Mouse (recorded and mapped along Marica Trail), and threatened flora species also recorded.	Bogs and Fens endangered ecological community are located throughout the Plateau area, and threatened flora species also recorded.	Threatened flora species recorded adjacent to Tantangara Reservoir and Tantangara Road.	Rock Forest is just outside of the KNP, consisting of predominantly derived grasslands as a result of historical clearing and grazing.

Table 3.1 Snowy 2.0 site surrounds – key features requiring consideration

Attributes	Talbingo Reservoir	Lobs Hole	Marica	Plateau	Tantangara Reservoir	Rock Forest
Natural and cultural heritage	Historic Ravine Cemetery near Lobs Hole.	The historic Washington Hotel at Lobs Hole and geodiversity features (periglacial boulder stream and Devonian fossils) along Lobs Hole Ravine Road.	Historic heritage features associated with pastoralism, mining and the Snowy Scheme.	Historic heritage features associated with pastoralism, mining and the Snowy Scheme.	Aboriginal cultural heritage rock shelter near Tantangara Reservoir and geodiversity features (Kellys Plain Volcanics) including a former quarry and an outcrop of agglomeratic porphyry.	Historic heritage items relating to mining, agriculture and pastoralism.
Built environment						
Reservoirs	Talbingo Reservoir is a large storage dam (921 GL total, or 239 GL active storage) that operates between 534 m AHD and 543 m AHD. The reservoir is about 25 km long and has a surface area of approximately 19.4 km^2 (at spillway crest).	N/A	N/A	N/A	Tantangara Reservoir is a storage dam (254 GL total, or 240 GL active storage) that operates between 1,206 m AHD and 1,229 m AHD. It is about 14 km long and has a surface area of approximately 21.2 km^2 (at FSL).	N/A
Social infrastructure	No townships or existing social infrastructure present.	No townships or existing social infrastructure present. Former township of Lobs Hole.	No townships or existing social infrastructure present.	No townships or existing social infrastructure present.	No townships or existing social infrastructure present.	No townships or existing social infrastructure present.
Transport infrastructure	N/A	Lobs Hole Ravine Road, Lobs Hole Road, Mine Trail Road.	Marica Trail, Marica West Road, Snowy Mountains Highway.	Snowy Mountains Highway, Gooandra Track.	Snowy Mountains Highway, Tantangara Road, Quarry Trail, Pocket Saddle Road.	Snowy Mountains Highway.
Utility infrastructure	330 kV transmission easement.	330 kV transmission easement.	N/A	330 kV transmission easement.	11 kV transmission easement, 33 kV substation, Tantangara Dam.	N/A

Table 3.1 Snowy 2.0 site surrounds – key features requiring consideration

Attributes	Talbingo Reservoir	Lobs Hole	Marica	Plateau	Tantangara Reservoir	Rock Forest
Recreational features	O'Hares boat ramp, informal boat ramp at Middle Bay, boating, water sports, fishing.	Camping at Lobs Hole.	N/A	Camping at Bullocks Hill and 3 Mile Dam and Mt Selwyn ski resort.	Camping on reservoir foreshore, fishing, boating, water sports, horse riding trails, Wares Yard, Currango Homestead.	N/A
Historic heritage	Snowy Scheme.	Washington Hotel, Ravine Cemetery.	N/A	Kiandra courthouse.	Snowy Scheme.	N/A

3.1.2 Offset strategy

In considering the residual impacts of Snowy 2.0 Main Works, it is critical to place them in context. A fundamental objective of the project is to provide a large scale storage facility to enable the decarbonisation of the nation's energy system in order to achieve meaningful progress in emissions reductions as a key mitigant of climate change. The project's location within the largest alpine area within NSW gives particular merit to this mission given the potential long term impacts on many of the snow dependent species and communities of the local region.

Further, the configuration of the project takes advantage of existing reservoir infrastructure and is constructed almost entirely underground in order to minimise the surface impacts of the works. It is, however, acknowledged that the sensitive nature of the location of the works with KNP requires careful consideration to ensure the project retains a net beneficial contribution to the environment.

The key principles of the strategy are to ensure that an outcomes based program of management actions is developed to ensure that the residual impacts to key values of KNP, which include terrestrial and aquatic biodiversity, with a particular focus on threatened species and communities, and recreational uses in and around the Project area are proportionately offset.

Actions and outcomes to be achieved will be aligned with the Project's understanding of the key stakeholders objectives for impacted values, and Policies and programs such as Caring for our Australian Alps Catchments (Worboys and Good 2011) and the NSW Save our Species (SOS) Program. In particular, Snowy Hydro will work with NPWS, DPIE, DPI Fisheries and local stakeholders to further develop a suite of fully funded conservation and recreational management projects specifically for the improvement of KNP.

Once agreed, this offsets strategy will be implemented to fulfil Snowy Hydro's obligations under NSW *Biodiversity Conservation Act 2016* (BC Act) and EPBC Act. The key areas to be covered by the strategy are set out in Table 3.2 below, and further detail provided in the Offset Strategy attached to the EIS in Appendix M.3.

Table 3.2 Potential actions for residual impacts

Key values	Potential actions
Terrestrial ecology	Key focus species: ● Clover Glycine ● Kiandra Leek Orchid ● Eastern Pygmy-possum ● Smoky Mouse ● Booroolong Frog ● Alpine Tree Frog ● Alpine She-oak Skink Key focus communities: ● Bogs and Fens Management actions: ● Targeted research and monitoring actions to better understand species distribution, abundance and key threats, e.g. systematic camera surveys across KNP and surrounding National Parks and State Forests to document the distribution of Smoky Mouse, or annual systematic surveys of suitable habitat for Clover Glycine to determine the area and extent of populations, the number, size and structure of populations in KNP

Table 3.2 Potential actions for residual impacts

Key values	Potential actions
	• Habitat restoration works for threatened species and communities, eg restoration and dry open Eucalypt forests and woodland • Management of key threats in particular for predators and invasive competitors eg, weed control programs across KNP etc. Establishment of SOS sites to ensure good, targeted management of threats for key species and communities.
Aquatic species	• Targeted research and monitoring actions to better understand species distribution, abundance and key threats • Support for local / regional insurance population programs of Macquarie Perch • Habitat protection and enhancement activities for threatened species' with a focus on Murray Crayfish and stocky galaxias
Recreation	• With NPWS, Maritime and stakeholders, improve boat launching access at Talbingo and Tantangara • With stakeholders, develop a program for stocking of large fish (rainbow trout) in Tantangara • Upgrade camping facilities on the Tantangara foreshore and Lobs Hole and integrate with the new assets • Refurbish facilities that have been directly impacted as a consequence of the Project through lack of / increased use during the life of the Project

Specific details for the scope and implementation of the suite of proposed actions and measures will be developed further and agreed in consultation with key stakeholders, including DPIE and DEE.

The offsets strategy is expected to be implemented over time and deliver significant benefits for the natural values of the KNP and the people who use it.

3.2 Summary

In summary, it is evident that the NEM needs large-scale storage and there is considerable support for Snowy 2.0 at the Commonwealth, State and local level and through the forecasted demand and needs of the NEM, as evidenced by:

- the Commonwealth's commitment to fostering increased investment in renewable energy sources for electricity generation as supported by the REE Act and being a signatory to the Paris Agreement;
- the support for the project by the NSW government through the provisions of the Renewable Energy Action Plan and consideration of Energy Zones, which will likely require large-scale and longer term energy storage;
- the goals of improving energy security and reliability as the NEM transitions away from coal-fired, dispatchable, baseload power to variable renewable energy (ie wind and solar) characterised by intermittency;
- the economics of main grid electricity supply has shifted to energy being supplied by variable renewable energy sources (ie wind and solar), however the advantages of these sources can only be realised with energy stored for later use when required;

- the provisions of the KNP PoM, including the current working arrangement for the Snowy Scheme through the Snowy Management Plan, and the SHC Act which entitles Snowy Hydro to the grant of tenure for Snowy 2.0, subject to obtaining the necessary planning approvals; and

- the support for Snowy 2.0 through the relevant regional and local plans.

4 The need and benefits of Snowy 2.0

As Australia decarbonises, Snowy 2.0 is required to support an orderly transition, prevent blackouts and put downward pressure on energy prices. Snowy 2.0 provides new dispatchable energy generation with large-scale storage to provide secure and reliable energy to the NEM, which ultimately benefits consumers.

Snowy 2.0 will play a crucial role in providing long term storage and dispatchable generation that can fill the void left from the exit of fossil fuel generation.

4.1 Modelling Snowy 2.0 in the NEM

An independent study was carried out by MJA on the operation of Snowy 2.0 in the NEM. The study involved modelling of the NEM with and without Snowy 2.0 for a number of future market scenarios. A detailed account of the methodology and the findings of the study are documented in a detailed report (MJA 2018a).

4.1.1 Modelling approach

MJA's future base case market state estimation in the NEM was built upon the current and known regulatory framework, and State and Federal renewable targets. Transmission upgrades were based on the AEMO ISP published in July 2018, plus further analysis. However, other scenarios modelled included:

- low emissions – policy increases emission reduction targets;
- coal early closure – key coal-fired power plants are closed earlier than planned;
- high demand – high demand is forecast (AEMO Fast Scenario) requiring greater investment and development in VRE and battery storage;
- increased and decreased hydro generation – changed Snowy 1.0 and Snowy 2.0 generation volumes;
- high EV penetration – rapid development of electric vehicles requiring battery charge;
- new coal – new coal generators and higher emissions; and
- high battery – reduction in battery costs and increase in battery development.

The study required the NEM to be modelled over the period 2018/19 to 2074/75. Further, the modelling was required to properly represent the hourly/daily/weekly/seasonal variations that are fundamental to the operation of generators in the NEM. For each scenario modelled, the impact of Snowy 2.0 was determined through:

- modelling the NEM over the study period on the basis Snowy 2.0 is developed. In all scenarios this is referred to as the 'With Snowy 2.0 case';
- modelling the NEM over the study period on the basis Snowy 2.0 is not developed and that all assets between the with Snowy 2.0 and without Snowy 2.0 (existing or new) are the same. This is referred to as the 'Without Snowy 2.0 case' or the 'No Snowy 2.0 case';
- based on the without Snowy 2.0 case (for any scenario), assign a portion of the developments that occurred in the market that did not occur in the with Snowy 2.0 case. This is referred to as the 'No Snowy 2.0 with Replacement' case. This case assumes the assets transferred to Snowy Hydro are operated and priced the same; and

- comparing the differences on an annual or quarterly basis between the two modelled cases.

4.1.2 Study conclusions

The MJA (2018b) study highlighted the need to distinguish between dispatchable capacity and firm capacity. Dispatchable capacity is that which is controllable (either up or down) and firm capacity is that capacity which is both dispatchable and which can be relied upon to be available.

To date, except in SA, the accommodation of VRE in the NEM has not been difficult. This is because the NEM has had enough dispatchable and firm capacity to absorb the variability of VRE production. Expressed differently, the NEM has had sufficient firming capacity.

From a supply reliability perspective, as the coal power stations close (which could see all existing coal generators close by the mid 2040s) it will be necessary to replace both the dispatchable and firm capacity (MW) and energy production (MWh) that was provided by these generators. The options to replace this capacity and energy production were identified as:

- VRE (solar and wind generation). This provides energy but only a relatively small amount of capacity that can be relied upon;
- Gas generation. This provides both firm capacity and energy but produces emissions, noting that emissions are about half that of black coal generation; and
- Storage. Provides dispatchable and firm capacity noting that the latter would require a storage duration of 24 hours or more.

Again, while the MJA modelling in the lead up to FID in late 2018 is still very relevant and underpins the strong economic case for the project -since this time, the energy market has evolved and changed much more quickly than originally anticipated even just a year ago.

i The NEM without Snowy 2.0

In the absence of Snowy 2.0, the study concluded the replacement of the closing coal power stations with VRE, gas generation and storage would occur as follows:

- using VRE to replace the lost energy production from the closed coal generators;
- using dispatchable generation (most notably gas) to fill in the gaps when VRE is not generating;
- gas generation does not address the issue of capturing “spilt” VRE generation and thus has an economic limit on this nature of firming. Taken by itself, firming with gas generation can be viewed as gas generation using VRE to minimise gas use;
- using battery storage to capture VRE generation that would spill and using it when needed. Not capturing this generation would mean VRE generators would increasingly provide less generation to the market resulting in increased costs of the usage energy from VRE. This would be reflected in decreasing prices VRE would receive from the spot energy market, which would be increasingly lower compared to average spot price levels. The substantial “discount” solar and wind generation receives on spot prices would present a significant hurdle to VRE economics;
- the cost and limited hours of batteries mean that they can only capture part of the daily variation in VRE and do not provide firm capacity; and

- the outlook is that even with the projected reduced costs of batteries, the level of storage required means that gas generation will be required for firm capacity and to address the majority of the variations in VRE output.

Batteries will have a role to play in the future of NEM, but within this scenario, the economics and limited hours of batteries mean that they can only capture part of the variation in VRE and, on their own, do not provide sufficiently for firm capacity. The outlook of this case is that even with the projected reduced costs of batteries, the level of storage required means that more expensive gas generation will be required for firm capacity and to address the majority of the variations in VRE output.

ii The NEM with Snowy 2.0

With Snowy 2.0, the study concluded that Snowy 2.0 would influence the operation of and asset mix that replaces the closing coal power stations as follows:

- significantly more "spilt" VRE output would be captured thereby improving the economics of VRE entry. Additional VRE generation would be developed. The diversity of VRE output means that Snowy 2.0 would provide for significantly more than 2,000 MW of additional VRE to enter;
- the firm capacity provided by Snowy 2.0 would provide for about 2,000 MW less of gas generation (CCGT and OCGT) to be developed; and
- less battery storage would also be needed, although the reduction in battery storage would reduce as battery costs become lower late in the study period.

The net result is improved market efficiency, more reliable market operation, and lower emissions.

4.2 Benefits of Snowy 2.0

Snowy 2.0 is the largest committed renewable energy project in Australia. By expanding the current Snowy Scheme's renewable energy capacity by almost 50%, the NEM will be served with an additional 2,000 MW generating capacity. In terms of the future energy market, the key benefits of Snowy 2.0 are summarised as follows:

- Snowy 2.0 makes a significant contribution to the continued decarbonisation of the economy;
- Snowy 2.0 provides large-scale energy storages at the least cost to allow more flexibility to respond to seasonal variability when compared to other VRE and batteries;
- Snowy 2.0 will improve the overall efficiency of the NEM by absorbing and storing excess energy from the system at times of excess demand (through pumping) and generate at the critical times of peak times;
- Snowy 2.0, being a closed system, can move water between reservoirs and not rely on natural inflows that may vary seasonally, offering valuable seasonal storage and insurance against drought risk;
- Snowy 2.0 will have the capability to run for over seven days continuously before it needs to be 'recharged'. By comparison, small and large-scale batteries have limited storage (typically one to four hours) and their already high prices increase significantly when used for more than one charge/discharge cycle per day; and
- Snowy 2.0 has a 100 year design life and will operate for generations to come.

The following sections provide further detail on the benefits of Snowy 2.0 within the NEM.

i Supports trilemma of issues of reliability, price and emissions reduction

On a NEM wide basis the above relationships would provide for Snowy 2.0 to directly and substantially contribute to the trilemma issues of reliability (firm capacity), price (least-cost new entry solution), and emissions reduction (optimises VRE storage over time) as the existing fleet of coal-fired generators closes and replacement firm capacity and energy production is required. Lithium ion technology is economically marginal as the reliability (up to 4 hours only) and price (along the learning curve) are not sufficiently profitable in the short to medium term.

ii Avoids excess supply

Snowy 2.0 would utilise otherwise unused low-cost generation (unused coal and VRE) and provide dispatchable and firm capacity that can operate for days if required, with the effect that the NEM would operate more efficiently and with lower emissions.

iii Emissions reduction

Before the closure of NSW Eraring power station, the lowest cost option for reducing emissions is replacing coal generation with VRE generation, together with the level of firming required (with most firming being available from the existing dispatchable generation).

Once Eraring power station and other coal-fired generators close, increasing levels of VRE would require increasing amounts of new firming assets, with economics having this increasingly composed of gas generation. This limits the level of emissions reduction to about a 65% level of abatement (compared to the 2005 level).

A constraint on emissions when coal plant has substantially closed would involve VRE with substantial storage and a reduced reliance on gas generation. The value of large storage is magnified under such conditions.

iv Green energy economy supported by Snowy 2.0

As shown in Figure 4.1, Snowy 2.0, the least-cost economic entrant, displaces both gas (grey bar) and battery (green bar) new entry requirements. In addition, it economically supports wind (black bar) and solar (yellow bar) new entry by converting intermittent dispatchable energy into firm energy using its unique storage and capacity value capabilities.

Snowy 2.0 provides support and firming for VRE generation. It results in about 3,000 MW of additional VRE generation and a reduction of about 2,000 MW of gas generation (mainly combined gas cycle turbine (CCGT)). Snowy 2.0 results in a reduction of about 1,000 MW of Lithium ion batteries in the initial years of Snowy 2.0 operation, with this reduction diminishing due to the additional VRE that enters in the medium term.

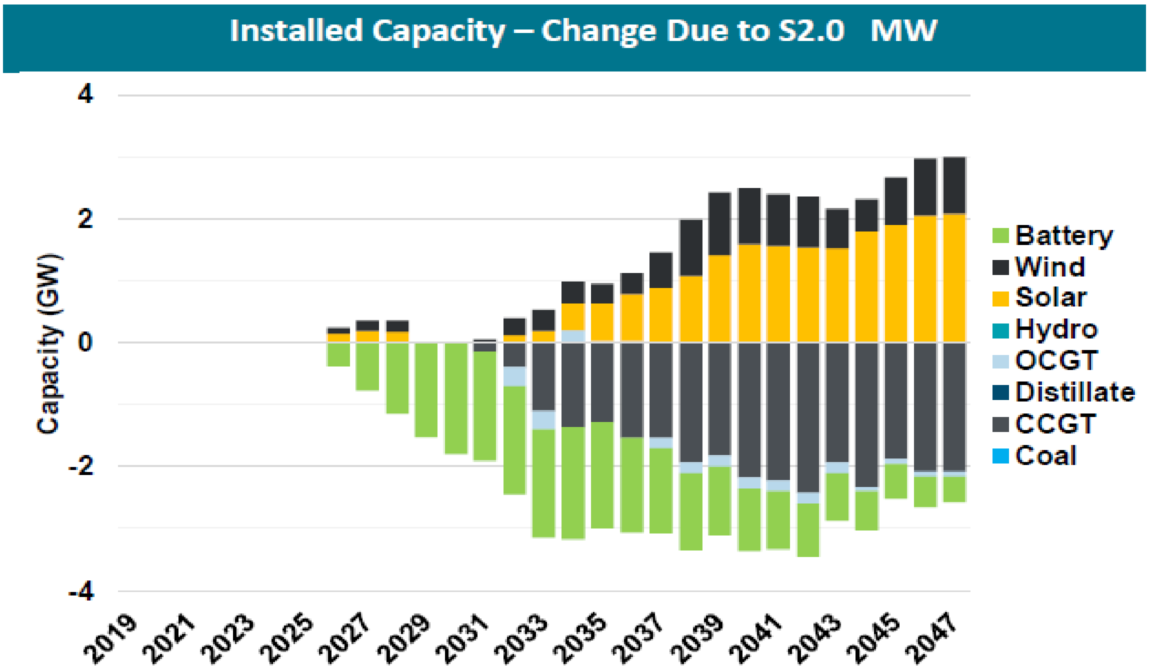


Figure 4.1 MJA modelling – installed capacity changes due to Snowy 2.0 over time

The chart below in Figure 4.2, is largely consistent with the ISP (AEMO 2018) decarbonisation prediction shows the benefits Snowy 2.0's unique capabilities can provide to enable the transition to a reliable green energy economy. There is very significant coal-fired generation capacity out to 2047. It is replaced with wind and solar energy, battery value (from Lithium ion and Snowy 2.0) as well as capacity/value from open cycle gas turbines (OCGT) and CCGT.

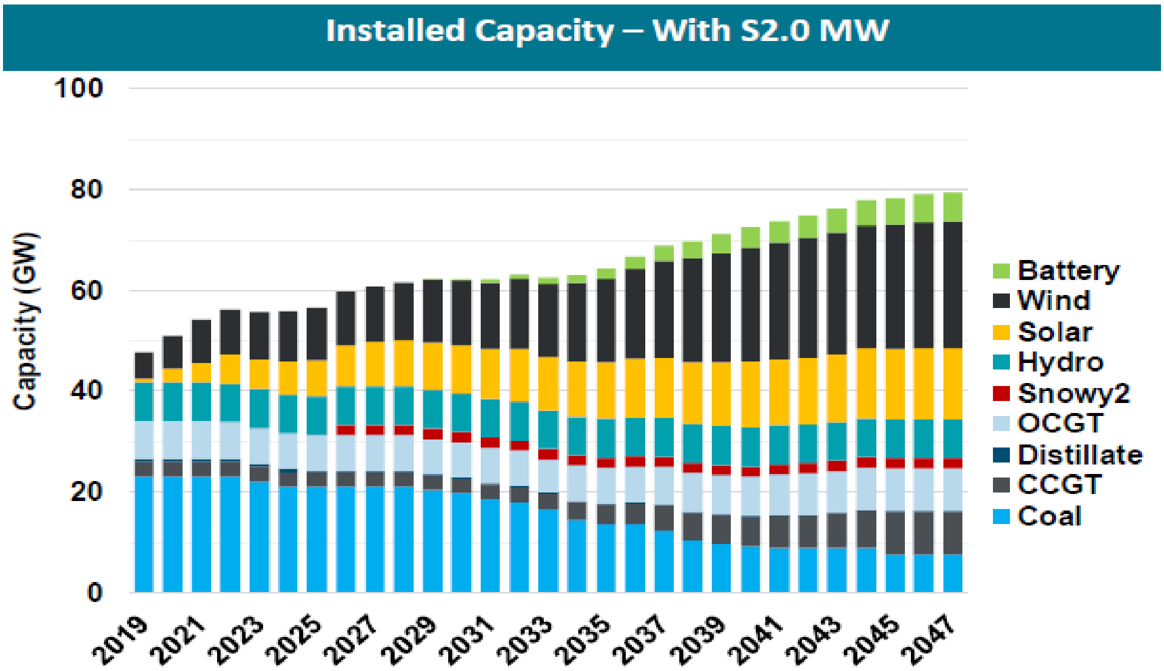


Figure 4.2 MJA modelling – installed capacity with Snowy 2.0 over time

v Supply side options and costs considered in MJA modelling

Lithium ion battery and gas plants were both considered the two possible next best alternatives to Snowy 2.0's capabilities. The full list of generator options considered in the MJA modelling were as follow:

- high efficiency low emission coal plant;
- gas plant – CCGT;
- gas plant – OCGT;
- gas plant – reciprocating;
- solar generation; and
- wind generation.

The main storage providers in the NEM that were considered in the modelling were as follows:

- Large scale pumped hydro schemes. There were only two:
  - Snowy 2.0 which includes the potential further development of Snowy 3.0; and
  - Battery of the Nation – Basslink II plus potential developments to the hydro systems in Tasmania. This is supported by the Australian and Tasmanian governments and has economics that requires Riverlink to be developed (which is near being financially committed) and increased VRE development. Battery of the Nation has not been costed and has unknown economics.
- Lithium Ion Batteries. Batteries were the principal storage technology developed in the AEMO ISP modelling, and possibly are the most direct competitor to pumped hydro storage in the NEM. However, on the current cost curves, batteries with storage hours of over 4 hours will not be economic from spot price revenues until past 2040.
- Small scale pumped hydro schemes. The geography of Australia limits the number of sizeable and economic sites. Two that were considered included:
  - Kidston in northern Queensland (200 MW and 8 hours of storage); and
  - Cultana in South Australia (up to 250 MW). The Kidston project was assumed to be developed in the MJA modelling.

vi Lithium ion battery as the next best alternative

Not all value that a battery or storage can provide will be translated into a corresponding revenue stream. For example, reducing the costs of coal-fired generator ramping does not appear as a revenue stream.

However, the potential value and revenue streams for batteries that can be modelled and the approach to this assessment of the respective revenue streams includes:

- spot price arbitrage;
- risk value through sustainable operation (associated with storage availability); and

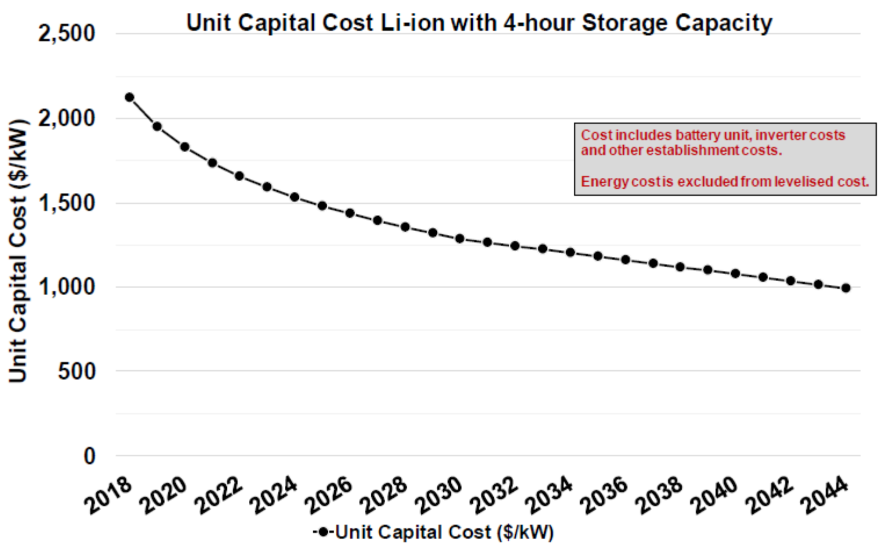
- risk value through the sale (or avoided purchase) of 5-minute cap response products.

The first two of the above increase in value through increased energy in storage.

Another economic factor has been noted:

- batteries can be developed in conjunction with a solar/wind facility. This can have a battery charge directly from the solar plant and discharge when economic. This can have benefits to transmission use of system charges. (if applicable).

The following Lithium ion battery cost curve shown in Figure 4.3 was employed across time on best available, current information on wholesale battery costs.



Battery Costs $/kW/year

Battery costs are more appropriately expressed as $/kW/year based on a specified level of storage (usually expressed as hours of operation when storage is full).

Source: Marsden Jacob Associates

Figure 4.3 MJA modelling – Lithium ion learning cost curve

The development of battery storage is complex. The issue with battery storage is that battery storage (with limited hours of storage) is and will likely continue to enter despite batteries currently not being economic and an outlook (based on the forward cost curves) that batteries will not be economic until past 2040 (for storage with hours of storage over about four hours).

On the basis that batteries will be required to support VRE entry, the analysis concluded batteries will likely enter through the following means:

- limited storage with a solar or wind generator to smooth the VRE profile;
- government-sponsored for reliability and security; and
- by regulation. This would require VRE enter to be with a battery for daily smoothing (such as to address minimum load issues) and security post 2030. This would be influenced by other storage such as Snowy 2.0.

The economics of batteries would require very high arbitrage revenues and it is unlikely that there would be a surplus of battery storage competing for VRE charging energy. Consequently, gas generation would form an important component of firming and price setting.

i OCGT and CCGT gas as the next best alternative

OCGT and CCGT gas generation will likely be needed to provide the firm capacity shortage resulting from the closure of coal plant and the limited expected battery development. MJA economic modelling shows that gas generation is the next best alternative under most scenarios rather than Lithium Ion battery technology due to the latter's constrained energy duration.

ii Summary of key benefits

Snowy 2.0 would result in benefits distributed to the wholesale market, retailers, and consumers. The scale and centralised location of Snowy 2.0 in the NEM enables the system stability, energy reliability and firming capability benefits to be enjoyed by all segments of the NEM as summarised in Figure 4.4.

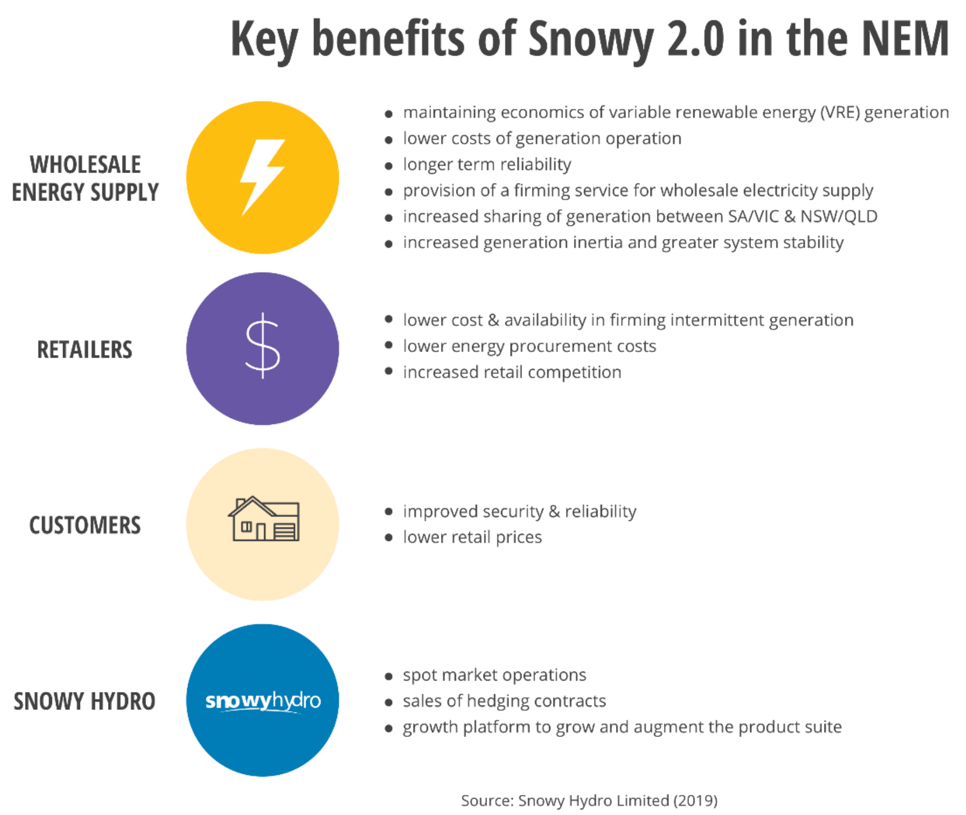


Figure 4.4 Benefits of Snowy 2.0 by market segment

4.2.1 Alternatives to Snowy 2.0

If Snowy 2.0 is not developed, the likely alternative is that a combination of gas-fired and diesel peak electricity generating plants would be built.

Compared with other alternatives, Snowy 2.0 provides:

- increased supply of energy generation and competition for the NEM putting downward pressure on energy prices;
- increased efficiency of the NEM by absorbing excess energy;

- increased storage capacity, longer lifespan for storage, and cheaper full life cycle cost when compared to current lithium-ion storage batteries;
- more efficient dispatch of electricity to major load centres and less emission generation when compared to traditional electricity generating plants; and
- improved security and reliability of supply when compared to the intermittency of primary renewable energy sources (such as wind and solar).

While Snowy 2.0 is a critical project for the NEM, more developments will be needed to meet the future needs of a decarbonising NEM. Other pumped-hydro projects, gas and diesel peakers, commercial scale batteries and demand-side solutions will also be needed.

5 Summary and conclusion

The NEM is undergoing a paradigm shift with significantly more renewables development brought about by more urgent action on climate change, coal-fired power station closures due to asset age or damage, and increases in demand. Measures are required to ensure ongoing energy system security and reliability.

The development of Snowy 2.0 would provide the infrastructure for new capacity through additional pumped storage within the Snowy Hydro scheme.

Snowy 2.0 is a critical project for the NEM as it moves to a low-emissions future. As the transition to renewables accelerates, reliable supply cannot be achieved without large scale energy storage. Snowy 2.0 is the least cost option to build large scale storage and is centrally located between the NEM's two biggest load centres, Sydney and Melbourne.

Snowy 2.0 would build on the Snowy Scheme's existing capabilities and meet the needs of the market and consumers by providing fast-start, clean energy generation to address supply volatility, as well as fast-start capability and large-scale storage to address the intermittency issues associated with renewables.

The high degree of urgency with which Snowy Hydro is progressing the project reflects the rate of change being experienced across the NEM and the critical need for the energy market products that Snowy Hydro sells. The falling costs of new renewable projects makes them economically favourable, even with a cost added for 'firming'.

As the transition to renewables accelerates, the need for energy storage will only increase and pumped-hydro projects across the NEM, gas and diesel peakers, commercial scale batteries and demand-side solutions will all play a role.

Snowy 2.0's 350,000 MWh or 175 hours of energy storage is enough to underpin the stability and reliability of the NEM even during prolonged weather events, such as wind or solar 'droughts'. The Independent Review into the Future Security of the National Electricity Market - Blueprint for the Future (Finkel et al 2017) (also known as the Finkel review) concluded that a secure power system is a necessary condition for a reliable supply of electricity to consumers and recommended options for improving security, including large-scale pumped hydro-electric storage.

Snowy 2.0 would bring much-needed competition to the market by not only adding new generation supply but also underpinning the supply of additional 'firmed' energy. This will encourage new entrants to build more VRE which will place downward pressure on peak energy prices, and provide economic benefits to the consumer.

In addition to the above, Snowy 2.0 would also:

- reduce generation variation that would previously have been provided by existing coal- and gas-fired power stations;
- have generation capacity ready to operate when needed, such as during periods of very high demand and/or during periods when existing major generators are out of service (either due to planned outages or due to unforeseen breakdowns); and
- provide generation through periods of drought when conventional hydro-generation is lower than under normal conditions and the daily opportunities to pump are reduced.

It is considered that Snowy 2.0 will provide a significant contribution to the NEM's reliability and stability to ensure an orderly transition as the economy decarbonises away from traditional energy sources (through the retirement of coal-fired power stations) and towards renewable energy.

Snowy 2.0, with its 2,000 MW of electricity generation and quick-start capabilities for delivery of about 175 hours of storage (350,000 MWh), is well-positioned to ensure the reliable and secure electricity needed for NSW’s continued economic strength. For these reasons, it is considered that Snowy 2.0 is consistent with the broader objectives of the NSW Renewable Energy Action Plan and the NSW Climate Change Policy Framework as well as Australia's commitments under the Paris Agreement.