Final report from the Energy Security Taskforce

NSW Chief Scientist & Engineer

19 December 2017

Chief Scientist & Engineer

The Hon Donald Harwin MLC
Minister for Energy and Utilities
52 Martin Place
SYDNEY NSW 2000

Dear Minister,

Final Report of the Energy Security Taskforce

In February 2017 you asked me to chair the NSW Energy Security Taskforce to advise you on the resilience of the NSW electricity system and provide recommendations on areas of vulnerability, particularly considering extreme weather events in the context of climate change.

I am pleased to submit the final report of the Taskforce. This report looks at the longer-term resilience of the NSW electricity system in the context of a National Electricity Market that is going through a period of considerable change and innovation.

The report particularly looks at areas where the NSW Government can do things within its remit to support the market to operate effectively, and where it can encourage focus on particular issues of strategic importance at COAG Energy Council.

I would like to thank and acknowledge my Taskforce colleagues, Mr Dave Owens and Dr Brian Spalding. I would also like to thank the Taskforce's secretariat, staff within the NSW Department of Planning & Environment, and everyone who provided information or made submissions to the review.

Yours sincerely,

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19 December 2017

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EXECUTIVE SUMMARY

The NSW Minister for Energy and Utilities established the Energy Security Taskforce in February 2017, chaired by the NSW Chief Scientist & Engineer, to advise on the resilience of the NSW electricity system and how well NSW manages energy emergencies.

The Initial Report of the Energy Security Taskforce (May 2017) concluded that there are indications that when electricity demand is very high, generally during extreme hot periods, the reliability of generation supply and thus system reserves may not be as high as expected. This led the Taskforce to make a series of recommendations that needed urgent attention before the 2017-18 summer, and to ask whether the market incentives that are supposed to drive reliable supply are operating effectively.

This second and final report of the Energy Security Taskforce examines issues that need to be addressed to strengthen the longer-term resilience of the NSW electricity system. The report considers the challenges of achieving a stable and reliable power system, which is characterised by low electricity costs and low emissions, while managing the transition to new forms of generation technologies in a changing environment.

The Taskforce examined a series of issues including:

- emerging risks to the electricity system, including from extreme weather
- market or regulatory barriers to new capacity entering the market and the opportunities associated with technology and new business models that could improve security and reliability in NSW
- risks to NSW and the Sydney CBD in particular of a black system event and how the Government might reduce these risks and ensure NSW is well prepared in the unlikely event of a state-wide blackout.

It is clear that the electricity system is in a period of transition, innovation and reform. The market response to the changes arising from the Independent Review into the Future Security of the National Electricity Market (Finkel Review) and the proposed National Energy Guarantee will evolve and become clear over time and must be watched closely so that governments can have adequate assurance of future reliability. However, this transition will also bring great opportunity for innovation and hence productivity growth.

In general, the Taskforce identified a series of risks and emerging issues for NSW that the Government needs to monitor closely.

Risks from extreme weather are likely to continue to increase and test the resilience of the system. This includes risks from heatwaves that are projected to increase in frequency, duration and intensity, as well as drought, intensifying rain and an increasing number of fire danger days.

There has been much public discussion about the planned closure of AGL's Liddell power station in 2022. However, while AEMO is projecting an increased risk of unserved energy in NSW following the closure of Liddell, it is not predicting that levels of unserved energy in NSW will breach the 'reliability standard'.

The risk of supply not being able to meet demand in NSW in the medium term is largely limited to a small number of hours late in the day on a small number of days (most likely in February) each year when demand is high, and unexpected coincident events, such as plant failure or fuel unavailability, may reduce available reserves. This will tend to coincide with prolonged periods of extreme heat when high demand is driven by air conditioning and when the heat poses extra operational challenges for generation and transmission infrastructure.

Several generators told the Taskforce that in their view the market was already working to incentivise appropriate maintenance of existing plant and to bring forward new investment in both dispatchable and intermittent generation resources in NSW before 2022. However, the NSW Government, along with other governments involved in the National Electricity Market (NEM), will need to be watching the market closely to see that these plans are implemented and to have assurance that new generation with the right capabilities is coming online where and when it is needed.

The Taskforce also observed that the types of market players and ways of interacting with the market are becoming more diverse, as large energy users seek to take more control over their energy costs and new business models emerge to hedge businesses against energy costs and supply risks better.

In this environment of change, the Government should ensure that it is well informed about emerging risks and well prepared to take steps if needed to support the market to work effectively. It will be important for the Government to use the levers within its control to support the market to operate, and avoid directly intervening, for example, by funding new generation capacity which may have the unintended consequence of discouraging private investment in the market.

This period of transition creates opportunities for innovation to increase the future reliability and security of the electricity system. The Taskforce has identified a number of areas where the Government can support innovation including by removing regulatory barriers to the deployment of new technologies and leveraging the research strengths in NSW universities and other research institutions.

The Government can also be on the front foot to anticipate new types of energy infrastructure that may be proposed for NSW, for example, new pumped hydro development, and be proactive in preparing to assess the environmental implications of such developments that may not have been explicitly considered before.

The Government should also continue its leadership role at COAG and COAG Energy Council to encourage focus on issues of particular importance across the whole NEM, for example, inter-regional transmission and cyber security issues.

Finally, since the Taskforce's Initial Report, the Government through the Department of Planning & Environment has done a significant amount of work ahead of the coming summer to improve the linkages between management of the energy system and the emergency management structures in NSW. This includes new legislation that will improve the processes for enacting emergency powers if needed, and appointing new senior staff to key positions. Substantial progress has been made and this work should continue to be prioritised.

In this report, the Taskforce examined the risks posed by potential black system events. While generally considered unlikely in NSW, the Taskforce is concerned that NSW is not well prepared for a prolonged black out or a black system event, particularly the Sydney CBD where load restoration following a black system event would take a long time. Such an event would lead to significant economic costs at the state and national level, and pose health and safety risks to the community.

RECOMMENDATIONS

The next decade will be a period of transition and disruption for the energy market, which will create opportunities for innovation.

The Australian Energy Market Operator (AEMO) is warning that supply and demand are tightening and there are emerging risks that need to be managed. While a national way forward is emerging to provide investment certainty and mitigate these risks, the market impact of these reforms will take some time to be realised. Therefore, the NSW Government needs to be alive to the short-term risks over the coming summers and manage risks proactively when needed.

The Taskforce's recommendations are informed by the principle that the Government should allow the market to work through this transition. This means avoiding directly intervening or investing in new generation or other electricity infrastructure. However, the Government should do what it can within the state and through the COAG Energy Council to remove regulatory barriers and streamline processes to ensure the signals are there for the right type of new investment, in the right places at the right time.

In light of these issues, the Taskforce makes two types of recommendations:

- things for the NSW Government to do
- areas where the NSW Government can promote focus on issues of strategic importance through COAG and COAG Energy Council.

Recommendation 1
Monitoring and information: That the Government establish mechanisms to monitor the electricity system and the market to ensure the Government has sufficient warning of any emerging risks, particularly those that fall within the remit of the Government, and can have assurance about ongoing reliability of the system in NSW. This can inform any decisions about whether actions at the Government level may be required to support the effective functioning of the market.

This should include:

a) **path to closure and maintenance for large plant:** that Government engage with generators to understand better the path to closure of ageing plant, likely derating of plant over time, and the risk of plant being offline for prolonged periods or closing before expected
b) **fuel:** that Government engage with generators to understand and monitor risks to the fuel supply chain. The Government should prepare relevant regulatory arrangements that may be required in a fuel supply emergency to ensure fast response if required (e.g. moving coal by road)
c) **energy market monitoring:** that Government monitor electricity market data to watch for trends in fairness and efficiency of the market
d) **transparency of the contract market**: that Government work with the energy market bodies to improve transparency of the contract market so that Government can have visibility about how risks are managed and how the contract market is driving investment in sufficient generation capacity and operational decisions to meet demand, including peak loads. This could be achieved through the requirements placed on retailers through the National Energy Guarantee
e) **investment pipeline:** that Government watch the balance between the amount of generation leaving the system and new generation coming online, including transmission and distribution system adequacy for new generation. This should include watching the investment capital structuring for energy investments. If issues

are identified, the Government should look at where it can take action that will support the market to bring forward new generation capacity or manage demand better

f) **extreme weather signals:** that Government establish processes to watch for warning signs and patterns in extreme weather events, and continue to support the work of the Office of the Environment and Heritage in filling research gaps about the risks of future extreme weather to energy infrastructure and consequent interdependencies for the operation of essential services

g) **risks from other states:** that Government establish mechanisms for keeping informed of developments in other states that may pose risks to the NSW electricity system.

Recommendation 2
Strategy: That the Government develop an electricity strategy for NSW that identifies objectives for an ideal electricity system in NSW and can inform trade-offs, decision-making, regulatory arrangements, and program design in NSW.

The strategy should also inform the NSW Government approach to negotiations at COAG Energy Council, including to promote the review and effective operation of the Australian Energy Market Agreement.

Recommendation 3:
Demand response focus over next period: That the Government focus on improving uptake of efficient demand management options to manage risks during peak demand periods and over the longer term to encourage more efficient use of the network and reduce costs.

Particular focus should be given to mapping out the technical capacity of the NSW system to conduct effective demand response and load shifting at scale to manage security risks during peak demand periods and accelerate the roll out of technology that will address any limitations. This will include supporting the work of AEMO and network businesses to improve the visibility of distributed energy resources in NSW, including those that may be of use during an energy emergency.

The Government should also establish a work program to examine barriers to uptake of distributed energy resources and demand response opportunities, for example, by low-income households, tenants, and apartment residents.

Recommendation 4
Enabling environmental permissions: That the Government do pre-work on environmental permissions for likely new styles of energy infrastructure, for example pumped hydro, in order to facilitate the smooth adoption and development of appropriate energy technologies.

Recommendation 5
Innovation: That the Government encourage innovation in the energy sector by focussing on: product and safety standards; removing regulatory barriers; open access to data; leveraging current research expertise and building research capacity further; and the workforce skills needed for a changing energy system.

This should include:

a) **standards:** that Government ensure safety and product standards keep up with emerging energy technologies and international best practice, and are appropriately designed to protect consumers and enable more efficient and effective technologies to be developed and commercialised, including for export

b) **regulatory barriers**: that Government identify regulatory barriers at all levels for new generation or network technologies, or new business models that will contribute to greater security and reliability. For example, the Government should review regulatory arrangements at the NSW level to ensure efficient regulation of network innovations such as microgrids and other forms of embedded networks which have the potential to improve resilience of the NSW electricity system. This should have a particular focus on consumer protections, accessibility for regional communities, reliability and performance requirements, and safety issues
c) **energy data:** that Government facilitate more easy, open access to electricity data to inform decision making by governments and market participants at all levels from households to large organisations. This would be complementary to data provided to the market by AEMO and other market bodies
d) **research and development**: that Government encourage and promote dynamic and long-term partnerships between Government, industry and universities and other research institutions to support the NSW energy sector to remain at the cutting edge of technological developments in energy. This should have a particular focus on getting costs down, building on the research strengths of the state, and leveraging funding from the Commonwealth and other sources
e) **skills:** that Government encourage employers to partner with and leverage universities and vocational education and training providers to develop curricula that will deliver the targeted pipeline of skills and capability required to meet the future needs of the energy system.

Recommendation 6
Transmission corridors/generation zones: That the Government encourage COAG to ask the Energy Security Board to unpack the Finkel Review recommendation to develop "an integrated grid plan to facilitate the efficient development and connection of renewable energy zones across the National Electricity Market" and provide advice to jurisdictions about the role of land reservation for transmission corridors or renewable generation zones across jurisdictions.

Recommendation 7
Cyber security: That the Government encourage COAG to commission ongoing studies on cyber risks and possible responses right across the system including transmission, distribution, retailers' communication platforms, smart meters and other customer-facing demand management technologies and address any identified risks.

Recommendation 8
Emergency management: That the Government improve communications and more proactively drive processes to ensure essential services and sensitive loads are managed effectively in an energy emergency.

This should include:

a) **load shedding procedures and communications**: that Government through the Jurisdictional System Security Coordinator make sure load shedding protocols minimise impact on sensitive loads such as essential services and central business districts and that the Energy and Utilities Services Functional Area Coordinator be more proactive in communicating to the public and private sectors (leveraging the Trusted Information Sharing Networks) any new information about load shedding
b) **impacts of a black system:** that Government get a better understanding of the potential economic impact of an extended black system event and identify the risks and vulnerabilities within the public and private sectors that need to be planned for and managed to minimise impacts on the economy and the health and safety of the community

c) **system restart procedures:** that the Government:
    - proactively work with AEMO, TransGrid and the distribution businesses to enhance the black start load restoration plan for NSW so that it prioritises load of strategic importance and estimates likely timeframes for load restoration
    - coordinate regular black start exercises between relevant NSW and ACT Government energy and emergency management representatives, AEMO, TransGrid, distribution businesses and generators
    - highlight at COAG Energy Council the need to assess the adequacy of the existing system restart procedures in each state and territory with specific consideration being given to the time anticipated to bring major economic centres back online

d) **back-up fuel supplies**: that Government develop an internal NSW Government register of back-up generation fuel supplies in NSW and the ACT to identify where supplies would come from, how they would be prioritised, and how long they would last during a black system event

e) **NSW Government Continuity Plan**: that Government, through the Office of Emergency Management, the Department of Premier & Cabinet, and the Department of Planning & Environment, develop a whole-of-government business continuity plan for responding to longer-term, widespread power outages and/or black system events.

Recommendation 9

Governance: That the Government identify any gaps in emergency response/management arrangements post-leasing of transmission and distribution businesses. Government should give consideration to the role of the Jurisdictional Responsible Officer and determine whether any additional emergency management or information sharing protocols need to be put in place given the role now sits within a leased entity, and not within a Government organisation.

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1 INTRODUCTION

The NSW Energy Security Taskforce was established by the Minister for Energy and Utilities in February 2017 after the so called ‘hot day’ when power use in NSW had to be curtailed to one large consumer to maintain the security of the electricity system.

The Taskforce has been asked to advise the Minister on the resilience of the NSW electricity system in the face of changing risks and extreme weather events. The Taskforce is chaired by the NSW Chief Scientist & Engineer, Professor Mary O’Kane. Other members of the Taskforce are Mr Dave Owens, former NSW Police Force Deputy Commissioner, and Dr Brian Spalding, Commissioner of the Australian Energy Market Commission. The full terms of reference for the Taskforce are at Appendix 1.

The Taskforce delivered its Initial Report to Government in May 2017. This Initial Report had a particular focus on what the Government needed to do urgently to prepare for possible energy risks in the coming summer.

The Government accepted all seven recommendations made by the Taskforce in its Initial Report and the Department of Planning & Environment (DPE) has made significant progress in implementing these recommendations. Key progress includes:

- the development of the *Electricity Supply Amendment (Emergency Management) Act 2017* to improve the speed and ease with which the Government can respond to an energy emergency
- strengthening the Energy and Utility Service Functional Area within DPE to improve the structural processes underpinning the management of energy emergencies in NSW to ensure a stronger link between energy management and emergency management
- the development of a new Energy and Utility Service Functional Area Supporting Plan and commencement of drafting an Electricity Supply Emergency Sub Plan
- the coordination of energy emergency management exercises involving both emergency management and energy personnel
- the development of communication materials to assist the public prepare for the upcoming summer
- establishment of a working group to develop protocols for government agencies in NSW and the ACT to reduce electricity demand and increase behind-the-meter supply during peak periods of energy use
- appointment of new staff to key senior positions within the energy team in the Department.

This second and final report of the Taskforce takes a longer-term view of the security and reliability risks NSW may face as the National Electricity Market (NEM) and the NSW electricity system transitions. The Taskforce also looked at the strategic opportunities for NSW during this period of change.

1.1 CONTEXT

Since the Taskforce delivered its Initial Report there have been significant national developments in the electricity sector, most notably: the finalisation of the ‘Finkel Review’; the agreement at COAG to adopt 49 of 50 of the recommendations from that review; the establishment of the Energy Security Board; and the subsequent proposal from this new board for a National Energy Guarantee.

Other developments include the closure of the 1,600 MW Hazelwood power plant in Victoria, the announcement of a feasibility study for increasing the capacity of hydro power generation in the Snowy (Snowy 2.0), and the South Australian Government commissioning new sources of capacity including a grid-scale battery as an emergency measure for this summer.

These developments have been accompanied by increasing concerns about rising energy prices for consumers, fuel availability and future reliability of the system as large, ageing, coal-fired generators leave the system at the end of their operating life.

There has also been significant commentary from industry, businesses groups, politicians, think tanks, the press, and the community about the merits or otherwise of these various developments.

This is a period of disruption, transition, innovation and reform for the NEM. The transition is being driven by the market reform proposals as well as rapid technology developments, the falling cost of new generation technologies and community and business preferences about managing energy use. This disruption presents opportunities for innovation (and hence productivity growth) and for NSW to take a leadership role.

1.1.1 Reform in the NEM

Many recent reports, including the Finkel Review, conclude that changes are needed in the NEM to safeguard future security and reliability of the system and take advantage of the wave of technological change to reduce emissions while keeping costs as low as possible.

The Finkel Review stated “Australia has a once-in-a-generation opportunity to reshape our electricity system for the future. A wave of technological change is sweeping across us. The key driver – innovation – cannot be reversed. Taking advantage of these technological changes requires a culture of proactively developing new approaches, and ways of thinking to facilitate the next wave of development rather than hold it back” (Commonwealth of Australia, 2017).

49 out of 50 of the Finkel Review recommendations have been agreed by COAG and the new Energy Security Board has been established. These recommendations aim to improve security and reliability of the NEM, lower emissions and reward consumers for their role in maintaining reliability and security of the system. The recommendations also address many of the areas of emerging risk identified in the Taskforce’s Initial Report.

A significant development following the release of the Finkel Review and the Federal Government’s rejection of the recommendation to have a Clean Energy Target has been the Energy Security Board’s proposal for the National Energy Guarantee. This is designed to ensure the “necessary level of flexible and dispatchable resources are maintained in the NEM” (Energy Security Board, 2017).

Importantly, the proposed mechanism aims to use the existing contract market to draw through both sufficient dispatchable capacity into the system as well achieve emissions reductions. It is designed to provide the right signals to the market to bring forward dispatchable, flexible capacity of various kinds and, most notably, it brings together energy reliability and emissions reduction into one mechanism.

While further development of the National Energy Guarantee is proceeding for COAG Energy Council, for the purposes of this report the Taskforce assumes that some form of market mechanism that addresses both dispatchability and emissions reduction will be agreed by the NEM jurisdictions. In any case, a mechanism will be needed and NSW should continue to advocate to achieve this nationally.

Already, there have been several recent developments progressed by the Australian Energy Market Commission (AEMC) that will contribute to improving security and reliability in NSW and the NEM more broadly including:

- a new rule for system strength requiring networks to maintain minimum levels of system strength to keep the system stable – one aspect of this rule is to place an obligation on new connecting generators to 'do no harm' to the level of system strength necessary to maintain the security of the system (1 July 2018 commencement)
- a new rule for inertia which places an obligation on transmission network service providers (TNSPs) to procure minimum required levels of inertia or alternative frequency control services (1 July 2018 commencement)
- development of a new rule intended to align operational dispatch and financial settlement within the NEM at five minutes which will commence in July 2021.

1.1.2 Market trends

In addition to the major reforms to governance of the NEM, consumer and investor behaviour in the market is already driving change. In brief some of these key trends include:

- many commercial and industrial users shifting their approach to energy by purchasing energy directly from the source rather than through large retailers, investing in their own generation, and hedging against the risk of high spot prices by investing in back-up generation
- apparent lack of investor interest in new coal-fired generation driven by investment risk, falling cost of renewables, and Corporate Social Responsibility/Environmental Social and Governance risk management policies of potential investors
- new business models emerging that give consumers more direct control over their energy use, and seek new solutions to managing supply and demand through the system at lower cost.

1.1.3 NSW Government initiatives

The NSW Government has a range of initiatives underway to improve resilience of the NSW electricity system. Some of these include:

- the Government provided $7.5 million to the joint ARENA/AEMO project to procure demand-response capacity for the coming summer – successful projects in NSW should make 61 MW of demand response available in NSW this summer, and 80 MW by 2020
- the Government through the Office of Emergency Management is developing a Critical Infrastructure Resilience Strategy for NSW which is focused on ensuring the state is able to continue the provision of essential services during emergencies, including the provision of electricity (Emergency NSW, 2017)
- the Office of Emergency Management completed the 2017 State Level Emergency Risk Assessment which examines 12 hazard scenarios to which NSW is exposed and highlights the importance of continued mitigation, prevention, preparedness, response to and recovery from these hazards which include infrastructure failure which on the whole relates to power outages (NSW Government, 2017a).

1.1.4 Other relevant work and reviews

The energy system is subject to many detailed reviews and evaluations and the Taskforce has undertaken its review with consideration of these other reports. Some of the key reviews relevant to the Taskforce's work include:

- the Energy Security Board's 'Health of the NEM' December 2017
- the AEMC's Reliability Frameworks Review
- the AEMC's 2017 Energy Sector Strategic Priorities review

- the Australian Competition and Consumer Commission's (ACCC's) Retail Electricity Pricing Inquiry (final report due June 2018), and its Gas Inquiry 2017-20
- Commonwealth Climate Change Review due by the end of 2017
- energy security reviews in Queensland, Tasmania and South Australia.

1.2 PROCESS OF THE REVIEW

Throughout the course of the review the Taskforce had 23 meetings and consulted with the stakeholders listed at Appendix 2. In completing this review the Taskforce:

- commissioned analysis from Data 61, Professor Mike Sandiford from the University of Melbourne, and the Capital Markets Cooperative Research Centre
- examined the implications of the Finkel Review recommendations and looked closely at other relevant reviews including the ACCC's preliminary report on retail electricity pricing, various reports from the market bodies, reports of the Queensland and Tasmanian Energy Security Taskforces, and the Independent Review of the Extreme Weather Event South Australia
- analysed available data on the longer-term supply and demand outlook and investment pipeline in NSW
- examined extreme weather risks using analysis from NSW and ACT Regional Climate Modelling (NARCliM), the ARC Centre of Excellence for Climate Extremes headquartered at the University of NSW, the Bureau of Meteorology (BOM) and the Office of Environment and Heritage (OEH)
- consulted with relevant participants and examined available market material on the energy investment sector
- reviewed available emergency protocols and conducted a series of consultations with the public and private sectors to examine the state's preparedness for an extended power outage.

The Taskforce also called for public submissions to inform the review. A total of 17 submissions were received. A list of the submissions received is at Appendix 2.

On 31 October the Chief Scientist & Engineer provided evidence to the Legislative Council Select Committee on Electricity Supply, Demand and Prices in NSW.

1.3 STRUCTURE OF THIS REPORT

The remainder of this report outlines areas of risk and opportunity for NSW as the electricity system continues its transition.

Chapter 2 examines potential areas of risk for NSW in the short and longer term as the market transitions and it suggests issues that the NSW Government should be keeping a close eye on.

Chapter 3 analyses the barriers (market, technical or regulatory) that the NSW Government can act on to enable innovation that will improve security and reliability in NSW.

Chapter 4 describes potential risks associated with extended load-shedding events or a black system event in NSW, including emergency management issues.

2 EXAMINATION OF RISKS

The Taskforce was asked to advise on risks to the reliability and security of the NSW electricity system, particularly with reference to extreme weather events in a changing climate. This chapter examines the key areas of risk and what the NSW Government should be monitoring to be well informed and prepared to manage these risks, and support the effective operation of the market through this period of transition.

There are four key elements essential for reliable supply of electricity to consumers:

- a secure power system that operates within its technical parameters, even in the event of a fault such as the loss of a large generator
- reliable transmission, including interconnection between regions
- reliable distribution
- sufficient generation to meet demand at any given time, plus a margin for contingencies.

Electricity in eastern Australia and in South Australia is delivered through the NEM. The market is built around a number of drivers and incentives working together to support reliability of the electricity system. Within this market there are issues within the domain of the NSW Government, and COAG Energy Council, that can support the market to work most effectively and efficiently.

As discussed in the Initial Report, the electricity system overall has generally been robust, delivering sufficient generation to meet demand with capacity in reserve. Historical instances of unserved energy have been rare. However, there are indicators that the supply and demand balance is now tightening and new risks are emerging.

Under normal conditions the NSW system is generally secure and reliable. However, the system can be vulnerable during the infrequent and short duration periods of peak demand when there may be limited reserves available and the system can be significantly affected by events in other NEM regions, the failure of large generation plant or extreme weather events. It is important to note that, at the moment, the risk in NSW is largely confined to only a small number of hours a year when demand is unusually high, generally during extended heatwave conditions.

The risk profile for NSW will change in the lead up to and after the planned closure of the Liddell power station in 2022. As the NSW system continues to transition through the retirement of traditional thermal plant and increased uptake of intermittent renewable generation sources, the key priority for the Government is to be well informed and well prepared for potential risks so that, if necessary, informed decisions can be taken that support the operation of the market and do not unintentionally prevent the market from working effectively.

2.1 RELIABILITY SETTINGS IN THE NEM

The AEMC explains that a reliable power system is one that has “enough generation, demand-side and network capacity to supply customers with the energy that they demand with a very high degree of confidence” (AEMC, 2017g).

Among other things, this requires efficient investment, retirement and operational decisions by market participants leading to an adequate supply of dispatchable capacity (AEMC, 2017g).

There are a number of incentives within the market that are intended to drive participant behaviour. In particular, decisions about investment in dispatchable capacity are made in response to price signals and incentives through the spot and contract markets (AEMC, 2017g).

Higher prices in the spot market when supply is scarce are expected to encourage new investment, and also to provide signals about the kind of generation that is most needed in the market (Wood & Blowers, 2017a).

The contract market then allows participants to hedge uncertainty and future price risk, although some participants also seek to achieve this through vertical integration (AEMC, 2017g).

The electricity system cannot be guaranteed to be 100% reliable. The reliability standard sets a planning benchmark for generation sufficiency based on an amount of expected unserved energy[1] each year. The reliability standard is currently set at 0.002% expected unserved energy (e.g. out of 100,000 MWh of demand, no more than 2 MWh of outage could be expected (AEMC, 2013)).

Performance standards for the reliability of transmission and distribution networks are set separately by individual jurisdictions.

The reliability standard is underpinned by four reliability price settings that aim to limit exposure to extreme prices whilst driving investment in generation that is sufficient to ensure reliability (AEMC, 2017c). These settings are:

- the market price cap (currently $14,200/MWh)
- the cumulative price threshold (maximum total price for one week is currently $210,800)
- the administered price cap (currently $300/MWh)
- the market floor price (currently -$1,000/MWh).

The reliability standard and settings are currently under a regular statutory review by the AEMC's Reliability Panel which will be completed by 30 April 2018, in which it will consider the changes being experienced in the NEM (withdrawal of coal generation, increased renewable/intermittent generation, new technologies and increased prices) (AEMC, 2017f). The draft report, released on 21 November 2017, found that the "current reliability standard and settings are … achieving their purpose and are likely to continue to do so out to 2023/24" (AEMC, 2017c). The draft report notes that not changing the settings and standard will provide some level of regulatory stability "given the current impact of policy uncertainty on investor confidence and the rapid technological change underway in the national electricity market" (AEMC, 2017c).

The market also has mechanisms for intervention if judged necessary by AEMO to manage reliability, for example through use of the Reliability and Emergency Reserve Trader (RERT). However, historically interventions have been rare. The reserve capacity under the RERT mechanism has only been sought by NEMCO (AEMO's predecessor) or AEMO four times and has only been actually used once (AEMC, 2017g). The Taskforce notes that capacity under the RERT has been procured for Victoria and South Australia for the coming summer, and was used in Victoria on 30 November 2017[2].

[1] "Unserved energy is the amount of energy that cannot be supplied to consumers, resulting in involuntary load shedding (loss of customer supply), because there is not enough generation capacity, demand side participation, or network capability, to meet demand." (AEMO, 2017d)

[2] AEMO Electricity Market Notice: 60142 30 NOV 2017 15:20 - MARKET INTERVENTION: RERT Activated, AEMO activated the reserve contracts to maintain the power system in a reliable operating state. The reserve contracts were activated at 1530 hr 30/11/17 and were forecast to apply until 2130 hrs 30/11/17.This followed LOR2 notices issued for the region (AEMO, 2017i).

Increasing reliability can significantly increase the cost of electricity. Generally, community tolerance is higher for weather related disruptions to power, usually in the transmission and distribution networks, compared with instances where generation issues cause a problem on a blue sky day.

Consumers are willing to pay for reliability, but how much they are willing to pay depends on the sector. A survey of NSW electricity customers noted that they place a “relatively high value on a reliable electricity supply” (AEMC, 2012). When asked about their willingness to pay for 60 minutes less outages a year, 60.8% of those surveyed said they would be willing to pay at least 1% more for improved reliability, with 22% willing to pay 2% or more (AEMC, 2012). When asked about willingness to accept more outages, customers would require a significant discount on their bill to accept poorer reliability (AEMC, 2012).

Socioeconomics also plays a role in tolerance and ability to deal with the costs associated with reliability, in relation to extended outages. This is especially important for low income households, which may be unable to deal with the knock-on costs of the extended outage such as take-away meals and hotel stays (AEMC, 2012).

Another survey on the Value of Customer Reliability (VCR) looked at business customers (AEMO, 2014). This survey found that larger businesses generally had lower VCRs than small and medium businesses. This may be because that they may have a greater ability to mitigate the impact of outages.

The Productivity Commission noted that decisions regarding reliability should be based on the tradeoffs between costs of achieving that reliability versus what customers are willing to pay. It noted that “the price-quality tradeoff is invisible to most consumers”, with most consumers being unaware of how much they pay for reliability or how much they would need to pay to improve it (Productivity Commission, 2013).

2.2 INFORMATION FOR THE MARKET

The operation of the market is underpinned by flows of data to inform market participants and provide signals for investment. For example, AEMO forecasts the potential for unserved energy which provides signals to the market that more capacity may be required to avoid shortfalls that may breach the reliability standard.

AEMO publishes information across a range of timescales to inform the market of where action may be needed. This includes:

- **Projected Assessment of System Adequacy** (PASA)
    - the **Short-Term PASA** is released every two hours and looks at the supply and demand for the next six days in the NEM (AEMO, 2017j)
    - the **Medium-Term PASA** is released weekly and provides forecasts for the next two years (AEMO, 2017j)
    - these models can allow the identification of possible low reserve conditions[3] in regions of the NEM. If a low reserve condition is identified, AMEO will issue a market notice to encourage action by participants - these are known as **lack of reserve notices**
- the **Electricity Statement of Opportunities** (ESOO) provides long-term projections. The report is produced annually to provide a projected 10-year outlook of supply adequacy under a number of scenarios (AEMO, 2017d). The report looks for future possible breaches of the reliability standard. The aim of the report is to provide signals to the market about when and where investment is required in the NEM

[3] Low Reserve Condition – “When AEMO considers that a region’s reserve margin (calculated under 10% Probability of Exceedance (POE) scheduled and semi-scheduled maximum demand conditions) for the period being assessed is below the Reliability Standard.” (AEMO, 2017d)

- the **Energy Adequacy Assessment Projection** (EAAP) models possible energy constraints. This includes water storages during drought conditions or constraints on fuel supply for thermal generation (AEMO, 2017e).

2.3 EMERGING RISKS AND INFORMATION GAPS

The following sections analyse available data about the electricity system in NSW to identify where there may be emerging risks or gaps in information, and where there may be issues within the domain of the NSW Government, or COAG Energy Council, where action can be taken to support the effective functioning of the market.

2.3.1 Supply and demand outlook

While there is generally enough supply to meet demand in NSW, there are some extreme situations, such as during heatwaves, in which reserves can be lower than expected. This section examines data around supply and demand, including demand patterns, current and projected future capacity, and investment trends.

2.3.1.1 Demand patterns

For reliability, electricity generation and distribution must be sufficient to meet estimated maximum (or peak) demand. Generally, demand in NSW ranges between 6,000 and 10,000 MW, but has historically reached a peak of 14,744 MW in 2011.

Through the period 1998-2008 both average and peak demand increased at a relatively constant and predictable rate of around 2% per year (Sandiford, 2017). Figure 2.1 shows that since 2008 average demand has essentially flat-lined, while changes in year-on-year peak demand have become more variable. Also, whilst mean and minimum demand is remaining lower, recently peak demand has begun to increase.

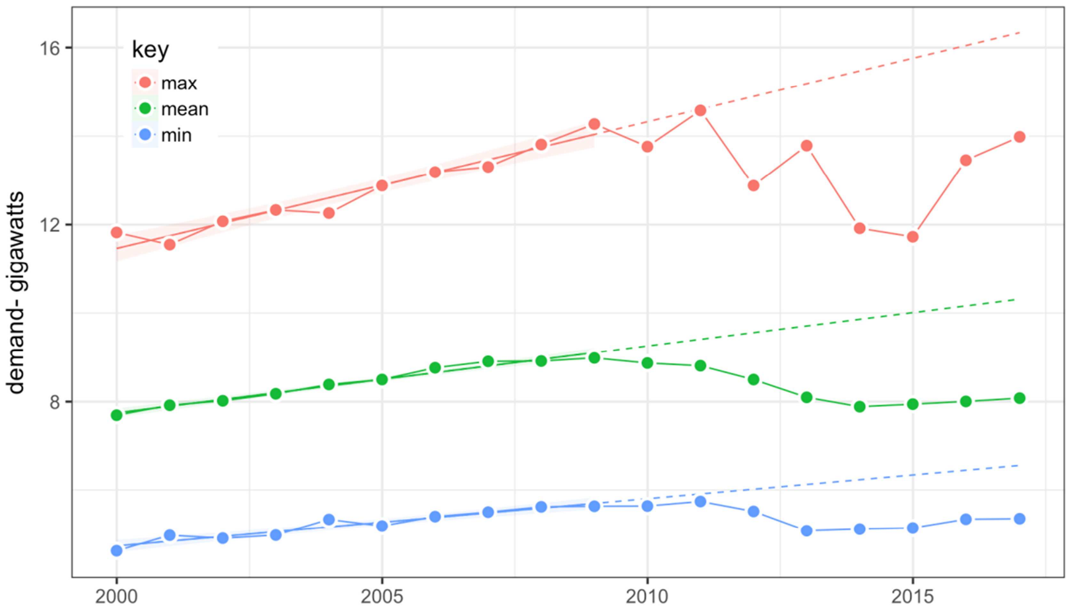

Figure 2.1: NSW demand by financial year in terms of maximum (peak), mean and minimum
Dashed lines show the trends for each projected on the basis of FY 1999-2000 to 2008-2009 growth rates. Source: Sandiford (2017)

As a consequence, projections for electricity demand made in the late 2000s (shown as dashed lines in Figure 2.1) were not realised. This can be attributed to a range of factors such as increased penetration of rooftop solar PV, energy efficiency measures and structural changes in the economy especially during and following the global financial crisis (GFC). Waning demand and low prices associated with growing capacity oversupply in the years following the GFC led to a number of generators, e.g. Mumorah and Wallerwang C in NSW, leaving the system.

Following several years of very low peak demand in the summers of 2014 and 2015, peak demand has increased substantially in the summers of 2016 and 2017, while average demand has remained flat. These changes have resulted in the system becoming increasingly 'peaky', with an overall reduction in the system load factor. The load factor (average load divided by peak load) is a measure of the variability of demand/generation with lower load factors indicating more variability in demand.

The grey line in Figure 2.2 (below) shows how load factors in NSW have decreased over time. Through the early to mid-2000s load factors were reasonably steady at about 65-70%. Since 2008 load factors have been generally declining to less than 60% in 2016 and 2017. The extent of the changing outlook for demand is highlighted by the red line, which shows the ratio of average demand to peak demand outlook based on pre-GFC trends (as shown in Figure 2.1). The increasing year-on-year variability in load factor reflects that year-on-year variability in demand is increasing, while the general downward trend implies less efficient utilisation of the grid.

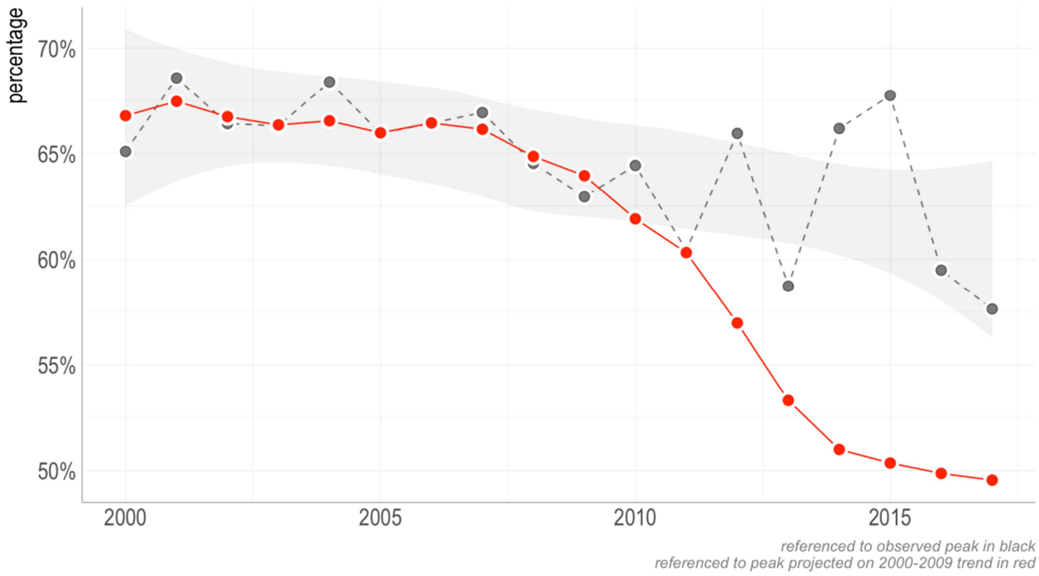

Figure 2.2: Measure of grid utilisation in relation to load factors
Defined as the ratio of mean to peak load (grey) and the mean to projected peak (red) using the trends based on 1999-2000 to 2008-2009 growth rates (as in Figure 2.1). Based on these metrics, over the last decade grid utilisation has become more variable, while decreasing from 65-70% to around 60%. Source: Sandiford (2017).

Weather plays a key role in determining electricity demand and air conditioning is a significant factor in peak electricity demand, with a strong correlation between maximum daily temperature and maximum demand. The most extreme demand events (>13 GW) occur in the late afternoon in summer when the temperatures are still rising, household air conditioners are running and before commercial, railway and public sector demand has substantially diminished. The sequencing of hot days is also important to peak events, since runs of hot days in long hot spells lead to increased air conditioning. In a warming climate the numbers of hot days are expected to increase, as is the length and intensity of hot spells (discussed further in Section 2.3.2).

Rare, high demand, peak events, dictate the level of peaking capacity required in the system, and can account for a very significant component of the wholesale market turnover. Therefore, higher peaking capacity requirement associated with lower load factors can attach a significant cost premium in the provision of electricity. Moreover, because peaking capacity relies on gas, as well as hydro and demand response, recent increases in Australian gas market prices are having an impact on the costs of meeting demand.

Increasing variability also lowers confidence in predicting future peak demand trends which adds to the risk associated with investments in both generation and network infrastructure.

Increasing penetration of intermittent renewable sources of electricity requires systems to respond more rapidly and flexibly, other factors being equal. In combination with more peaky demand, new storage capacity in the form of batteries and pumped hydro is likely needed to provide this capability.

Changes in the structure of demand and the associated costs can indicate the importance of efficient demand side management in managing the risks associated with peak demand events. Demand side management is discussed in Section 3.2 of this report.

More detailed supplementary data, figures and examples illustrating demand patterns in NSW, including general changes in demand, impact of temperature, load duration curves, and power production by fuel type are provided in Appendix 3.

2.3.1.2 Projections for generation adequacy

The ESOO is released annually by AEMO as a requirement under the National Energy Rules (NER). The ESOO forecasts supply and demand conditions across the NEM providing the estimated timings of possible shortfalls of supply. These projections are indicators of when there might be periods of high prices which should indicate to the market that there may be opportunities for investment in new generation.

The most recent projections in the 2017 ESOO (5 September 2017) indicate that under high demand scenarios there is a heightened risk that the reliability standard will not be met in the NEM (AEMO, 2017d). Most notably, in peak summer periods targeted actions may be necessary to provide additional dispatchable capability to reduce supply interruption risks. The greatest risks are for Victoria and South Australia where there are risks for this summer (2017-18). However, the projections for after this summer show decreasing levels of unserved energy because new capacity is expected to enter the market (AEMO, 2017d) (Figure 2.3).

Projections for NSW do not show any breach of the reliability standard for the next ten years even under high demand scenarios (see Figure 2.3). However, the risk of shortfalls begins to increase after the closure of the Liddell Power Station that has been announced for 2022. AEMO notes that the risk of load shedding in NSW would increase if other coal generation is lost quickly or unexpectedly in NSW without replacement by firming capability (AEMO, 2017d). Shortfalls may occur during times of peak demand, such as during heatwave events, when there is low wind and solar generation and/or plant failure.

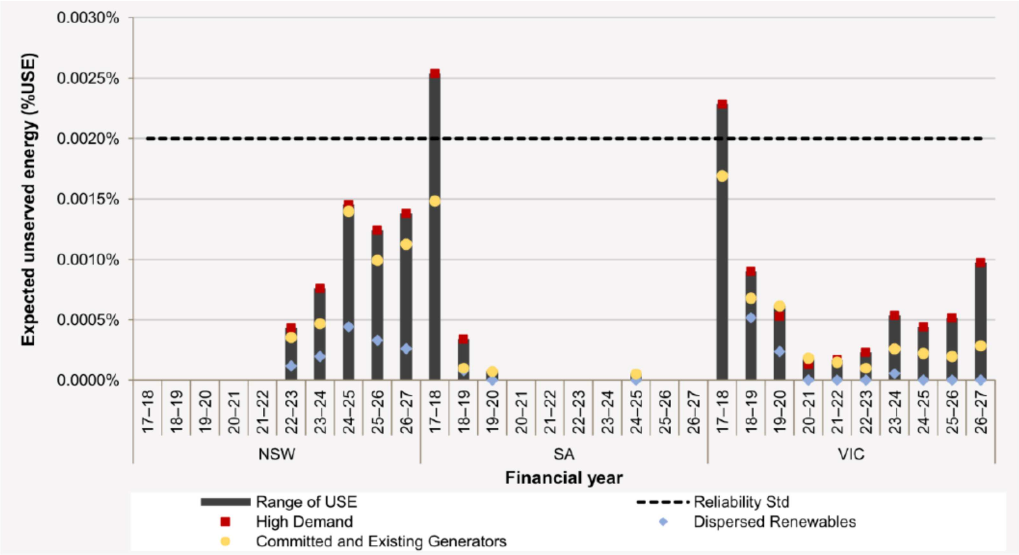

Figure 2.3: Range of unserved energy (USE) outcomes for New South Wales, South Australia and Victoria with key drivers
These include:
"**Committed and Existing Generators** shows USE if only existing generators and generation projects that meet AEMO's commitment criteria were operating. Not all potential renewable generation required to meet State and Federal renewable energy targets and the Paris COP21 commitment has been developed in this scenario.
Dispersed Renewables shows USE if, as well as all existing generators and projects meeting AEMO's commitment criteria, additional renewable generation was to be developed to deliver a national renewable generation outcome, leading to greater penetration than can be achieved if geographically concentrated.
High Demand shows the impact on USE if demand growth was in the upper range of expectations, assuming generation was developed according to the Dispersed Renewables pathway. The effect of higher demand on USE would be even greater if modelling assumed only Committed and Existing Generators."
Source: AEMO (2017d)

Modelling the future of the electricity system requires a number of assumptions to be made. The assumptions are based on data currently available to AEMO, such as capacity that is registered now and into the future, demand profiles and economic scenarios. The ESOO provides indications of what could happen in the future and what the market needs to do to prepare.

Past ESOO analyses provide some indication that the market has historically been responding to projections over time. Analysis by the Grattan Institute indicated that the number of years until a shortfall is predicted generally stay the same or increase over time (Wood & Blowers, 2017a). However, in South Australia and Victoria there have been rapid changes in the projected time frames to possible shortages due to major unforeseen changes in both of these regions including the major loss of coal powered generation capacity (Northern, Playford and Hazelwood) and, in South Australia, the significantly increased penetration of intermittent renewables especially wind.

While AEMO is warning of risks of unserved energy for South Australia and Victoria for the 2017-18 summer, the subsequent years are shown to have much reduced risk due to new capacity expected to enter the market. This shows the importance of notice within the market. The market needs time to prepare and make the required investments or adjustments.

In discussions with the Taskforce, generators have noted that the market is working to bring forward new projects with planning underway. However, they indicated that confirmed decisions on these new projects will not be made until around 2019 (only three years before the closure of Liddell).

The NEM is rapidly evolving and with appropriate notice the market can adjust. The South Australian region is currently adjusting to the changes in its local market and the rapid closure of Hazelwood in Victoria. The full capacity of the Pelican Point gas power station (485 MW) has been available since July/August. This has provided greater security and has meant that instead of being a net importer, the state has become a net exporter (Slezak, 2017). This has also been associated with a reduction in wholesale electricity prices in the state, with South Australia in October 2017 having the cheapest average wholesale prices in the NEM (Slezak, 2017).

2.3.1.3 Lack of reserve

Lack of reserve (LOR) notices are a way for AEMO to get a market response when it looks like supply and demand is getting tight and to prevent load shedding. Load shedding has been a rare event in the NEM and has only occurred on a small number of occasions. There are three levels of LOR describing escalating levels of risk. When it reaches LOR3, load shedding is happening or is about to occur.

In the last year there has been a much greater number of LORs in the NEM (Figure 2.4), with a very large number in South Australia. In 2016-17 there were more LOR2 notices than LOR1. Normally this should be the other way around due to the incremental nature of the LOR notices (AEMC, 2017g).

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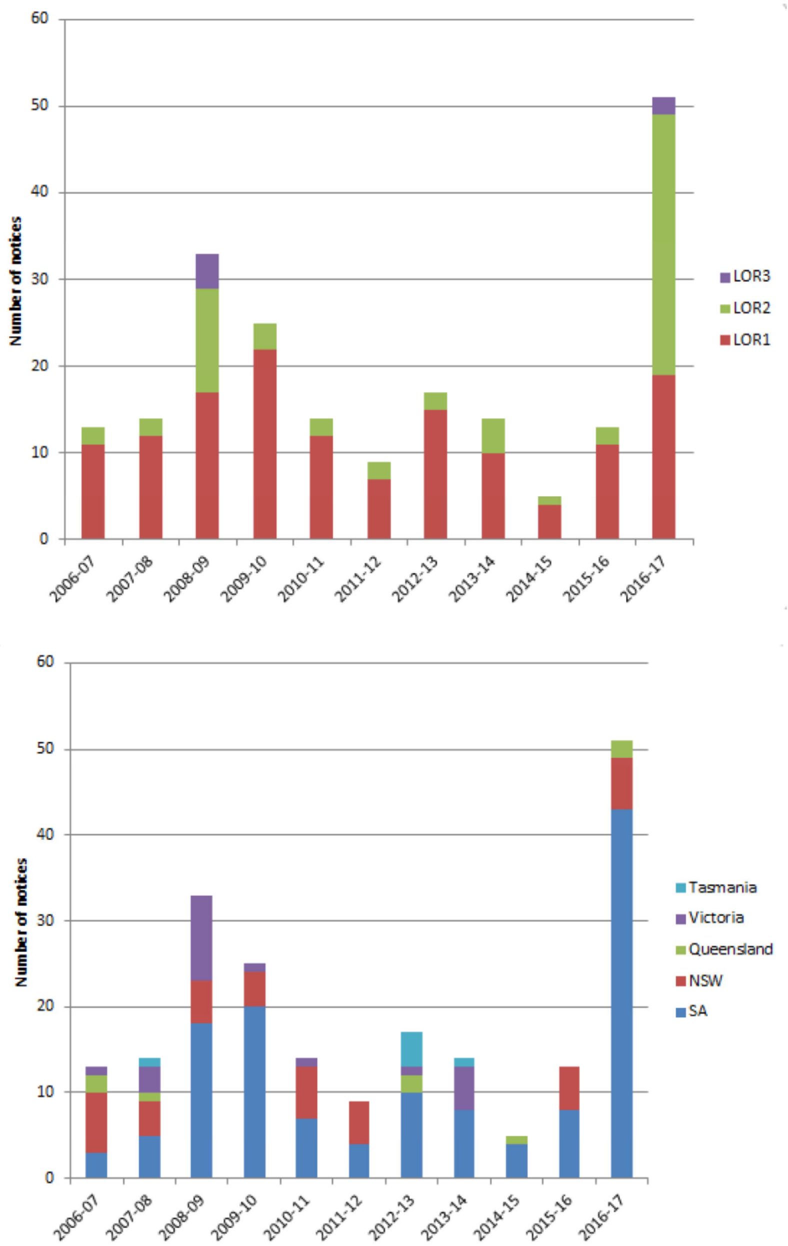

Figure 2.4: Lack of reserve notices
A) by number of LOR1, LOR2 and LOR3 notices issued, and
B) by total number of notices by AEMO, by region
Source: AEMC (2017g)

AEMO has determined a number of variables leading to the increased rate of LOR conditions, including:

- “short-term grid demand forecast error, particularly during extreme hot weather, which is in turn affected by surprisingly small errors in weather forecasts
- short-term large-scale wind and large-scale solar generation forecast error
- widespread partial availability reductions in thermal generation during stressful ambient conditions
- variations in network constraints” (AEMO, 2017h).

The changing and more complex nature of the NEM has led AEMO to request a rule change in relation to LOR conditions. The changing nature of the system is leading to rapid unanticipated declines in reserves and a growth in forecasting errors. Issues leading to LOR conditions are not always being caused by large generators – non-contingency based deviations were the main cause of reserve deterioration in South Australia. AEMO believes it is crucial that a more sophisticated warning and intervention trigger be used to determine the probability of load shedding. The Taskforce agrees. The rule change would aim to clarify the purpose of LOR conditions, remove the detailed definitions of LOR from the NER, require AEMO to develop and maintain public “reserve level declaration guidelines” and employ risk assessment measures and improve those measures over time (AEMC, 2017d).

2.3.1.4 Investment pipeline and generator withdrawal

Consultation with different segments of the energy investment sector confirmed that the energy sector in NSW and Australia is in a period of transition.

Generation infrastructure in NSW and across the NEM is changing in terms of scale, distribution, type and ownership. The system is generally moving from high capacity, dispatchable, relatively centralised, government funded and owned, high cost public works, such as thermal coal and the Snowy Scheme, to lower capacity, intermittent, distributed, modular, lower cost, investor funded generation, such as wind and solar PV, except for the proposed Snowy 2.0.

On the whole, investors are signaling that coal fired power stations (new and existing) are generally no longer attractive as an investment. That said, some existing players are actively pursuing opportunities to buy or upgrade plant. However, these players are likely doing so with a view to how such an investment could operate if the National Energy Guarantee is introduced and the future role that dispatchable generation will play.

Further, households and businesses are taking control of their own power ‘behind the meter’ through increased rooftop solar PV and other renewables, as well as through major changes in energy efficiency.

This section examines available information about the investment pipeline, and describes several market and investment trends that have been observed that are relevant to future reliability and security.

Generation infrastructure withdrawals and investments

Over 2,000 MW of coal fired generation has left NSW in the past five years, and 2,000 MW of nameplate capacity will be lost when Liddell retires in 2022[4]. With an ageing coal fleet and with other developments, more will leave over time. The risks associated with an ageing generation fleet are discussed in Section 2.3.5.

As coal generation withdraws, wind, solar and some gas are taking its place. Figure 2.5 shows a number of possible future developments either registered with AEMO, and/or that have development approval or have submitted planning applications. The Federal Government has also announced a feasibility study for 2,000 MW of pumped hydro, as part of Snowy 2.0 (Snowy Hydro Limited, 2017).

[4] Due to age and reliability issues the effective capacity of Liddell power station is reported at 1,680 MW (AGL Energy Ltd, 2017b)

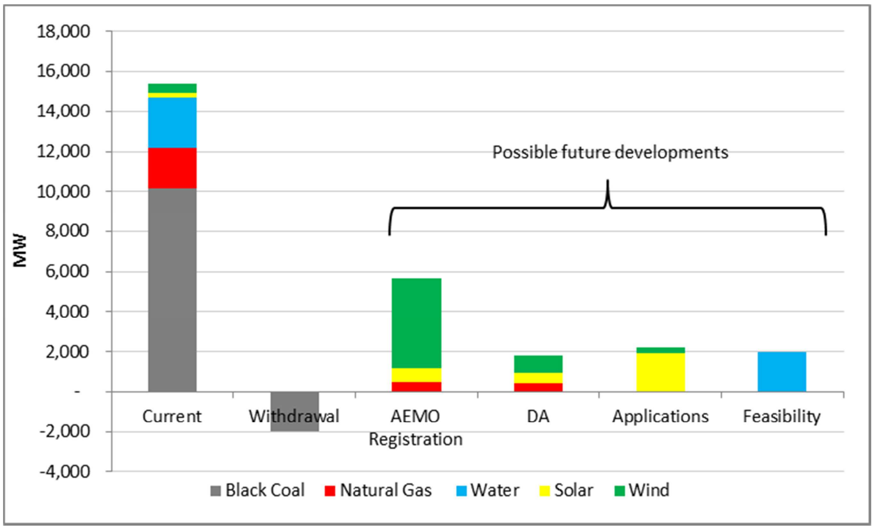

Figure 2.5: Capacity of generators in NSW, including current as well as future withdrawals and possible developments
Possible future developments include those currently registered with AEMO (2017g), those with NSW Development Approval (but not registered with AEMO) and those that have made planning applications (NSW Department of Planning and Environment, 2017). The feasibility column represents the announcement of a feasibility study into the expansion of the pumped hydro-electric storage in the Snowy Mountains Scheme, also known as the Snowy 2.0 project (Snowy Hydro Limited, 2017). Data Sources: AEMO (2017g) and NSW DPE (2017)

The proposed and committed developments across the whole NEM are mainly in solar and wind, with smaller amounts in gas and biogas, shown in Figure 2.6. Therefore, while the pipeline shows a considerable number of projects are planned to come online, the majority of these do not provide dispatchable capacity. The issues associated with moving from synchronous, baseload generation, such as coal, to intermittent generation sources were discussed in the Initial Report, as well as the Finkel Review (Commonwealth of Australia, 2017). The proposed National Energy Guarantee aims to address these issues by requiring retailers to source energy from both low emissions and dispatchable sources.

It should also be noted that the new generation being developed and planned is smaller and distributed more broadly across the state. The current coal generators have an average capacity of 2,000 MW, which is much greater than the average and wind and solar projects at 201 MW and 93 MW respectively. Generation has generally been geographically concentrated around fuel sources – hydro in the Snowy region and coal in the Hunter region. The smaller scale of the wind and solar projects means that they can be more distributed around the landscape.

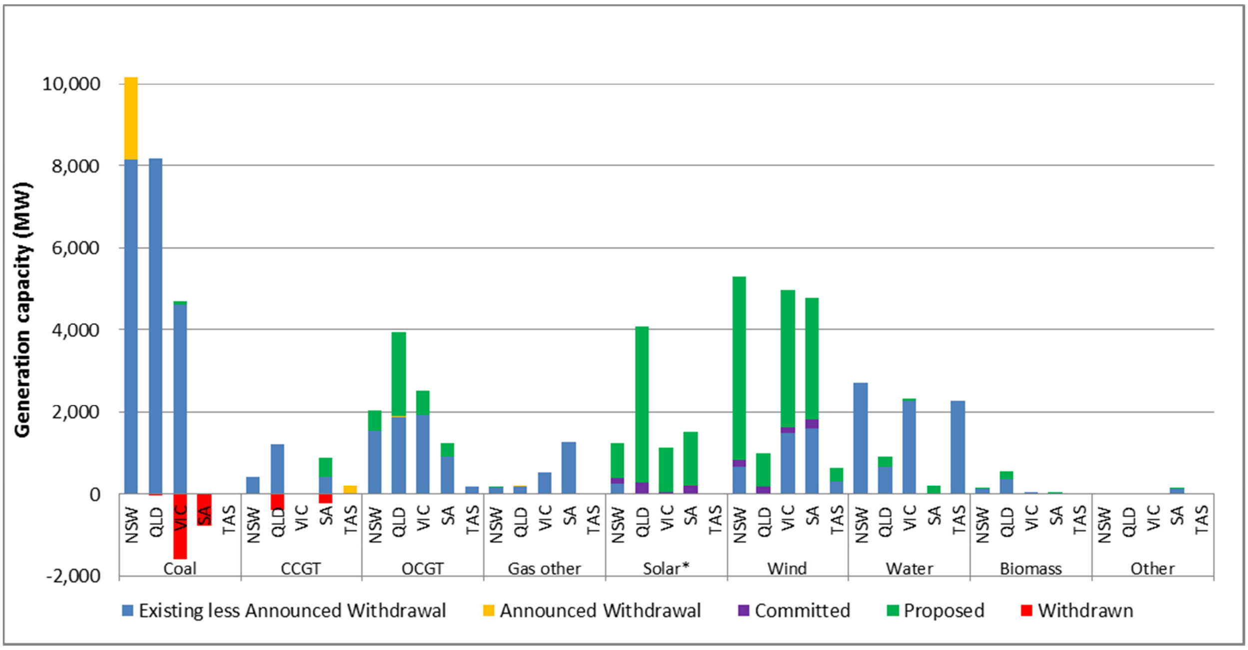

Figure 2.6: National Energy Market existing and potential new developments by generation type
*Solar excludes rooftop PV installations
OCGT: Open Cycle Gas Turbine, CCGT: Combined Cycle Gas Turbine.
Source: AEMO Generation Information (2017g). Updated to include the return of Smithfield GT in NSW for summer 2017-18 AEMO (2017d)

Considerable recent media attention has been given to the planned closure of Liddell power station. AGL announced the withdrawal of Liddell in 2015, giving the market seven years notice.

There was considerable discussion about the possibility of AGL extending the life of the coal fired generator and/or replacing the 1,000 MW of capacity that AEMO says will be needed in the market once Liddell closes (AEMO, 2017a). Other market participants noted that the withdrawal of Liddell provides an opening in the market and several generators described plans to bring forward new capacity, but will not make confirmed decisions until closer to the withdrawal date. Therefore, the capacity that is likely to replace Liddell may not yet be visible to the market.

On 9 December 2017, AGL announced its plans for the retirement of Liddell (AGL Energy Ltd, 2017a). This “NSW Generation Plan” includes a mix of generation, storage and system security technologies such as “a mix of high-efficiency gas peakers, renewables, battery storage and demand response, coupled with an efficiency upgrade at Bayswater Power Station and conversion of generators at Liddell into synchronous condensers” (AGL Energy Ltd, 2017a). The plan also includes exploring the feasibility of pumped hydro in the Hunter region (AGL Energy Ltd, 2017a).

Changing ownership

Historically government has been the major investor in generation infrastructure, both through large scale public works and the provision of subsidies. The NSW Government built and, until recently, owned the coal fired power stations in NSW (apart from Redbank which was privately owned). The NSW Government currently owns 58% of Snowy Hydro.

Some of the coal fired power stations in NSW were either decommissioned or sold between 2012 and 2015. They were attractive to investors as they were fully depreciated assets, making them cost competitive (IGCC, 2017). They are now owned by the publicly listed companies AGL, Origin Energy, and EnergyAustralia, as well as Delta Electricity which is owned by the private company Sunset Power International Pty Ltd.

As seen in Figures 2.5 and 2.6, the majority of recent and planned investment in generation in NSW is in wind and solar generation. These investments are being made by a broader group of companies and investors, including Australian renewables companies (e.g. Epuron, CWP renewables, and Infigen Energy) and international renewable and investment companies that have Australian subsidiaries (e.g. Canadian Solar, Canada; Neoen, France; Photon Energy, Netherlands; Union Fenosa, Spain; Ratch, Thailand; RES group, UK; and, First Solar, USA).

Changing risk profiles

Coal is increasingly being viewed as having too great a risk profile given the lack of certainty about what cost liabilities it may attract due to potential future climate policy. Feedback received by the Taskforce indicates that most public company boards do not currently view investment in coal fired power plants as a sound investment prospect. This is particularly the case for risk adverse companies which are looking for investments with very safe risk profiles to invest in for their shareholders over the longer term.

Changing environmental policies and market attitudes

Many companies have publicly written into their Corporate Social Responsibility policies and Environmental Social and Governance risk management policies a commitment to invest in ‘pro-green’ projects (National Australia Bank, 2017) or alternatively, in the case of some funds, explicitly decided not to invest in or fund coal related projects.

ANZ, which is the largest lender to the coal industry in Australia, has been an early adopter of the Financial Stability Board’s Task Force on Climate Related Financial Disclosures (2017) which is supported by over 100 CEOs in the energy investment sector and aims to increase transparency and disclosure regarding climate-related risks. ANZ stated in its 2017 Annual Review released in November that “companies must improve their reporting on their management of their carbon risks and opportunities for their shareholders and banks to make more informed decisions… we have undertaken climate-related scenario testing of customers in the thermal coal supply chain, including customers with operations in thermal coal extraction, coal rail transport, coal associated ports and coal-fired power generation” (ANZ, 2017).

Changing costs

As highlighted above, new coal generation currently represents carbon and capital risk for investors. The cost of intermittent renewables has come down dramatically making them a much more attractive investment than may have previously been the case. The revenue stream from large scale generation certificates under the Renewable Energy Target scheme (RET) has also incentivised investment in renewables.

The Finkel Review noted the falling costs of solar and wind generators as well as the lower capital costs of gas generators (Commonwealth of Australia, 2017). The review referred to an AGL report which indicated that wind and solar with firming costs (e.g. gas peaking generation) are cheaper than CCGT and are either lower or close to on par with the levelised cost of new black and brown coal generators (Commonwealth of Australia, 2017).

Changing contract terms and timeframes

Energy generation developments typically rely on long-term contracts which provide a long-term revenue guarantee for investors. This is necessary to recover the sunk costs of the capital investment. Potential investors want to ensure that enough revenue will be collected over the life of the asset to pay at least for the initial investment by entering into forward contracts. In the absence of longer-term price certainty and sufficiently liquid forward markets, potential investors may be reluctant to invest in a project due to the associated merchant risk exposure (Weiss & Sarro, 2013).

The Grattan Institute observes that a “lack of long-term contracting may be limiting new investment in the NEM” and that policy uncertainty reduces the ability of parties to enter into long-term contracts (Wood & Blowers, 2017a).

Many new generation projects are only able to secure shorter contract terms due to the unknown merchant exposure after the RET finishes. While the RET encouraged retailers to enter into power purchase agreements with new renewable energy generators, now that the RET incentive is nearing its end date, the policy uncertainty of future prices associated with large scale generation certificates is reducing the willingness of retailers to contract for long term agreements that are generally needed to reach financial close (Ernst & Young, 2016; Wood & Blowers, 2017a).

The problem presented by shorter contract terms is that the reduced timeframe makes it challenging to create a long-term business case to provide the necessary return on investment and therefore attract finance for new generation capacity. This is an issue for the security and reliability of an electricity system which currently relies heavily on assets that have a 20-50 year lifespan. Not surprisingly, feedback from the electricity sector indicates that policy stability with less frequent government intervention is needed to create the investment conditions needed to allow for longer contract terms.

Investment capital structuring for energy investments

The funding models for new types of energy infrastructure, for example wind and solar, are different from traditional generation such as coal and gas.

This is summarised well by The Brattle Group (Weiss & Sarro, 2013). Renewable projects (e.g. wind and solar) typically involve large up-front capital investments, with no fuel cost over time. The cost of the power predominantly reflects the capital cost, as there are no ongoing fuel costs. For other technologies, like gas, the market price of gas affects the market price of the power generated. Therefore, for more traditional technologies a significant portion of the project’s lifetime cost is variable fuel costs and the market price can reflect the fuel price, creating a ‘natural hedge’ between fuel and power prices. This ‘natural hedge’ does not exist for renewable projects which creates some risk, as the cost of the capital investment is not linked to the future market prices for power (Weiss & Sarro, 2013).

Project developers (and investors or lenders) will need confidence that returns over time will cover the cost of capital and operating expenses as well as a rate of return.

Government and the market bodies need to monitor these trends so that they can judge when proposed projects in the pipeline can be considered secure.

A shift to companies investing in energy in a new way

There has been a change in the way many companies are purchasing energy. There has been a shift away from companies locking in purchasing agreements with large energy retailers over a number years due to the fact that this could leave companies exposed to higher prices when they come off contract (Ludlow, 2017).

Many companies are now being driven by a focus on reducing their energy consumption and minimising the direct cost of energy to their bottom line as well as reducing their carbon emissions. Ben Burge, Telstra Energy Executive Director, highlights the fact that companies “can’t just wait around for the government to solve the problem – it’s not the role of government to provide hedging services for corporate Australia. We take the view that we have to be more active in managing that risk” (Ludlow, 2017).

Purchasing energy directly from the source. There are numerous examples of large scale customers investing directly in generation and purchasing energy direct from renewable projects. Solar is the most popular source of renewable energy for companies due to its lower prices, ease of installation and long equipment life cycles (ARENA, 2017a). The agriculture, food manufacturing and construction industries are more likely to use biomass/biogas as it allows recovery and reuse of waste and effluent to convert it to energy on site (ARENA, 2017a). Sydney Water generates around 21% of its total energy through renewable projects such as biogas and solar (Sydney Water, 2017).

Telstra, whose energy costs account for 60% of operating costs, has entered into a long-term PPA through an investment of $100 million in a new 70 MW solar farm in Emerald, Queensland which is being developed and operated by RES Australia (Ludlow, 2017). Telstra will take the entire output from the solar farm (McCarthy, 2017). In addition, Telstra has become a registered generator with AEMO which will allow the electricity generated from the solar farm to “take the edge off its own power bills as well as sell it back to the grid” (Ludlow, 2017).

Similarly, North Queensland zinc producer Sun Metals is developing a 116 MW solar farm to assist in meeting its power needs following a five-fold increase in its power costs (Ludlow, 2017). And the owner of the Whyalla steelworks has flagged the development of a 1 GW solar power plant to reduce power costs and sell surplus to the grid (Tasker, 2017).

A similar trend in large customers purchasing energy directly from the source is being seen internationally. Microsoft for instance has entered into a wind energy agreement with GE in Ireland to purchase all the 37 MW of wind energy generated from GE’s Tullahennel wind farm for 15 years. The investment also integrates battery technology into the wind turbines to store wind energy. This investment is part of a broader 600 MW renewable energy portfolio held by Microsoft (Griffith, 2017).

Interestingly some commentators have argued that large customers contracting directly with generation projects is not helpful in the instance that one customer (which may account for 10-20% of consumption) is not large enough to finance the whole project. In such an instance developers therefore need to be able to meet the gap in funding which is then creating uncertainty for investors regarding who will take the remaining offtakes.

Also, when a customer purchases power from an intermittent source either the retailer or the customer will need to take other measures to manage the increased risk of uncertain supply.

Hedging against risk by investing in back-up generation. Large scale customers are increasingly using back-up generation and storage technology to hedge against extreme spot price exposure and risks. Telstra for example has approximately 1 GWh of storage capacity and 200 MW of stand-by generation which has mostly been used for back-up power in emergencies. Telstra is seeking to optimise this generation capacity through improved battery storage technology and contributing back-up energy into the grid (Ludlow, 2017).

Investment in customer solutions. New business models are also emerging that provide innovative customer solutions to purchasing and managing energy usage both at the commercial and residential scale, for example, custom energy service providers such as Reposit Power.

The investment trends described in this chapter and projections for supply adequacy and capability should be watched closely by the NSW Government, particularly in the years leading up to the closure of the Liddell power station when confirmed investment decisions for new capacity are likely to be made. For example, it seems that 2019 will be an important milestone for investments to be locked in and commenced. The changing nature of investments and the financial structures that will support these should also be watched closely so that the Government can have good intelligence about the investment models that are most likely to be effective. If there appears to be growing risk of unserved energy as 2022 approaches, the NSW Government can examine what the causes may be (for example, delays in the planning system or constraints in financial markets) and whether there are issues that can be managed at the state level to support appropriate investments coming forward.

2.3.2 Risks from extreme weather

In its Initial Report, the Taskforce drew on the work of NARCliM and other projections to provide an overview of the risks from extreme weather and changing climate to the electricity system. These events have the potential to interrupt power supplies by constraining or stopping generation as well as damaging distribution and transmission networks.

Electricity outages related to weather will happen and not all can be prevented. To do so would be cost prohibitive. This is one of the reasons why AEMO is only expected to operate the system to withstand credible events, not all possible events.

The Initial Report noted there is a clear trend, already being experienced, of heatwaves increasing in frequency, duration and intensity. This section of the report discusses these trends as well other extreme weather events with respect to the NSW electricity system, and past examples of weather-related effects on the electricity system. These trends and changing risks need to be understood by market participants (generators, transmission and distribution networks), operators and governments to ensure that all are well prepared and can respond appropriately when these events occur.

Figure 2.7 uses the example of the thermal coal generation supply chain to provide an overview of some of the impacts of extreme and changing weather patterns on the electricity system, and how they can combine to create greater risk. The trends and potential impacts of different events are described in more detail in the following sections.

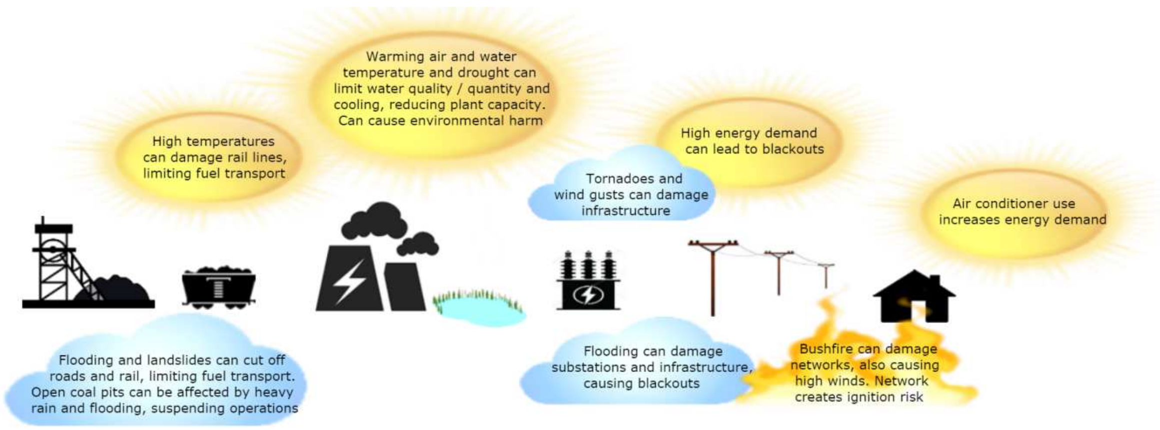

Figure 2.7: The potential impacts of extreme weather events on thermal generation supply chain

2.3.2.1 Heatwaves and increased temperatures

Heatwaves[5], or long periods of consecutive hot days, e.g. where the temperature is above 30˚C, are obvious risks to the electricity system. High temperatures cause demand to increase due to air conditioner use, and can reduce the performance of generation plant and transmission and distribution networks.

The number, length and intensity of heatwaves in NSW is increasing (Argüeso, Di Luca, Evans, Parry, Gross, Alexander, Green, & Perkins, 2015; OEH, 2015). By 2030, on average, an additional 1-1.5 heatwaves each year is projected almost everywhere in NSW. By 2070,

[5] Heatwaves are defined by the BOM by "using the forecast maximum and minimum temperatures over the next three days, comparing this to actual temperatures over the previous thirty days, and then comparing these same three days to the 'normal' temperatures expected for that particular location" (BOM, 2017b).

the number of heatwaves is projected to increase by 2.5-4.5 events per year, with the largest increases in the central and northern parts of NSW. The largest changes in heatwave length are projected to occur in the north-east (OEH, 2015).

By 2030, the longest heatwave in the year is projected to last an average of 1.5-3.5 more days over most regions in NSW apart from the coast and south-west (OEH, 2015). By 2070 the longest heatwave is projected to be 2-11 days longer on average (OEH, 2015). The intensity of heatwaves is also projected to increase across most of the state by 2030 and, to an even greater extent, by 2070, though increases in the east of NSW may be less significant than those in the west.

The potential impacts of heatwaves on the electricity system include:

- energy **demand increases,** generally peaking in the afternoon due to residential air-conditioner use (Ausgrid, 2015) and electricity demand typically peaks on the third consecutive hot day (Endeavour Energy, 2017)
- **the efficiency of networks reduces in high temperatures**, and coincident high demand can result in congestions and constraints on transmission lines and interconnectors (Orme & Swansson, 2014). Typically this will result in higher prices, more stress on the network and risk of blackouts
- large coal thermal plant generally **will not perform as well in extreme hot weather** and can also have output limited by environmental constraints, for example, cooling pond temperature limits. On 10 February 2017, during the peak demand period the capacity of available large thermal generators in NSW was reduced by about 805 MW, largely due to high ambient temperatures and cooling pond temperature limits[6] (TransGrid, 2017c). The Taskforce understands that several generators have been working closely with the NSW Environment Protection Authority to negotiate amendments to Environment Protection Licence (EPL) conditions in the lead up to this summer
- as heatwaves are likely to run closer to each other, thermal generation plants may have to **run at higher output for more days in a row** than historically, with shorter periods in between to replenish fuel stockpiles and maintain plant if needed
- **the efficiency of solar PV reduces** as temperatures rise. PV output reduces by 0.4-0.5% for every 1°C increase in cell temperature – this is a fundamental property of the solar cells. Therefore, for example, for any 10°C rise in temperature a 200 W output would be reduced to about 190-192 W (Green, 2017)
- **increased risk of bush fire** (discussed below).

The Taskforce also considered the risk of heatwaves affecting multiple major population centres simultaneously, which would pose greater risk to the electricity system due to widespread high demand across the NEM. Trends regarding the future geographical extent and the risk of heatwaves affecting multiple states are not clear. The BOM reports that due to the nature of the weather patterns involved in extreme heat days across southeast Australia: "it is very rare for the heat to extend from north-to-south (Brisbane to Melbourne) and east-to-west (Sydney to Adelaide) at the same time... Since 1960, there have been no instances of days over 35°C concurrently in Brisbane, Sydney and Melbourne" (BOM, 2017e).

There is a higher risk of simultaneous extreme heat days being experienced across smaller regions, such as north (Brisbane and Sydney), south (Melbourne, Hobart and Adelaide) and east (Brisbane, Sydney and Canberra) (BOM, 2017e). There are some historical instances of heatwaves affecting Adelaide, Hobart, Melbourne, Canberra, Sydney and Brisbane at the same time. However, these were at the lower end of the intensity scale (BOM, 2017e).

[6] On this day two Liddell units were also unavailable and a further 1,000 MW was lost due to failures at two gas generators.

2.3.2.2 Dry spells and drought

Water is both a fuel source for hydro power generation and critical to the operation of thermal plants. This was seen during the 2007 drought where water for hydro generation was limited, as was water for cooling in thermal generation where both water quantity and quality can limit production. Water shortages also lead to competition for water supply with other industry and utility groups (Commonwealth of Australia, 2010).

For hydro power generation, low water availability will generally reduce generation capacity and cause price volatility. Hot and dry conditions increase evaporation from reservoirs (Coughlin & Goldman, 2008) and reduce streamflow leading to low dam levels, limiting hydropower production (Coughlin & Goldman, 2008; Commonwealth of Australia, 2010).

Climate change projections for the alpine areas show that they are particularly vulnerable. NSW's alpine region is projected to experience higher temperatures, fewer colder nights, and lower rainfall in the near and far future (OEH, 2014b). This could pose risks to the current Snowy Hydro as well as reserves for Snowy 2.0.

Thermal generators rely on water reserves for cooling. Drought conditions may lower levels of water intake bodies for thermal generators, potentially causing higher water temperatures and increased concentrations of suspended solids, lowering the ability to use the water for cooling (NETL, 2009). Both water temperature and quality is essential to steam-generating plants (AGL Energy Ltd, 2014). Mean and maximum temperature increases lead to a shorter transfer capacity and an increased rate of equipment ageing (Coughlin & Goldman, 2008), increasing the periods in which equipment operates close to technical limits (Orme & Swansson, 2014).

2.3.2.3 Thunderstorms, extreme rainfall and winds

Storms and rainfall present risk to all parts of the electricity supply chain. High wind gusts and flooding have the potential to damage a range of equipment and to have both localised and widespread impacts on electrical supply. Above-ground powerlines are particularly vulnerable to wind damage. The vulnerability of mines and coal pits to flooding and water damage can limit thermal coal power by restricting fuel supply. In addition, the burning of wet coal from heavily soaked coal stockpiles can limit a coal fired power station output.

Extreme wind can occur during strong cold fronts, low pressure systems such as East Coast Lows (ECLs), severe thunderstorms and tornadoes (Geoscience Australia, 2016).

ECLs are associated with significant wind speeds along the NSW coast. There are currently around 10 per year, with 3-5 of those systems producing severe coastal impacts with gale force winds and flooding rains (OEH, 2010). They generally occur from autumn through to spring, mainly in the winter (OEH, 2010). More strong and extreme ECLs are projected for future, although the total number of ECLs might decrease.

Thunderstorms produce hailstones, wind gusts, flash flooding and tornadoes; and may occur more than 100 times per year in NSW and the ACT (BOM, 2017d; BOM, 2017a). In NSW, the severe thunderstorm season is between September and March, typically peaking between December and January and occurring between 2-6 pm (BOM, 2017a; BOM, 2017d). Tropical cyclones do not often affect NSW, but those that do have caused flooding and wind damage (BOM, 2007).

Tornado occurrence in Australia is not uncommon. In NSW they mostly occur in late spring to summer, along the coastal fringe (BOM, 2003; Allen & Allen, 2016). Whilst there are limitations in tornado records (Allen & Allen, 2016), the BOM database records 364 tornadoes in NSW between 1795-2003 (BOM, 2003). Our ability to monitor and predict them currently is limited (Allen & Allen, 2016). During the period 28 September to 5 October 2016, multiple supercell thunderstorms in South Australia produced at least seven tornadoes, hail and intense rainfall, damaging three major transmission lines and 22 transmission towers (AEMO, 2016c; BOM, 2016a). These tornadoes were part of the reason for the black system event in South Australia. The highest wind gust speed of three of the tornadoes was estimated at 190-260 km/h (BOM, 2016a).

Rainfall intensity has increased over the past century. In most regions in NSW and ACT rainfall intensity is not projected to increase significantly in the near future (2020-2039), but by 2060-2079, significant increases in rainfall extremes are projected for some regions (Evans, Argüeso, Olson, & Di Luca, 2014). The most significant increases in precipitation indices are in the Far West, Murray Murrumbidgee, New England and North West regions of NSW (Evans et al., 2014). Some significant increases are also predicted in the Hunter and South East and Tablelands regions (Evans et al., 2014). As rainfall intensity increases, the extent of runoff also increases, leading to more severe flooding (Office of the Queensland Chief Scientist, 2017).

The impacts from these weather events can be wide ranging, examples of which include:

- **damage to power lines and substations, which can cause power outages**. During Spring 2007, a tornadic super-cell thunderstorm in Dunoon on the North Coast damaged power lines and the substation exploded when hit by airborne debris (BOM, 2008). More than 3000 homes were without power in the region (Gilmore & Mitternacht, 2007). About three weeks earlier in nearby Lismore, a super-cell thunderstorm caused hail, wind damage, flash flooding and power outages (BOM, 2008). On 11 February 2017, wind gusts related to a storm moving through the Wagga Wagga area and over the Snowy region collapsed two transmission towers (TransGrid, 2017a)
- **flood damage to the electrical network and pipelines** potentially causing large blackouts and risk of **inundation from storm surges and sea level rise** on networks and infrastructure in coastal areas
- **impacts on the rail transportation of fuel to power plants**. During autumn 2015, floods in the Hunter Valley cut off rail lines and damaged rail equipment affecting coal transport in the region (Claughton, 2015)
- **floods and landslides affecting open coal pits**, as well as suspension of operations in some open-cut mines. In June 2012, torrential rain in the Gippsland region of Victoria led to the failure of the Morwell River levee causing flooding of the open cut mine and stopping the operation of coal conveyor belts supplying the Yallourn Power Station (Goswell, 2012; Levy & Arup, 2016)
- **solar PV energy production may be limited by cloud shading**, which has the potential to create instability due to sudden drops in PV output (Fulcrum 3D Pty Ltd, 2016). Technology has been developed such as CloudCAM PV generation forecasting to accurately predict changes to PV output 1-20 minutes ahead of time (Fulcrum 3D Pty Ltd, 2016).

2.3.2.4 High risk fire weather

Bushfire is a high risk to electricity supply, particularly to the overhead power lines and timber poles of the distribution system. The network itself also creates risk as a potential source of bushfire ignition, predominately due electrical arcing and faulty or ageing infrastructure (Parliament of Australia, 2010; Parliament of Victoria, 2010a; Essential Energy, 2017). Bushfires can also generate other weather conditions such as high wind gusts, or air columns and wind shear that create a tornado.

Fire risk is influenced by high temperatures, wind, humidity, rainfall and the state of available fuels. Incidences of high fire weather in south-eastern Australia increase from spring to mid-summer (BOM, 2017c). There has been an overall trend of increase in danger days, and the fire season has lengthened since the 1970s (BOM, 2016b). By 2030 an increase in the number of fire danger days is projected, and by 2070 larger increases are projected, with the greatest increases being projected for the west of NSW (OEH, 2014a; CSIRO & BOM, 2015).

Fires are a risk to electricity supply, but the distribution network itself is also a hazard that can lead to bushfires. Dry spells and low humidity increase bush fire risk and voltage faults in the distributor network, increasing the risk of bushfire ignition (Jacobs, 2014). A study covering NSW and Victoria using data from 12 years, between 1997-98 to 2008-09, found fires started by powerlines were responsible for a third of all houses destroyed during this period (Collins, Penman, & Price, 2016). The 2009 Victorian Bushfire Royal Commission found that five out of the 11 fires examined were started by a failure of electrical assets which led to recommendations regarding network operations and responsibility (Parliament of Victoria, 2010b).

High fire risk and bushfire can also affect the operations of generation infrastructure. AGL noted that high fire risk can limit repairs, such as welding, that cannot be conducted without special authorisation which could extend an outage. Bushfire can also interrupt the rail network, which can affect the delivery of coal to generators. AGL noted that this occurred during the 2017 summer, and that once a delivery is interrupted it can be difficult to reschedule due to network congestion (AGL Energy Ltd, 2017b).

2.3.2.5 Simultaneous extreme weather events

Extreme weather events such as floods, bushfires and heatwaves are rarely the result of a single climatic or environmental factor. Multiple extreme weather events may also occur simultaneously in the one region, or across multiple regions, and pose risks to the electricity system across the NEM. Energy shortages resulting from extreme weather occurring in one jurisdiction of the NEM have potential to influence the whole of the NEM.

For example, in June 2007 a combination of extreme weather events had significant impacts on the NEM, and power supply for NSW. Drought constrained hydro-power generation in the Snowy, Tasmania and Victoria (AER, 2007b) and flooding and storm activity associated with an ECL in the Hunter region reduced coal generation capacity up to 4% in NSW (AER, 2007a). At the same time in Queensland lack of water for generator cooling restricted generation capacity of two coal plants by about 800 MW (AER, 2007a).

Due to this combination of events, supply and demand was very tight and some of the highest electricity prices in NSW occurred since the start of the NEM. Spot prices exceeded $5,000/MWh 42 times in June 2007 (AER, 2007a). This was influenced by the reduced generation capacity, increased demand due to cold winter days, and in part by generator rebidding which influenced prices (AER, 2007a).

2.3.2.6 Monitoring and modelling of weather risks

Extreme weather events are not isolated occurrences. In many cases there is a lead up or a combination of weather and environmental conditions that form likely conditions for extreme events such as heatwaves, storm activity, droughts and floods.

These pose challenges to modelling and understanding the complex environmental interactions and cumulative effects, and understanding the interaction between environmental processes and extreme weather.

Determining and managing the potential risk from complex weather events to infrastructure, operating costs, financing costs, and investor confidence is also complex.

The BOM provides weather forecasts, warnings and observations in Australia at a range of timescales. It provides warnings for extreme weather events including cyclones, storms and heatwaves. These warnings provide information to the community, government and emergency services to allow planning and preparation for extreme events.

For longer-term planning, OEH uses NARCliM climate projections to identify regional vulnerabilities and opportunities to respond, adapt and prepare for climate change. The Integrated Regional Vulnerability framework considers the social, natural, physical and financial characteristics of an area (OEH, 2013a).

OEH is leading work to understand integrated infrastructure risk better and to undertake vulnerability assessments. OEH and partners are well advanced in developing methodologies and tools to examine extreme weather and climate risks to infrastructure and the cross-dependencies between different assets and systems.

Considering weather risk from a spatial perspective is important. Map-based analytical risk management tools have been successfully applied in NSW by water utilities (AdaptWater) and Manly Council for roads (AdaptRoads), and are now being applied across the Sydney metropolitan region through the 'Cross Dependency Initiative – XDI Sydney' (OEH, 2017a).

The XDI Sydney project aims to identify cross-dependent climate change impacts on power, water, transport and communication and built environment (OEH, 2017f). XDI Sydney uses data on extreme weather and climate change, costs associated with damage to an asset, impact diagnostics for each asset and a quantification of the social impact and disruption of businesses (OEH, 2017f). The tool can be used to assist in making the most appropriate decision to manage risk, adapt to changing conditions, and support collaborative decision making.

For example, water assets may be dependent on an electrical substation that is subject to flooding that is projected to worsen under climate change; which in turn is related to an LGA's responsibility to manage stormwater infrastructure to reduce flood risk to houses (OEH, 2017f). By identifying risk and the interdependent infrastructure, cost-sharing adaptive management can be undertaken. This risk quantification tool appears to be one of the most advanced pieces of work among Australian jurisdictions in this area, and can be applied to any region, across NSW or across the NEM.

2.3.3 Fuel

In its Initial Report, the Taskforce commented on potential risks to fuel availability, including coal, gas and water. The Taskforce recommended that in producing its revised EAAP, AEMO pay particular attention to the generator fuel positions so that the market can see in aggregate if there is sufficient fuel in the system and can anticipate major changes.

The most recent AEMO EAAP was released in June 2017 and published as part of the Energy Supply Outlook for Eastern and South-eastern Australia (AEMO, 2017e, 2017f). It reported that advice to AEMO from coal-fired generators indicated no expected limitations to an aggregate increase in generation to replace generation that had been withdrawn with Hazelwood's closure (AEMO, 2017f). It also noted that this would require an increase in NSW black-coal generation from recently observed levels.

However, the Taskforce has heard from generators that because they have been generating more since the Hazelwood closure, they have been seeking uncontracted coal from the spot market for this increased output. This is more expensive and has presented some logistical challenges for transport as it was not scheduled well in advance.

Since the EAAP was published, there has also been a major concern over coal supply from the Springvale mine for the Mount Piper power station after the NSW Court of Appeal held that the consent for Springvale mine was invalid due to failure to comply with a water quality standard for significant developments in the Sydney water catchment. Springvale is the sole supplier of coal to the 1,400 MW Mount Piper power station. In October, the NSW Parliament amended the *Environmental Planning and Assessment Act 1979* to "clarify how water quality impacts are assessed for ongoing development in the Sydney drinking water catchment" and "validate the State significant development consent for the Springvale mine extension" (Parliament of NSW, 2017).

There have also been some other general risks to coal supply raised with the Taskforce that the NSW Government and AEMO need to be monitoring closely. AEMO needs to be across these issues so it can inform the market of energy constrained capacity so that the market can respond. The NSW Government should be aware so that it can work to manage issues that may be within its domain to address. The issues include:

- industrial relations issues – a number of Glencore mines that supply NSW generators are currently affected by industrial disputes relating to pay and conditions
- rail capacity – there can be congestion on the rail network and there is a need to liaise with the Hunter Valley Train Coordinator to ensure sufficient train capacity is available for transporting supply to generators in the lead up to and over summer. There are reportedly also potential industrial relations issues with rail operators. The NSW Government may need to prepare regulatory arrangements that can allow coal transport by road in the case of major disruption to rail lines
- risks within mines – mines with existing permissions can encounter unanticipated geological problems that may compromise supply at times, for example, when shifting to a new long wall within a mine
- policy uncertainty – which can affect commercial decision-making by generators regarding coal reserves and contracts.

While domestic gas supply generally has been the subject of significant public discussion, owners of gas powered generators in NSW have not raised any issues with the Taskforce about securing adequate gas supply.

However, on 10 February 2017 the gas generator, Colongra, failed to start during the peak period when requested by AEMO due to low pressure in the gas supply lines, as the units had run on gas earlier in the day (AEMO, 2017l). The operators attempted to start the units on fuel oil which failed, though two units were eventually started and transitioned to fuel oil.

The NSW Government and AEMO should work closely with generators to ensure there is accurate information to inform the market about gas plant availability at periods of high demand, including seeking confidence that there is sufficient gas supply in advance of these events (noting that all generators are obliged to inform AEMO of their fuel models as required under the EAAP).

The NSW electricity system is also vulnerable to water shortages, which can reduce water available for hydro generation and thermal power plant operation (also discussed in Section 2.3.2). On 10 February 2017 NSW was highly reliant on hydro generation which contributed 2,619 MW at the time of peak demand.

Most climate modelling projections indicate some drying of south-eastern Australia (Sandiford, 2015). Long-term drying tendencies will be amplified in terms of stream flow and dam filling since longer intervals between rain means greater depletion is soil water stores and therefore a lower proportion of precipitation is directed to stream flow (Sandiford, 2017).

Researchers have also pointed out that effective management of the Australian Alps ecosystem is important to ensure future water delivery and quality. This includes managing erosion and weeds and managing the damage invasive animals do to swamps, stream lines and vegetation (Nicotra, Freudenberger, Cary, Hope, Worboys, Banks, & Venn, 2017).

2.3.4 Transmission and distribution limitations

Most disruptions to power supply that customers will experience will be due to damage in the distribution network (AEMC, 2017a). As discussed in Section 2.3.2, the transmission and distribution networks can be vulnerable to extreme weather events.

In NSW the reliability performance standards that apply to the transmission and distribution systems are set by the Minister and compliance is overseen by Independent Pricing and Regulatory Tribunal (IPART). These standards for transmission and distribution are different to the reliability standard described earlier which focuses on generation sufficiency to meet demand. The recent ACCC report (2017) on retail electricity prices describes the relationship between reliability standards that have been set for networks, and cost. The ACCC reports that increases to residential bills between 2007-08 and 2015-16 were primarily driven by higher network costs and that a “significant driver of network costs in NSW and Queensland from 2009 was the need to meet more stringent reliability standards” (ACCC, 2017).

The Taskforce consulted TransGrid, and the NSW distribution network service providers (DNSPs) (Ausgrid, Endeavour Energy and Essential Energy) for this review.

Transmission

The NSW transmission system historically has a high level of reliability (IPART, 2016). However, new pressures on the network are emerging with the increasing connection of new generation. TransGrid advised that interest in new generation connections exceeds network capacity in some regions (TransGrid, 2017a). As of June 2017, TransGrid reported around 8,000 MW of new renewable generation connection proposals in NSW and that many of these projects are looking to connect in remote locations where network capacity is limited (TransGrid, 2017a).

TransGrid proposes the establishment of renewable energy precincts that would allow more connection of renewable generators in areas with good renewable resource, and help manage the emerging network constraints. It also proposed greater interconnection to increase capacity to share generation and network security services between states. Interconnectors and transmission planning are discussed further in Section 3.8.

TransGrid and Ausgrid have raised concerns about risks associated with ageing assets and increasing load in the Sydney CBD and have warned of higher risk of network failures and unserved energy in inner Sydney. A project called Powering Sydney’s Future has been established to work through the network and non-network options for securing reliability for the CBD. In its draft determination for TransGrid’s revenue allowance for 2018-23, the Australian Energy Regulator (AER) has argued that these risks are likely to be overstated and the optimal timing for the project within 2018-23 regulatory period has not been established, and therefore did not include the proposed capex for the Powering Sydney’s Future project in its substitute estimate of total capex (AER, 2017c). However, given the uncertainty in future demand forecasts, the AER also considered that with appropriate justification the work could be considered a contingent project if certain triggers were met during the coming regulatory period. At the time of drafting this report TransGrid is preparing its revised revenue proposal in response to the AER’s draft determination. However, TransGrid is responsible for delivering a reliable supply and must prioritise its funding to do so.

Distribution

Essential Energy operates across 95% of NSW, covering mostly regional areas. Like TransGrid, Essential described the challenges associated with connecting high volumes of new, renewable generation sources. While the Essential network is generally not constrained, the volume of new connection applications may lead to some constraints. Essential reported a large increase in the number of connection inquiries in the last six months, which it attributed to the approaching 2020 target date for the RET. Essential reported that it has approximately 5,000 MW of connection applications, while demand on its network is only approximately 2,500 MW. Essential highlighted the need for longer-term thinking and planning about the placement of new renewable generation. This is discussed further in Section 3.8.

It also reported that many proponents for new renewable energy connections often underestimate the technical implications of such a connection.

Essential also highlighted the emerging risks associated with increasing amounts of distributed and embedded energy in its network, much of which it may not have any visibility of. This can create risks for the management of the network, including during a system restart when it may not have detailed information about whether what is about to be reconnected is a load or an energy source.

Endeavour Energy also highlighted the challenges of a lack of visibility of behind the meter generation in managing the network. Endeavour estimates that 16% of its customers have roof top solar and the intermittency of this output can create risks when managing the network. The Taskforce notes the Finkel Review recommendation to develop a data collection framework “to provide static and real-time data for all forms of distributed energy resources at a suitable level of aggregation” (Commonwealth of Australia, 2017) and the COAG Energy Council (2017b) rule change request to the AEMC to establish a register of distributed energy resources. These initiatives should help to manage the risks described by the DNSPs.

Endeavour also commented on the extreme heat that customers in its network can experience. Endeavour’s network includes the western parts of Sydney, which during heatwaves can experience temperatures in the order of 10 degrees higher than other parts of the city. This creates risks for overall energy use, as well as heightening peak demand on those extreme warm days. Overall, Endeavour reported no significant constraints in its network and that its network capability is sufficient to manage heatwaves of the kind seen in February 2017 if they occur again this summer.

2.3.5 Ageing plant

The coal fired generation fleet in NSW and across the NEM is ageing. This poses risks to reliability and security across the NEM, and in NSW in particular where the loss of another large coal generator at the same time or shortly after Liddell’s closure would pose a major risk to reliability (AEMO, 2017d). However, as discussed earlier, there is the potential for considerable additional generation to be installed that will mitigate some of this risk.

There are a number of risks associated with ageing infrastructure that the NSW Government and AEMO need to be watching closely.

Closure, both planned and unexpected – Coal fired power stations in NSW, and across the NEM, are getting older with many reaching end of life. Many will close as they reach their end of life (e.g. Liddell), or others may unexpectedly close due to major breakages or because the cost of keeping the power station open (e.g. major repair and refurbishment costs) may exceed the benefits.

The lifespan of a coal generator is considered to be 50 years. There is a possibility to extend this with upgrades and retrofitting but that ability will depend on a number of factors (Warren, 2017). Liddell is currently the oldest coal generator in the NEM at 46 years. Internationally, only 1% of coal power stations are in operation beyond 50 years (Nelson, 2017). Based on this it has been estimated that a number of power stations in the NEM will reach end of life and potentially withdraw between 2028 and 2035 (IGCC, 2017).

Ten coal fired power stations have been decommissioned across the NEM progressively between 2012 and 2017. This included three from NSW: Munmorah, Wallerawang C and Redbank. Generally the power stations were decommissioned due to decreasing demand, age (ranged from 31-56 years), increased use of rooftop solar PV and costs associated with repairs and refurbishment.

Refurbishment and maintenance costs – There is potential to extend the life, reliability and efficiency of coal power stations through maintenance, upgrades and refurbishments. The financial viability of extending the operational life of a power station will depend on age, fuel type (black/brown coal), operational history, current fuel contracting/supply, current operation, and ownership (Jotzo & Anjum, 2017).

Generators told the Taskforce that there are incentives driving maintenance of plant. These include: meeting performance targets with certainty; safety; statutory compliance obligations; meeting contract positions in the NEM; reducing lifetime costs (upgrades may avoid maintenance costs); and potential increased revenue due to higher availability and shorter outages (AGL Energy Ltd, 2017b). Also, some generators discussed plans to improve efficiency and upgrade to increase capacity.

As a generator gets closer to its end date with less time to recoup costs, owners may choose to close rather than invest if something big needs fixing (Wood & Blowers, 2017a). It should also be noted that prices had been low for many years, so perhaps the incentives for maintenance had not been as strong before the last couple of years, which also led to the closure of a number of power stations.

The cost of refurbishment may be a barrier for some companies. New turbines cost ~$40-60 million and new rotor blades cost ~$10 million (Warren, 2017). This does not take into account the lost revenue from the length of the outage such as direct loss of generation revenue and impacts on trading portfolios. For the 2016 external boiler leak at Liddell this was estimated at $15-20 million net profit after tax (AGL Energy Ltd, 2016).

Unreliability – There may be increased incidences of breakages or inability to respond at critical times, including when needed for peak demand. AGL anticipates that Liddell will experience “unanticipated outages and will become less reliable as it reaches the end of its operating life” (Ryan, 2017). An external boiler leak in early 2016, and the required inspections and repairs “substantially” reduced its availability (AGL Energy Ltd, 2016). During the heatwave in February 2017 the station was running at less than 50% capacity due to ongoing equipment problems (Morton, 2017). As at 29 September 2017, Unit 1 was out of service for planned maintenance to return in mid-November (Laris, 2017). At the same time Unit 2 is out of service for repairs until early 2018 (Laris, 2017). The age of the power station means that, due to obsolescence, specialist parts are required that take time to procure.

Down rating of capacity – No power station can operate at its maximum capacity all the time due to outages and maintenance, and their capacity to do so tends to degrade somewhat over time. In the absence of new generation, such tendencies can lead to some reduction of the available capacity in the system. For example, Liddell power station has four units, each with a registered capacity of 500 MW. However, due to age and reliability issues these units are now rated at 420 MW each (AGL Energy Ltd, 2017b), reducing the effective plant capacity of the plant by 320 MW or 16%. Since 2009-10 Liddell has been operating at an average of around 50% of registered capacity (Figure 2.8). That is comparable to Eraring, but significantly lower than Bayswater, Vales Point and Mt Piper power stations. Factors affecting individual station production include market demand, plant outages and maintenance, and access to fuel supplies (Hannam, 2017).

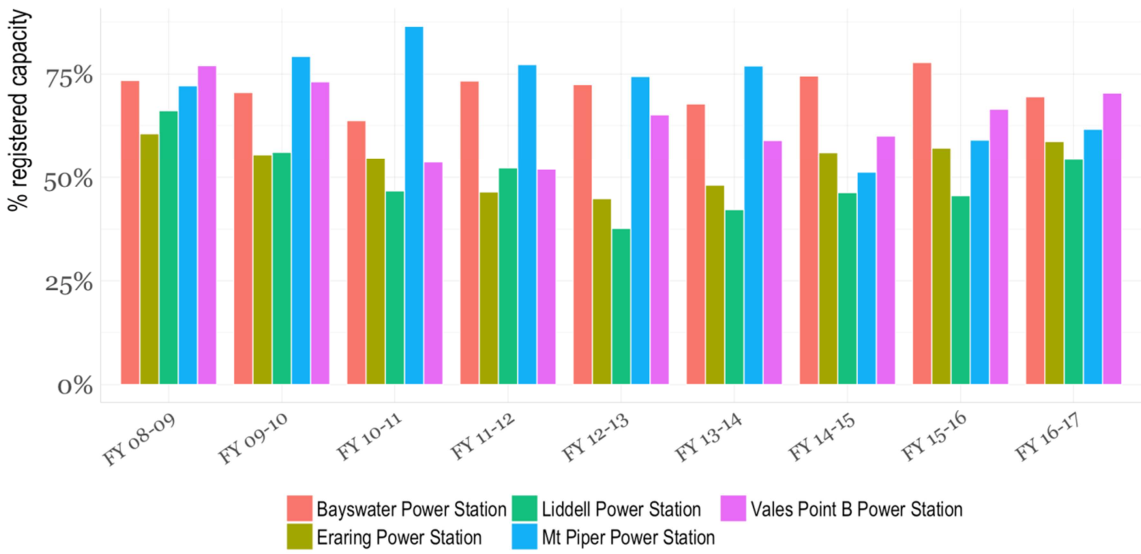

Figure 2.8: Power production as a percentage of registered capacity for the five NSW coal power stations averaged by financial year
Source: Sandiford (2017)

Occupational health and safety – Older equipment that has not been appropriately maintained can be a human safety risk. Before its closure the Hazelwood power station had a number of work improvement notices, entry reports and prohibition notices from Worksafe Victoria (Lazzaro, 2016).

2.3.6 Risks from other states

As a net importer of electricity, the security and pricing of NSW's power supply is sensitive to developments in other states. Recent changes in power generation in Victoria, following the closure of Hazelwood power station at short notice, provides an illustrative example.

Interconnector flow data can show how electrical power generation across the NEM has responded to Hazelwood's closure and how power flows between regions have adapted. Flow duration curves provide a summary of the duration of a particular flow across an interconnector, ordered from maximum in one direction to maximum in the reverse direction. Figure 2.9 compares before and after the closure of the Hazelwood power station showing April to September in 2016 and 2017. The flow duration figures show that in 2016 the interconnectors joining NSW were flowing strongly into NSW, at an average of 918 MW. After Hazelwood's closure there was a re-balancing of flows between NSW and Victoria, and substantial changes between South Australia and Victoria. The flows into NSW from Victoria were reduced from an average of 544 MW to 88 MW over the same time period.

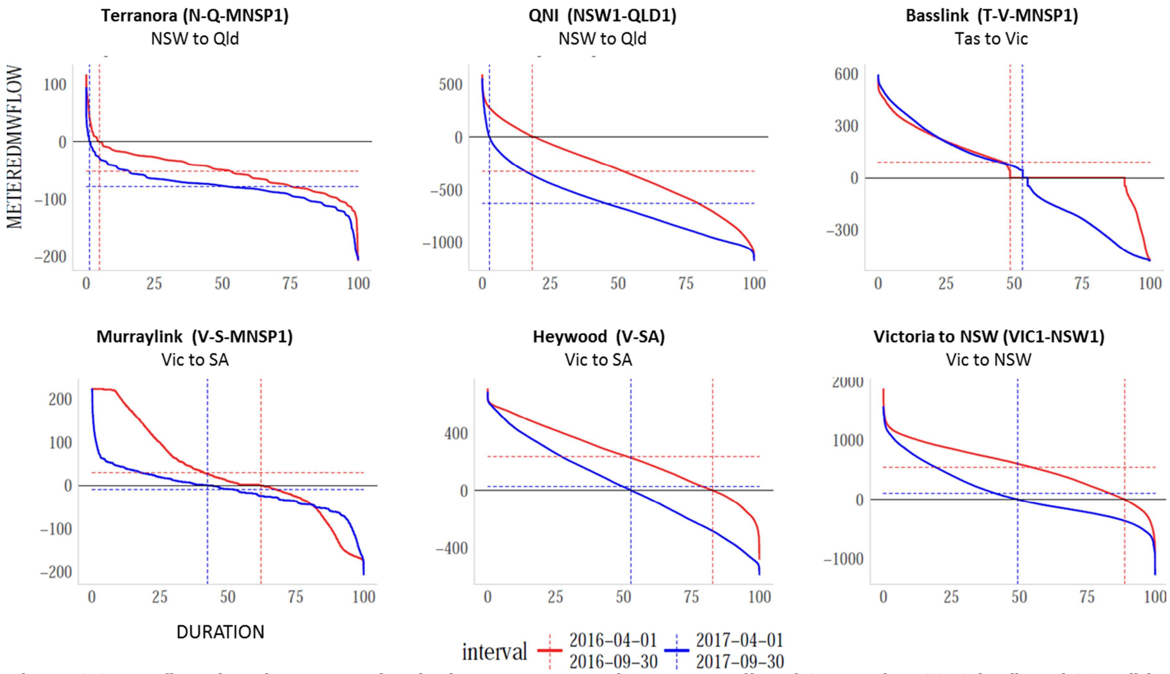

Figure 2.9: Net flow duration curves for the interconnectors between April and September 2016 (red) and 2017 (blue)
Source: Sandiford (2017)
Note: Vertical dashed lines show the proportion of time of normal flow direction. Horizontal dashed lines show average flow over the duration. The long 0 MW duration for Basslink is due to its outage during 2016.

Because it is an interconnected system, outages of large power stations can have significant consequences across the NEM, in terms of both market prices and security. This is exacerbated by the recent tightening of supply and because of the ageing nature of much of the NEM's generation capacity.

The Taskforce has been advised of some recent examples of such outages that, if repeated, could have a significant impact on NSW supply. This includes events in 2012 and 2014 in the Latrobe Valley that affected brown coal supply to Victoria's power stations which produce most of Victoria's electricity, highlighting supply risks due to slippage of mine walls, flooding and fires in the mines and even earthquake damage to the generators. For example, in June 2012 Victorian production was significantly reduced due to flooding of the Yallourn mine (Wakeham, 2012; Hepburn, 2014) and several days later the Loy Yang A power station tripped due to an earthquake (see Figure 2.10). At that time, brown coal output reduced from about 6,500 MW prior to flooding to as little as 3,800 MW in the few hours following the earthquake (Sandiford, 2017), equating to almost 10% of NEM wide system load for that time of year.

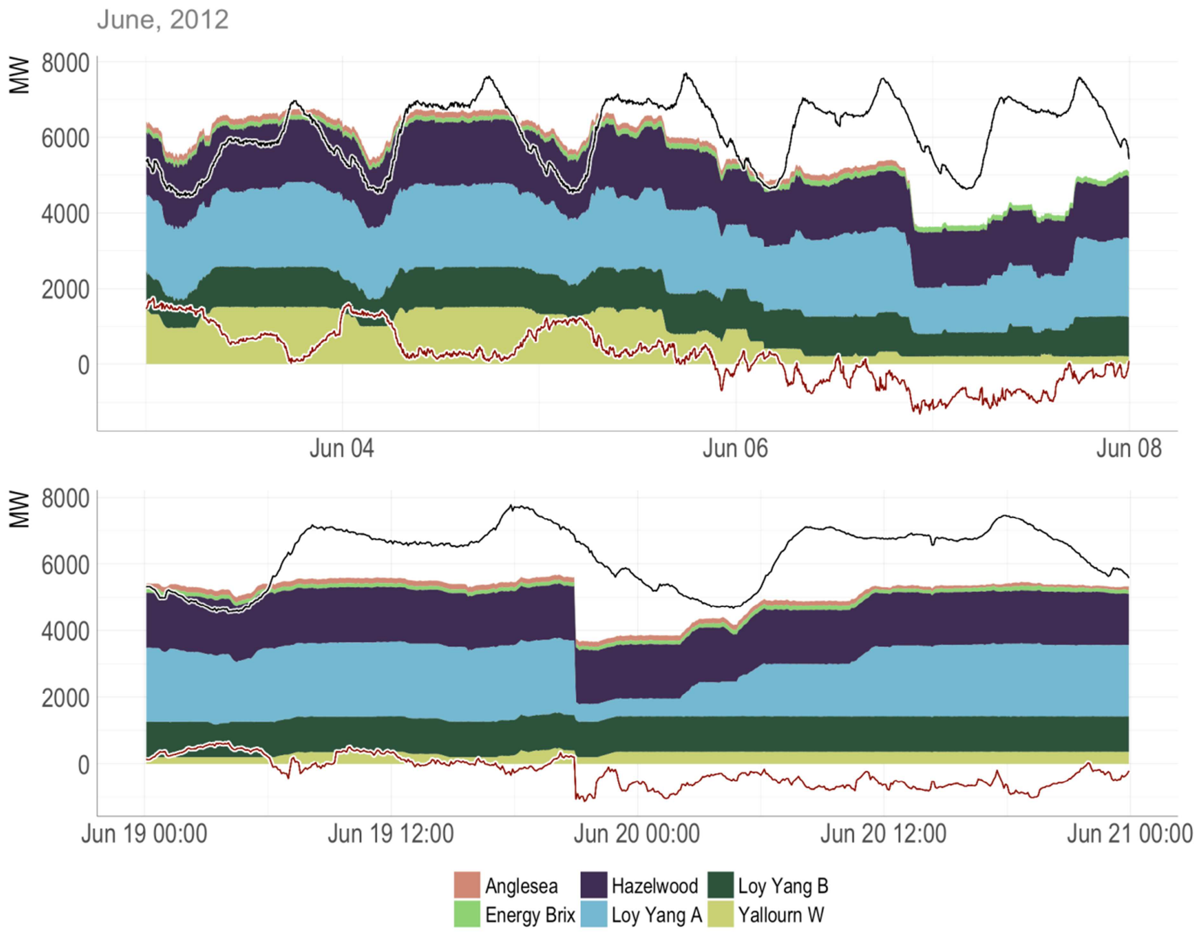

Figure 2.10: Details of Victorian coal production, demand and exchange for the period 3-8 June 2012 in relation to the Yallourn mine flooding event (top) and 19-21 June 2012 related to the Moe earthquake (bottom)
The black line represents total Victorian demand, and the red line is net exports (positive for exports negative for imports)
Source: Sandiford (2017)

Further, extreme weather events in Queensland such as from cyclones have the potential to pose risk to energy security in NSW.

2.3.7 Market composition and data

By standard metrics used to assess level of generation market competition, there is a high level of market concentration in NSW. This can be a barrier for entry for new entrants and expansion by others (AER, 2017h). NSW is dominated by the big 'gentailers'. AGL, EnergyAustralia and Origin Energy control 69% of generation capacity and supply 90% of retail customers (AER, 2017h). The vertical integration allows these gentailers to insure themselves internally against price risk in the wholesale market and reduces their need to hedge in the contract market (AER, 2017h).

AGL operates both Liddell and Bayswater power station in NSW, giving it a 30% market share of generation capacity. Pending outcomes of any new investment, the retirement of the Liddell power station in 2022 would reduce AGL's market position (see Figure 2.11). This would also reduce the market power indices, such as the Herfindahl-Hirschman index (HHI), but would still result in a moderately concentrated market place.

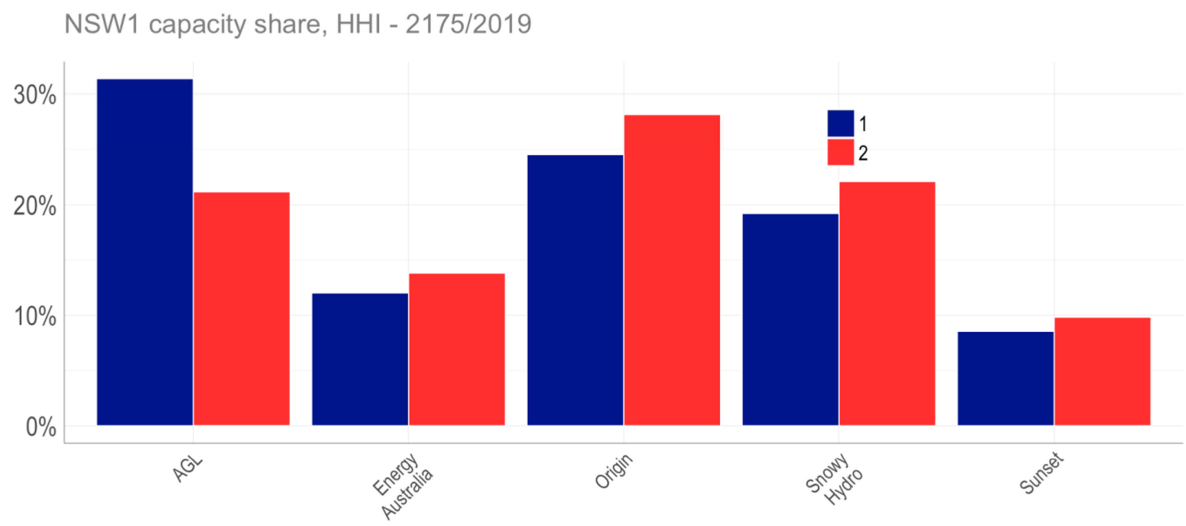

Figure 2.11: NSW generation market power of key participants, with (blue) and without (red) AGL's Liddell power station
Source: Sandiford (2017)

The issue of market concentration has been discussed extensively by the relevant market bodies and is included in AER's annual State of the Energy Market Report (AER, 2017h). Further, the COAG Energy Council in 2016 requested that the AER monitor and report on the whether the NEM is effectively competitive. The AER is currently developing frameworks to undertake this role (AER, 2017h).

The AER recently reported on competition and market operation in NSW, at the request of the Federal Minister for Environment and Energy. This report found that "markets with a limited number of large players are likely to be less competitive than markets with more competitors". However, the AER did not find evidence of "the sorts of opportunistic bidding" that would typically be associated with the exercise of market power. The AER did report that "there does appear to be reduced competitive constraints on the major participants in NSW at present" (AER, 2017a).

In this context, the Taskforce examined how data can be used to understand the NEM better, monitor for anomalous behaviour, identify risks to reliability, and inform good decision making. A large volume of data is available about the NEM. However, it is often in a format that cannot be easily used or understood without detailed analysis or interrogation.

The Taskforce commissioned the Capital Markets Cooperative Research Centre (CMCRC) to develop a tailored data platform for the energy market using the CMCRC's Market Quality Dashboard. This was built on the CRC's previous successful application of the framework in the finance and health sectors.

The Market Quality Energy platform developed by the CRC allows analysis of fairness and efficiency in the market by developing a series of metrics that can be used to monitor for irregular behaviour and trends in the market. The platform allows users to display visual representations of the impact of market events pre- and post- changes. These events can include government policy changes, amendments to market rules or supply disruptions and extreme weather events.

The intent is that the tool will go some way to democratising the use of data in the energy sector and could be used by a range of audiences:

- the NSW Government to inform state-based policy design and decision making and to assist monitoring emerging changes locally and in the NEM

- the market bodies (e.g. AEMO, AEMC and AER) to analyse the effectiveness of existing regulations, evaluate the impacts of future rule changes and monitor for anomalous behaviour
- generators, retailers and customers to reduce information asymmetry between participants and to inform business decision making
- the public more broadly.

2.3.8 Contract market transparency

The contract market is important for driving reliability in the NEM because contract markets support investment in capacity, and provide incentives for the capacity to be available when needed (AEMC, 2017b). Contracts also support reliability by providing certainty to investors that investments can be recouped, thereby enabling investment in new capacity (AEMC, 2017b).

The Energy Security Board's proposal for the National Energy Guarantee is designed to operate through these contracts, by placing obligations on the characteristics of the energy mix that retailers need to cover through these contracts (Energy Security Board, 2017).

Retailers cover their market position through physical plant, contracts and demand side arrangements, and this should drive reliability by ensuring sufficient capacity is available when it is required.

However, there is a lack of transparency in the contract market, and therefore it is difficult to know whether the financial markets are incentivising sufficient new dispatchable generation to enter the market at the right time. There is some uncertainty about whether the retailers are contracting or investing directly in capacity (physical plant or demand side arrangements) sufficiently to cover demand, including capacity for low probability peak demand days. The Taskforce was advised by a number of retailers that they only cover their retail position by physical plant, contracts and demand side arrangements to meet their forecast consumer demand at a 10% PoE level (i.e. so that in 1 year in 10 they will be short for an unspecified amount).

While there is some visibility of Australian Stock Exchange (ASX) traded products, there is no visibility of bilateral contracts (known as over the counter markets), or of internal hedging arrangements within vertically integrated 'gentailers'.

The requirements on retailers through the proposed National Energy Guarantee provide an opportunity to improve transparency of this data so that Governments and the market bodies can have more assurance that sufficient generation plant and demand-side arrangements are being procured to drive towards the reliability standard.

2.4 MONITORING AND INFORMATION

This chapter described a number of areas of potential risk to future security and reliability of the NSW electricity system that should be monitored closely by the NSW Government.

Recommendation 1

That the Government establish mechanisms to monitor the electricity system and the market to ensure the Government has sufficient warning of any emerging risks, particularly those that fall within the remit of the Government, and can have assurance about ongoing reliability of the system in NSW. This can inform any decisions about whether actions at the Government level may be required to support the effective functioning of the market.

This should include:

a) **path to closure and maintenance for large plant:** that Government engage with generators to understand better the path to closure of ageing plant, likely derating of plant over time, and the risk of plant being offline for prolonged periods or closing before expected

b) **fuel:** that Government engage with generators to understand and monitor risks to the fuel supply chain. The Government should prepare relevant regulatory arrangements that may be required in a fuel supply emergency to ensure fast response if required (e.g. moving coal by road)

c) **energy market monitoring:** that Government monitor electricity market data to watch for trends in fairness and efficiency of the market

d) **transparency of the contract market**: that Government work with the energy market bodies to improve transparency of the contract market so that Government can have visibility about how risks are managed and how the contract market is driving investment in sufficient generation capacity and operational decisions to meet demand, including peak loads. This could be achieved through the requirements placed on retailers through the National Energy Guarantee

e) **investment pipeline:** that Government watch the balance between the amount of generation leaving the system and new generation coming online, including transmission and distribution system adequacy for new generation. This should include watching the investment capital structuring for energy investments. If issues are identified, the Government should look at where it can take action that will support the market to bring forward new generation capacity or manage demand better

f) **extreme weather signals:** that Government establish processes to watch for warning signs and patterns in extreme weather events, and continue to support the work of the Office of the Environment and Heritage in filling research gaps about the risks of future extreme weather to energy infrastructure and consequent interdependencies for the operation of essential services

g) **risks from other states:** that Government establish mechanisms for keeping informed of developments in other states that may pose risks to the NSW electricity system.

3 OPPORTUNITIES FOR INNOVATION TO IMPROVE RESILIENCE IN NSW

This chapter discusses where the electricity system is heading, and identifies opportunities for the NSW Government to encourage innovation that will support reliability and security of the electricity system in the long term.

As discussed in the previous chapter, new capacity will be needed as traditional plant retires and the system will need to provide firming capability for intermittent renewables. There will need to be enough generation (i.e. capacity), but it will also need the right characteristics (ramp rates, inertia, fast frequency response etc.). Technology is advancing quickly, and should provide the answers to many of the challenges emerging in the market.

Overall, it is expected that the electricity system will become more weather-driven and distributed, more consumer-driven, more data-driven and more adaptive. This will drive a system that will need to be much more dynamic and responsive.

As larger thermal plant retires, demand response and storage will likely be key components for maintaining reliability and security of the system. Until big storage is viable, it is expected that demand response will be particularly important.

There is also likely to be a flourishing of new innovation and business models, and different approaches to managing risk – some new ideas will succeed and inevitably some will not.

This chapter focusses on areas that the Government can lead, or promote action through COAG Energy Council, to encourage innovation that will improve resilience in the electricity system. It examines whether there are regulatory, market or technical barriers to this occurring and what role there is for the Government or COAG Energy Council in resolving these to support the system transition and provide opportunities for innovation.

3.1 WHAT WILL CHARACTERISE THE FUTURE NSW ELECTRICITY SYSTEM?

To navigate the changing electricity environment, the Taskforce recommends that the Government develop a strategy and define a set of objectives for the electricity system in NSW and establish principles that can guide decision making, trade-offs and regulatory design where needed at the NSW level. It can also inform the Government's approach to negotiations at COAG Energy Council.

These principles are not intended to supersede national objectives and agreements. Rather, they are proposed as a guiding framework to inform local decisions, negotiating positions and resource allocation within the state.

The Taskforce proposes a set of objectives and principles below to help frame and guide these future considerations of the Government:

- **the system should provide reliable, safe and secure energy to consumers** – This reaffirms the National Electricity Objective which, in summary, is to promote long-term interests of consumers with respect to price, quality, safety, reliability, and security of supply; and to promote reliability, safety and security of the electricity system overall[7]

[7] The full wording of the National Electricity Objective is to *"promote efficient investment in, and efficient operation and use of, electricity services for the long-term interests of consumers of electricity with respect to price, quality, safety, reliability, and security of supply of electricity; and the reliability, safety and security of the national electricity system."*

- **the system should contribute to emissions reduction** – The Government's aspirational objective of achieving net zero emissions by 2050 should guide its vision for the future NSW electricity system, as the electricity sector will make a major contribution to this goal. However, the Government can also encourage COAG to agree a national approach to emissions reduction in the electricity sector that would likely be more efficient than a variety of state-based schemes
- **the system should be productive and efficient** – As illustrated in Chapter 2, the use of the grid is becoming increasingly inefficient in NSW, in part due to increasing variability in demand. This requires all market participants to question current approaches to network design and management to promote efficiency in generation, transmission, distribution and use of electricity, improve overall system productivity, and ultimately reduce costs to consumers
- **the system should promote affordability and choice for consumers** – This objective should guide the Government's approach to issues such as targeting protections for vulnerable customers, consumer safeguards and creating the appropriate structures for new business models. It should also inform issues such as removing barriers for customers to participate in new models of energy management including, for example, tenants, apartment dwellers or lower income customers. As the electricity system transitions, increasing choice for some consumers to reduce reliance on the grid via solar and batteries should not come at the expense of other consumers who cannot afford those capital costs. It also points to the need to examine and minimise the hidden subsidies between different types of consumers
- **regulatory arrangements and programs should be efficient, technology agnostic and enable innovation** – Innovation should drive increasing reliability, productivity and affordability in the electricity system. Regulatory arrangements should be flexible enough to accommodate change in technologies and business models, and the planning system should be proactive in keeping pace with new types of energy infrastructure. Innovation should not be held up by prohibitive or absent regulatory arrangements. Programs within government must efficiently respond to the changing needs of the energy sector, particularly start-ups, and adapt where necessary. This objective should be supported by enhanced capability within government to monitor technology developments and innovations in service delivery internationally so that government can proactively anticipate change and design appropriate frameworks to accommodate this progress
- **the system should be built on effective collaboration across the National Electricity Market** – This principle emphasises two points. Firstly, that the NEM is a market and decisions taken by the NSW Government should support the market to work, and avoid undermining confidence in private investment. It also emphasises that NSW is part of a connected network of jurisdictions and decisions in NSW should be taken in the best interests of the overall system. The NSW Government should continue to encourage other jurisdictions to do likewise. This can include reinforcing effective collaboration across the NEM though the review and recommitment to the Australian Energy Market Agreement.

Recommendation 2

That the Government develop an electricity strategy for NSW that identifies objectives for an ideal electricity system in NSW and can inform trade-offs, decision-making, regulatory arrangements, and program design in NSW.

The strategy should also inform the NSW Government approach to negotiations at COAG Energy Council, including to promote the review and effective operation of the Australian Energy Market Agreement.

3.2 DEMAND-SIDE MANAGEMENT

The previous chapter outlined the risks associated with greater 'peakiness' in demand in NSW which is likely increasing costs for consumers. It also increases the risk of costly and inefficient load shedding during the infrequent times when demand is particularly high and generation capacity may be compromised in some way, such as during extreme temperatures.

Demand response represents a low cost and as yet under-developed opportunity to maintain reliability and security (Commonwealth of Australia, 2017). This is probably in part due to the fact that, until recently, generation capacity has been more than sufficient to meet demand.

However, the nature of risks and the economics of energy management have shifted. There is now an opportunity for greater deployment of demand side measures in NSW which aim to restrict, or even reduce, peak-demand growth in NSW, and to manage demand reduction more efficiently in the event of a repeat of conditions of the kind that led to load shedding in February 2017.

Efficient demand management in NSW will have a number of benefits:

- allowing more efficient management of power system security and reliability risks when supply is tight and as generation comes and goes from the system
- reducing the trend of increasing peak demand, which should reduce overall system costs and lead to more efficient utilisation of the network
- helping to manage increasing intermittency in the system and contributing to emissions reduction.

It also has the potential to defer the need for network augmentation expenditure and reduce the need for involuntary load shedding that is relatively indiscriminate and potentially costly for consumers (AEMO, 2016b).

The UTS Institute for Sustainable Futures suggests that if the NEM had the same proportion of demand management as the average for states in the US, there would be about 3,000 MW of available capacity, significantly larger than the capacity of some of the large thermal plant slated to leave the system in coming years (Dunstan, Alexander, Morris, Langham, & Jazbec, 2017).

This section examines the existing demand response capability in NSW, including the capacity for different mechanisms to be deployed over multiple consecutive days if required, for example, during an extended heatwave or prolonged outage of large plant. It also canvasses some of the opportunities for greater deployment of efficient demand management initiatives.

3.2.1 What is demand management?

Demand management is an alternative to increasing supply capacity to meet periods of high or extreme demand, and can delay or reduce the need for long-term network augmentation, particularly as conventional thermal generation retires in the future (ClimateWorks, 2012; Dunstan, 2015; Wood & Blowers, 2017b).

The AER characterises three approaches to demand management (AER, 2017b):

- peak shaving: reducing energy demand at peak periods, early evening
- shifting load: moving load from peak to non-peak periods
- broad-based load reduction: energy efficiency measures at constrained parts of the network.

Demand management does not include involuntary or forced load shedding.

AEMO describes demand side participation as “any incentive for customers to reduce their load at certain times” including (AEMO, 2016b):

- centralised appliance control – for example, in Queensland Energex provides upfront discounts on air-conditioning units which allows them to alter temperature at maximum demand times remotely, which it also does with electric hot water units
- interruptible loads – typically commercial and industrial consumers that can rapidly reduce demand after trigger events like frequency disturbances
- behavioural demand response – where applications can incentivise residential and commercial consumers to reduce their load for peak events voluntarily.

It can also include orchestrated use of distributed energy resources, for example, customers' embedded generators and storage.

3.2.1.1 Demand response in NSW on 10 February 2017

As analysed in the Initial Report, the heatwave in NSW on 10 February 2017 resulted in NSW coming close to its historical peak demand on a Friday afternoon. After failures at two large gas powered generators, load shedding from Tomago Aluminium smelter was required to maintain system security. Load shedding of residential and other business customers was avoided.

One component of the events on that day was the call from the Minister for Energy and Utilities for people and businesses in NSW to reduce demand voluntarily. While the approach to reducing demand on 10 February was productive, it was ad hoc, not well orchestrated and had not been prepared for in advance. On the whole it consisted of a reactive series of calls and requests from the NSW Government directly to large users and the public. These events prompted the NSW Government to set up the Taskforce.

3.2.2.2 Sydney Water

The events of 10 February highlighted that Sydney Water has the potential to play a significant role in demand response during periods of tight energy supply, including by:

- reducing power used for ventilation
- reducing power used for centrifuges to dewater digested sewerage sludge
- reducing power by storing sewerage for processing at an off peak time when energy demand is lower
- generating energy for use by the plant to reduce demand on the grid and potential for cogeneration output (food and wastewater sludge to energy) to contribute energy to the grid.

While the viability of each option is plant specific, Sydney Water informed the Taskforce that approximately 4 MW of power could be reduced by undertaking the first three measures listed above. While further analysis is required, Sydney Water estimated these methods could be sustained for four hours for up to five consecutive days.

Sydney Water also has the ability to generate its own power using existing back-up diesel generators that are on site. Sydney Water was able to do this during the 10 February heatwave when it ran a diesel generator at the Malabar plant and decreased its demand on the power system.

Sydney Water is exploring other options to broaden the opportunities for power generation, including the co-digestion of food with sewerage in cogeneration energy facilities and the use of solar power at sites which could potentially be exported to the grid in times of high demand. As energy generation is not core business for Sydney Water, it is not currently captured under its operating licence which is determined by the IPART. Therefore, approval from IPART would be needed to conduct such activities.

3.2.2.3 Hunter Water

As noted in the Taskforce's Initial Report, Hunter Water was able to reduce energy demand by 4,600 kW during the 10 February heatwave by: augmenting the operation of bulk water transfer pump stations; limiting treatment plant operations to essential systems and processes; and utilising generators.

Hunter Water indicated that if it was approached to respond to similar demand response requests over several days it could potentially reduce electricity demand for short periods over numerous days. However, reduction of load similar to the volume achieved on 10 February would not be sustainable over several full days during heatwave conditions given that water would typically also be at peak demand.

Following the demand response requested by the NSW Government on 10 February, Hunter Water has been refining its demand response procedures with the aim of implementing this ahead of the 2017-18 summer. One initiative under consideration is 'smart integrated pump scheduling' (SIPS), which automatically schedules pump and valve operations to optimise energy efficiency and reduce costs through effective management of energy consumption, such as preferentially pumping during off peak, reducing consumption during peak electricity demand and avoiding capacity charges where possible.

3.2.2.5 Other large energy users

TransGrid has advised the Government that it is aware of potential demand response capacity of around 550 MW based on information from large energy users, expressions of interest and previous procurements (TransGrid, 2017c). This could include involvement from large and small mines; industrial consumers; data centres; residential batteries; controllable loads and demand management innovations and telecommunications back-up diesel generators.

Within the Sydney CBD there is also the ability to reduce power demand. For example TransGrid procured 40 MW of demand response (which was mainly load reduction) from the Sydney Inner Metropolitan area to reduce peak demand during the 2012-13 summer (TransGrid). TransGrid predicts that between 40 MW-80 MW of demand management could be procured from the CBD and Inner Sydney as part of the Powering Sydney's Future project, but this will not be available for summer 2017-18 (TransGrid, 2017c).

3.2.2.6 Broader community involvement

Residential consumers can assist with demand management though the installation of energy saving technologies on household equipment such as air conditioners, pool pumps and hot water systems and curtail power usage during periods of high demand and low supply (Energex, 2017).

Retailer Mojo Power illustrated the opportunity to engage residential customers in demand response procedures as part of a trial on 10 February 2017. Mojo used existing technology to facilitate demand response from its customers when the wholesale market was forecast to hit the market cap of $14,000/MWh on the afternoon of 10 February. That morning, Mojo messaged 500 of its smart meter-enabled customers in NSW and offered a $25 credit on their energy bills to reduce their energy consumption between 4-6 pm that afternoon. An estimated 194 customers responded, with 50% conducting observable changes and 20% decreasing their usage by 10-12 kW which was predominantly air conditioning units and pool pumps being turned off or down. Figure 3.1 below illustrates the change in energy usage of Mojo's top 20 customers that responded (Mojo Power, 2017a).

Mojo advised the Taskforce that requests for voluntary demand responses from the broader community are most effective when they are deployed for one hour at a time and for no longer than two hours to minimise disruption and any consequent risks.

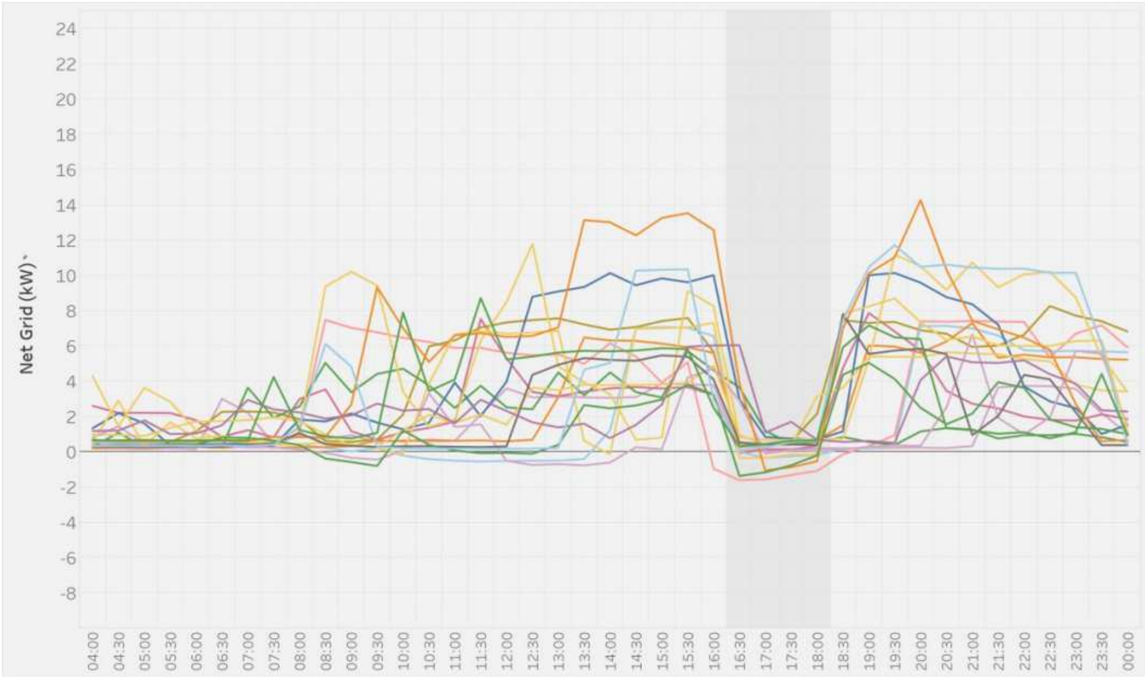

Figure 3.1: Load profiles of the top 10% of Mojo Power's demand response customers on 10 February
Source: Mojo Power (2017b)

3.2.2.7 Public Sector 'Code Warm' protocols

In the Initial Report, the Taskforce recommended that the NSW Government establish a working group, which included representatives from the Commonwealth, NSW and ACT Governments, to develop new protocols (termed Code Warm protocols) for agencies to reduce demand and increase behind-the-meter supply during periods of peak energy use such as sustained heatwaves. The NSW DPE has led implementation of this recommendation.

The 'Code Warm' protocol has been renamed the 'Government Energy Action Response' (GEAR) protocol to cover hot and cold weather conditions when demand reduction may be required. The scope of the protocol includes all NSW Government agencies as well as the Commonwealth and ACT Governments and extends to significant cultural institutions, schools and public landmarks. It is estimated that around 20 MW of demand management may be secured through the protocol if required.

The Department has also worked with relevant state owned corporations to scope voluntary demand response actions that could be implemented if needed to help avoid involuntary load shedding. In addition, some other large energy users are partnering with the Department to provide support in an energy emergency event, including a university and a local council. It is reported that some organisations were not willing to make the investments, for example in new technology, to facilitate more automated demand response, but are willing to act to provide support in an emergency if requested through this mechanism. While difficult to quantify, it is estimated that up to 23 MW may be secured through these partnerships, and this will grow as more partners are secured. The Department is also working with the distribution networks to identify large users that may also be able to support demand response activities.

3.2.2.8 ARENA and AEMO demand response pilot projects

Another important initiative of the NSW Government is the partnership with ARENA and AEMO to pilot a demand response program this summer, with a $7.5 million contribution from the NSW Government. In NSW four projects have been funded which will deliver a total of 80 MW, with approximately 61 MW available for 2017-18 summer. AEMO has indicated this capacity will be managed through the short-term RERT[8] (AEMO, 2017k).

The projects being funded in NSW are (AEMO & ARENA, 2017):

- AGL – 17 MW will be leveraged from NSW commercial and industry customers, with 3 MW also being leveraged from NSW residential households with smart meters
- Energy Australia – remote control load curtailment devices and battery storage will be used to leverage 18 MW from NSW commercial and industrial businesses and residential customers
- EnerNoc – remote control load curtailment devices will be used to curtail load from NSW large commercial and industrial businesses, resulting in a total of 20 MW load
- Flow Power – 5 MW will be leveraged by implementing their kWatch™ Intelligent Controllers in 100 NSW commercial and industrial customers.

3.2.1.9 Energy efficiency

Energy efficiency measures can further reduce costs for consumers and help to manage network constraints. Promoting greater energy efficiency includes: providing information to consumers about energy usage; providing information on and improving standards for appliances, buildings and vehicles; enabling upgrades and retrofits to office buildings; and improving the efficiency of the government sector (Banerjee, Moreno, Sinton, Primiani, & Seong, 2017; Energy Efficiency Council, 2017; OEH, 2017c).

The NSW Government has a number of initiatives in this area. For example, the NSW Energy Savings Scheme, administered by IPART, aims to reduce energy consumption by providing financial incentives for organisations to improve energy efficiency (IPART, 2017a). It places obligations on scheme participants, including all electricity retailers, to meet energy savings targets of 7.5% (2017) to 8.5% (2019-25) (IPART, 2015, 2017b). These targets can be met by purchasing energy savings certificates representing notional MWh saved, or paying a penalty (IPART, 2017b).

Under the Energy Efficiency Action Plan (OEH, 2013b), the Government provides advice on improving energy efficiency ratings, and purchasing appliances or small scale renewable energy generators (NSW DPE Division of Resources and Energy, 2017; OEH, 2017b). Financial incentive programs assist households to reduce costs by accessing energy-saving appliances and home improvements.

Government programs that support energy efficiency of large users include the Environmental Upgrade Agreement legislation to enable retrofits to large multi-residential or non-residential buildings (OEH, 2016), and the NSW Government Resource Efficiency Policy to drive energy efficiency and lower operating costs across government agencies (OEH, 2017d). The NSW Energy Efficiency Decision Making Node is a collaboration of stakeholders and researchers examining decision-making behaviour about energy efficiency options and technological developments (OEH, 2017e).

These programs highlight the importance of understanding consumer behaviour, addressing the challenges of affordability and enabling low income consumers to access energy efficient technologies, and assessing the most practical actions to save energy.

3.2.2 Barriers and opportunities

The NSW Government has acted to secure additional demand response capacity ahead of the coming summer, and there are opportunities to encourage a much more diverse suite of

[8] The RERT is a function of AEMO where reserve contracts can be used to maintain system security and reliability. AEMO can conduct expression of interest rounds to procure reserve energy on short, medium and long term notice as part of a RERT panel when AEMO has identified that the reliability standard may not be met. This can include: load that can be curtailed and restored on demand; generation capacity this is not normally available to the market that can be brought online when required.

efficient demand management responses that can better meet the network management needs in NSW.

The AER has developed a Demand Management Incentive Scheme and an Innovation Allowance Mechanism which aim to incentivise distribution businesses to undertake proven and efficient non-network options, and also to reward investment in as-yet-unproven technology and solutions for demand management projects that could reduce long-term network costs. The AER's consultation paper on development of this Scheme identified a number of barriers to demand management, including: lack of information on network constraints; lack of information on what demand management can deliver; underdeveloped market for demand management solutions; and potentially cultural biases within distribution businesses (AER, 2017b).

Another barrier that was raised with the Taskforce in interviews with retailers was that there is concern that not-well-understood technology could introduce a cyber security risk which could propagate across the network.

As well as helping to meet reliability outcomes, demand response through distributed energy resources can provide voltage and frequency services back to the network. AGL notes that responses to meet a supply constraint may only be needed a small number of times a year, but at other times, energy resources in a home or business can be used to meet the everyday needs of the customer. AGL points out that to achieve this 'value stacking' there is a need to make explicit the location and size of resources needed for grid support and their value, so that products and services can be designed and to facilitate the commercialisation of this area (AGL Energy Ltd, 2017c).

Given the likely importance of demand response for maintaining reliability and security in NSW over the next period, the Government would be wise to prioritise some focus in this area. In light of the program underway by the AER, and other work being driven through the private sector to develop new energy service models that can provide demand response services, the Government can support this activity by providing information and addressing barriers to entry for consumers and business to participate in these new opportunities. This should also include high quality information for consumers about energy usage and technology options to inform their capital investment decisions.

Recommendation 3

That the Government focus on improving uptake of efficient demand management options to manage risks during peak demand periods and over the longer term to encourage more efficient use of the network and reduce costs.

Particular focus should be given to mapping out the technical capacity of the NSW system to conduct effective demand response and load shifting at scale to manage security risks during peak demand periods and accelerate the roll out of technology that will address any limitations. This will include supporting the work of AEMO and network businesses to improve the visibility of distributed energy resources in NSW, including those that may be of use during an energy emergency.

The Government should also establish a work program to examine barriers to uptake of distributed energy resources and demand response opportunities, for example, by low-income households, tenants, and apartment residents.

3.3 STORAGE

Energy storage is likely to play a key role in the future energy system and technology is advancing rapidly. Storage technologies can play a number of different roles in the system depending on the type – including providing grid security services, peak demand management, and firming intermittent generation sources.

There is unlikely to be a single technology or category of energy storage that dominates the market, as different technologies are best suited for different functions (Godfrey, Dowling, Forsyth, Grafton, & Wyld, 2017).

The Australian Council of Learned Academies (Godfrey et al., 2017) reported that "Battery systems are the most cost effective when stabilising the grid, provided they have a 'fast frequency response' capability through appropriate power electronics to synthesise the fast frequency response, and are ready for immediate discharge when required. By comparison, where geology and water availability permit, large-scale energy storage by pumped hydro is most cost effective for delivering energy reliability".

Types of energy storage are usually broken down according to their method of energy storage (Luo, Wang, Dooner, & Clarke, 2015; Aneke & Wang, 2016):

- mechanical (such as pumped hydro or flywheel energy storage)
- electrochemical (such as conventional, rechargeable lead acid or lithium-ion batteries)
- electrical (such as capacitors)
- chemical (such as hydrogen fuel cells)
- thermal (heat storage, such as molten salts)
- geothermal reservoirs
- thermochemical (solar fuels).

This section primarily discusses batteries and pumped hydro and their potential for the NSW electricity system, and where there may be a role for the Government in managing any barriers to their efficient use in the system.

3.3.2 Pumped hydro energy storage

Pumped hydro energy storage (PHES) increasingly has potential in Australia to act as an effective electrical energy storage technology as an alternative to, or in conjunction with, batteries. PHES can contribute to both reliability and security of the grid, as it can provide the system security services associated with synchronous generation. Energy is stored when prices are low, such as from solar or wind energy, or overnight coal generation. During this time, water is pumped to the higher of two reservoirs and stored, then released when energy is needed.

PHES accounts for 97% of energy storage worldwide (Blakers, Lu, & Stocks, 2017a). Recent investment internationally has been in response to increased renewable generation as a flexible means to build reliability into electricity markets (Barbour, Wilson, Radcliffe, Ding, and Li (2016). In 2016, Japan had the largest PHES capacity at ~25 GW, followed by China at ~23 GW (Barbour et al., 2016). Europe currently has a combined installed PHES capacity of ~33 GW, with the largest proportion in Germany.

No large-scale PHES facilities have been constructed in Australia in the past 30 years (Godfrey et al., 2017). However, recently the Commonwealth Government announced a feasibility study to develop 2 GW of PHES through extension of Snowy Mountains Scheme. Further, ARENA has also recently funded a feasibility study for a coastal PHES project in South Australia that utilises the ocean as the lower reservoir. Also, construction of the Kidston PHES project in northern Queensland utilising a disused gold mine is due to commence shortly.

A study led by Andrew Blakers at the Australian National University identified over 22,000 potential PHES sites in Australia, with 8,578 potential sites in NSW, amounting to a combined storage capacity of approximately 29,000 GWh (Blakers, Stocks, Lu, Anderson, & Nadolny, 2017b). This assessment excluded national parks and protected land. Blakers et al. (2017b) also noted that the sites were often close to the transmission grid. Maps showing the locations of these potential sites are available (Blakers et al., 2017b).

Site selection for pumped hydro facilities requires multiple criteria to be considered with topography, climatic conditions and proximity to the grid being the main limiting factors. This is followed by water availability, wider environmental factors and ‘social license’. As described by Godfrey et al. (2017), “land use and water requirements for PHES have the potential to negatively influence the social license for the technology if environmental and water use impacts are not appropriately managed”.

There are also opportunities to capitalise on reservoirs that are owned and/or operated by the NSW Government for potential new pumped hydro projects.

In anticipation of proposals coming forward for new PHES developments, the Government should prepare for how it would manage approvals for this type of generation infrastructure in the NSW landscape through the planning system and what environmental approvals would be required. This could include developing guidelines for proponents, which could be similar to those developed for solar and wind developments (e.g. the Wind Energy Guideline by NSW DPE).

Recommendation 4
That the Government do pre-work on environmental permissions for likely new styles of energy infrastructure, for example pumped hydro, in order to facilitate the smooth adoption and development of appropriate energy technologies.

3.3.3 Batteries

Batteries can allow the storage of electricity, such as from intermittent generation (wind and solar) and/or during periods of excess supply enabling it to be used at a later time. Current battery technologies are mostly based on Lithium-ion (Li-ion) technology. Li-ion batteries have a fast response time, high cycle efficiencies, and low daily self-discharge (Luo et al., 2015; Aneke & Wang, 2016; Godfrey et al., 2017). The overall lifespan of a Li-ion battery is between 5 and 15 years, with most manufacturers offering up to 10 year warranty. However, there are still a number of issues around safety, especially overheating, scalability and cost of materials, and the additional management technologies required for Li-ion battery storage (Tichy, 2007; Lu, Han, Li, Hua, & Ouyang, 2013; Luo et al., 2015; Weise, 2016).

Large scale batteries

With the increase of wind and solar generation large scale batteries have been employed around the world to provide system security services.

There are several international examples of successful deployment of large-scale battery storage. The U.S. Advanced Research Projects Agency-Energy (ARPA-E) has provided funding of over US$85 million for R&D in cost-competitive stationary energy storage since 2009 (ARPA-E, 2016). ARPA-E is funding more than 70 demonstration projects (Anderson, 2016).

In Escondido, California, AES Energy Storage and San Diego Gas & Electric (AES Energy Storage, 2017; SDG&E, 2017) have built a battery-based energy storage system (using Li-ion technology), that has capacity of 30 MW/120 MWh (Energy Storage Association, 2015; AES Energy Storage, 2017), which could provide power to ~20,000 customers for up to four hours with the assistance of a smaller facility at El Cajon, California (7.5 MW) (AES Energy Storage, 2017).

A large scale battery system in Australia has been built in South Australia to store wind energy and provide system security. The Tesla system is Li-ion based and contains 16 individual battery packs for a total storage capacity of 100 MW/129 MWh (Tesla, 2017). This battery system was used on 30 November 2017, a day ahead of its opening, to help meet peak demand on a hot, low wind afternoon (Harmsen, 2017), and is currently the largest in the world.

However, this record may not last for long. In February 2018, the Hyundai Electric and Energy Systems Company is due to open the world's largest battery in Ulsan, South Korea. It will be a 150 MW lithium-ion battery, 50% larger than the South Australian battery (Williams & Sood, 2017).

Household battery storage

With reduction in battery prices, batteries are currently being installed and will be employed more broadly in homes to store energy from rooftop solar PV. AEMO expects that consumer investment in rooftop PV systems will continue to grow over the next two decades, with an estimated increase from approximately 6 GW (combined capacity from more than 1.6 million solar PV installations as of April 2017 (APVI, 2017; Australian Energy Council, 2017)) to 20 GW installed by 2036-37 (AEMO, 2017c). Battery storage uptake by residential and commercial stakeholders is also forecasted to increase to over 5.5 GW in the same period (AEMO, 2017c).

Wood and Blowers (2015) suggest that if the typical Sydney household installed a 7 kW solar PV system and combined this with 35 kWh of battery storage, this would meet 95% of the household's electricity needs annually (i.e. only 18 days where it would require grid power).

Issues and areas for energy storage research and development

There is considerable research being undertaken into battery technologies. Australia could be a world leader in energy storage research with world-class raw material resources for battery technologies (most notably lithium), and considerable expertise in research and development and integration of energy storage (Godfrey et al., 2017). There are several areas for research and development to enable better function and uptake of batteries.

Operating temperatures of Li-ion batteries - Although Li-ion batteries have a wide safe operating temperature range (-20°C up to 60°C), they also suffer from increasing degradation and decreasing maximum charge storage whilst cycling at higher temperatures (25°C-55°C) (Tichy, 2007; UL Global, 2012; Pesaran, 2013; Leng, Tan, & Pecht, 2015). Therefore, the optimal performance range for them has been recommended between -10°C to 30°C (Gartner, 2012; EERE, 2015). This could be problematic during extreme heat events, when they may be particularly needed to provide system services. Future research and development should target an increased temperature range.

Environmental impacts - Another issue with battery storage is the environmental impact from obtaining raw materials (including rare earth minerals), manufacturing, transporting, operation and disposal. For example, Lithium-based batteries have a Dangerous Goods classification of Class 9 for transport due to their environmentally hazardous substances that present a danger when transported (UN, 2009). There are also socio-political and human rights issues associated with resources used in some batteries, such as the mining of cobalt in the Democratic Republic of Congo (Godfrey et al., 2017).

Recycling Li-ion can reduce these environmental effects, and reduce the raw materials mined. There are different processes being used to recover rare earth materials from batteries, such as hydrometallurgy and pyrometallurgy, with low-temperature and plastic recovery processes providing the most beneficial recycling solutions (Gaines, 2014; Boyden, Soo, & Doolan, 2016).

Alternative materials - Different and new materials are being developed and used to make the next generation of batteries. For example, the start-up Gelion, a spin-off from University of Sydney, has generated worldwide attention and investment for its novel approach to a gel-based Zinc-Bromine battery (University of Sydney, 2016; Vorrath, 2016). Gelion batteries can be stored at zero charge indefinitely, and have advantages in scalability and flexibility. Since they are gel-based, they can be manufactured in many shapes such as for building infrastructure (Vorrath, 2016). Importantly, the gel is resistant to fire, which is an issue that continues to be a risk for Li-ion batteries in some circumstances (Weise, 2016).

Product and safety standards

Product and safety standards are important in the uptake of new technologies. There is a role for government to ensure that standards maintain a high level of safety, yet do not prohibit further developments or novel technologies or the pace at which these can be delivered to market.

Currently, there are standards, codes and other regulatory requirements that apply to different aspects of the energy system, including Australian Standards and building codes that cover energy storage and connections of these resources at the residence level. For example, in the NER the connection of micro-embedded generation units (such as domestic PV solar) refers to Australian Standard *AS 4777 Grid connection of energy systems via inverters*.

There are no Australian Standards governing the safety, installation or performance of residential battery storage systems (Crossley, 2017). There has been media coverage indicating community and industry concerns about a proposed Australian Standard *AS 5139 Safety of battery systems for use in inverter energy systems*, which relates to Li-ion batteries (Standards Australia, 2016; Parkinson, 2017a; Vorrath, 2017). Concerns are centered around the proposed fire hazard classification for Li-ion batteries, which is reported to not align with international practice and essentially prevent the installation of batteries inside residential homes or dwellings (Parkinson, 2017b).

Stakeholders noted that, where possible, Australian standards should reflect international best practice in regards to safety and technical specifications, e.g. European *IEC 62619:2017* which covers safe operation of secondary lithium cells and batteries (CEC, 2017). The adoption of international standards would also facilitate the export of Australian-developed energy technologies and encourage economies of scale.

The Taskforce also heard of concerns around alterations and upgrades to pre-existing systems, such as adding battery storage to complement solar PV, where requirements for pre-installed systems to be bought up to current codes if they are altered tend to result in the consumer either choosing not to upgade, or needing to purchase a new system (Reposit Power, 2017).

Product and safety standards are relevant across new forms of distributed energy resources generally and should be a focus for Government, in partnership with Standards Australia, to encourage innovation.

3.4 MICROGRIDS AND VIRTUAL POWER PLANTS

This section discusses the potential of microgrids including 'virtual microgrids' or 'virtual power plants' to contribute to efficiency, reliability and resilience within the NSW electricity system, with a focus on regulatory barriers that need addressing at the NSW Government level.

Microgrids and virtual power plants have the potential to integrate multiple distributed energy resources, enable effective demand response, decrease vulnerability in the grid, enable lower cost transmission and distribution lines and provide economic benefits to consumers (PowerGen Renewable Energy, 2016; The Advanced Energy Centre, 2016).

Microgrids have been defined as "an electricity distribution system, often containing distributed energy resources (such as photovoltaics (PV), batteries, and other generation and storage devices) that can be operated in a controlled, coordinated way. Microgrids can either be connected to the main power network, or stand-alone" (NSW Government, 2017b). Microgrids differ from embedded networks, which are defined as private networks connected to the NEM through a distribution or transmission network. Unlike microgrids, embedded networks are defined and recognised in the National Electricity Rules and are listed in an AER register of exempt retailers and networks (AER, 2017e).

Virtual power plants are a form of microgrid that are connected to the distribution or transmission network and use internet, smart meters and integrated hardware, and software such as aggregation platforms to manage electricity demand, storage and transfer (Asmus, 2017; Howell, Rezgui, Hippolyte, Jayan, & Li, 2017). Virtual power plants can tap into a range of power sources in the NEM, and they enable peer-to-peer trading, allowing households to buy and sell energy to each other. These platforms can connect multiple loosely aggregated (non-neighbouring) generators and users (Asmus, 2010) without the need for a separate network.

Increased uptake of virtual power plants will be supported through the roll out of technology that enables these innovations, such as smart meters, and providing reliable information to consumers.

There are some regulatory issues and gaps at the NSW level that restrict the efficient uptake of microgrids and operation of stand-alone systems. Many of these issues are also relevant to embedded networks. There are opportunities for the NSW Government to support the further deployment of these options by encouraging pilot projects and demonstrations at scale, and formally working through the regulatory issues that need to be resolved at the state level.

3.4.1 Microgrids

Microgrids can lower demand and reduce grid congestion at critical times and allow deferral of network augmentation expenditure which should ultimately reduce costs to consumers, by efficiently managing distributed energy resources (AEMO, 2016b). AEMO (2016b) indicated that micro-grids could "reduce the requirements for large-scale development to improve power system resilience" and that having generation and system security services closer to demand for electricity reduces the risks that could disrupt supply.

Microgrids that can operate as stand-alone systems part of the time could provide greater reliability of supply to remote areas (Western Power, 2016; Energy Networks Australia, 2017b), or serve as an alternative to backup generators and to avoid the risk of shortages and cost of diesel supply (ARENA, 2017b). Areas dependent on diesel generation in NSW include Lord Howe Island and other remote and rural locations as well as agricultural operations.

Powercorp is an example of an Australian company specialising in automated controls to support remote and isolated grids. It was bought by ABB in 2011. Powercorp has specialised in integrating wind power into the grid, using inverters and flywheel energy storage for frequency and voltage stability (Tweed, 2011). Projects have since included supplying microgrids for island and remote communities such as Coral Bay in Australia and Ross Island in Antarctica (ABB, 2017).

3.4.2 Regulatory environment

Gaps in regulation related to microgrids and other new supply models are being considered by COAG Energy Council, AER and AEMC (COAG Energy Council, 2016; AEMC, 2017e; 2017j; AER, 2017g; 2017f; COAG Energy Council, 2017a).

In June 2017 Western Power, a West Australian DNSP submitted a rule change request on alternatives to grid-supplied network services intended to remove regulatory barriers to distributors providing electricity supply through stand-alone power systems or microgrids, particularly to remote consumers (AEMC, 2017j). The AEMC did not make a draft rule on this issue because a rule change on its own was not sufficient and may create inconsistencies with the National Electricity Law. A range of changes to laws, rules and state and territory instruments are needed to enable microgrid systems to be used when cost effective and while protecting customers.

The regulatory responsibility of the NSW Government includes reliability and performance standards, safety and some consumer protection issues. To begin examination of these issues, in November 2017, the NSW Government released a discussion paper, 'Protecting consumers in a changing energy world' which is seeking comment on gaps in regulatory and safety regulations and consumer protections in NSW (NSW Government, 2017b).

Some of the regulatory issues that need to be considered include:

- ***safe and reliable electricity supply:*** DNSPs are subject to licence conditions under NSW legislation which define reliability and performance standards, safety and technical obligations. However, these do not apply to microgrids and embedded networks. The AEMC has determined that it is important to have reliability standards that apply to stand-alone microgrids, with enforcement mechanisms, but that these may not necessarily be the same as those that apply generally to grid-connected customers (AEMC, 2017j)
- ***consumer protection:*** Compared with customers who are supplied by the distribution grid, microgrid and embedded network customers do not have access to competitive supply offers. While an AEMC rule change emphasised that embedded networks should allow customers to access authorised retailers as an alternative, there is no requirement for authorised retailers to accept applications from customers in embedded networks (Energy & Water Ombudsman NSW, 2017). Several protections offered to grid-supplied customers are not provided to embedded network or microgrid customers, including: the Retailer of Last Resort Scheme provisioning for retailer insolvency; access to financial hardship schemes; access to government rebates; requirements to report on disconnections made in error and disconnections of customers on life support; and spot audits by AER (AER, 2017d; Energy & Water Ombudsman NSW, 2017)
- ***consumer protection regarding technology:*** Rapidly developing distributed energy resources technology and policy gaps may increase the risk to microgrid customers. Risks include: investing in technology that becomes obsolete; warranty breaches if suppliers leave the market; gaps in interoperability between systems; and barriers to switching to a different supplier or platform (Handberg, 2016; Crossley, 2017).

High-quality, reliable information and guidance for consumers are required to inform choices about participating in a microgrid and making capital investment decisions, for example in household solar and batteries.

3.4.3 Virtual power plants

Virtual power plants do not require a private network to match demand to supply in real time, which enables efficient use of variable renewable energy sources of power (GreenSync, 2017; Thompson & Murfitt, 2017). The regulation around virtual power plants is more straightforward than for stand-alone microgrids as customers are generally still connected to the grid and therefore have greater consumer choice, access to regulated tariffs, rebates and vulnerable consumer protection arrangements. A key limitation to efficient uptake is the roll out of appropriate technology in houses and businesses that will enable power management and aggregation at scale.

Households generally buy enough solar panels to meet their own needs, rather than sizing the system based on their rooftop capacity and storing or generating excess in order to sell it on (Thompson & Murfitt, 2017). In areas of very high solar PV penetration, new installations may be limited to ensure that network security is not affected and feeding in excess solar to the grid may be curbed (GSES, 2017; Thompson & Murfitt, 2017). Virtual power plant technology can remove these constraints on solar and can aggregate distributed resources to manage supply and demand more efficiently (Thompson & Murfitt, 2017).

Because virtual power plants allow households to buy and sell energy to each other, households may not need a large battery (EcoGeneration, 2017) or one at all to participate. Virtual power plants allow involvement of customers without solar and batteries, allowing greater choice for consumers such as renters, who may not have previously had the option to obtain local clean energy (Electricity Authority, 2017).

New business models are emerging. For example, Reposit Power's GridCredits scheme uses smart technology to allow a customer's excess stored energy to be sold to the grid, assisting in grid stabilisation when demand or wholesale prices are high (Reposit, 2017).

Virtual power plants using public communication networks and common networks might present cybersecurity challenges, although vulnerabilities are not different to those that DNSPs are already managing. Cyber security risks are discussed further in Section 3.9.

Removing barriers

Clarification of policy and regulation requirements at the state and national levels will give greater certainty for investors and potentially provide certainty on the requirements for establishment of microgrids (Energeia, 2016).

Other countries are developing policies that Australia can look to, particularly regarding the commercialisation of microgrids, increasing energy security, and improving operational standards. The US has supported research and policy creation, and has the largest microgrid capacity, mainly used to improve resilience for essential services (IRENA, 2017). Following extreme weather events, some US states such as Maryland supported microgrid deployment to avoid large blackouts in the future (Maryland Energy Administration, 2014). Alaska invested about US$1 billion for renewable mini-grids to lower costs and remove dependence on diesel generators (IRENA, 2017).

For both stand-alone microgrids and virtual power plants, there are new technologies and business models emerging relatively quickly that have the potential to support security and reliability of the system in NSW. It is important that regulatory arrangements at all levels can keep pace with these new technologies and business models, and not present barriers to uptake.

It is also important that small companies and start-ups with innovative business models are able to engage in the development of new regulatory approaches, as they are likely to raise different issues than larger incumbent energy service providers.

3.5 OPEN ACCESS TO DATA

It is important that all participants in the market, including consumers, have access to data that helps them make appropriate decisions. It is also important that it is easy to access, preferably free and provided in a way that is easy to use, for example, with high-quality visualisation tools.

For example, consumers need increased transparency and clearer information to understand better their energy usage and inform their capital investment decisions on energy technologies such as solar panels and batteries. The *NSW Home Solar Battery Guide* (2017) released by the Department of Planning & Environment seeks to help consumers better understand whether battery storage can help them save money and how to choose the right battery system. More information of this kind is needed.

The Government can leverage the expertise of the Data Analytics Centre (DAC) to advance this work.

3.6 RESEARCH AND DEVELOPMENT

NSW universities and other research institutions have significant research and development (R&D) capacity in energy and fields relevant to the NEM that can be leveraged to solve key problems facing the energy sector.

Examples of NSW expertise in the energy area include:

- **silicon photovoltaics** – Australian Centre for Advanced Photovoltaics, School of Photovoltaic and Renewable Energy Engineering, UNSW Sydney. The Director, Professor Martin Green, has been a long-term world leader in silicon photovoltaics
- **batteries** – Professor Thomas Maschmeyer (University of Sydney and Gelion Technologies Pty Ltd) and Emeritus Professor Maria Skyllas-Kazacos (University of NSW)
- **energy and resources** – Newcastle Institute for Energy and Resources (NIER) and the CSIRO Energy Centre, Newcastle
- **demand management and energy efficiency** - Sustainable Buildings Research Centre, University of Wollongong and the Institute for Sustainable Futures, University of Technology Sydney
- **energy markets** – Centre for Energy and Environmental Markets, UNSW.

NSW expertise in related fields includes:

- **data analytics** – Centre for Translational Data Science (USYD), Data Analytics Centre (NSW Department of Finance Services and Innovation), Data 61 (CSIRO)
- **market analytics –** Capital Markets Cooperative Research Centre (CMCRC)
- **climate and weather extremes –** ARC Centre of Excellence for Climate Extremes (headquartered UNSW); Bushfire and Natural Hazards Cooperative Research Centre; National Climate Change Adaptation Research Facility (Macquarie University)
- **big robotics –** Australian Centre for Field Robotics, University of Sydney
- **materials –** Australian National Fabrication Facility (ANFF) with nodes at UNSW Sydney, University of Sydney, Macquarie University, University of Wollongong, University of Newcastle
- **cyber security** – NSW Cyber Security Network (network of NSW universities and research institutions).

In moving to a new energy system the Government can encourage more research concentration and excellence in energy research to solve particular problems in the energy sector and reduce costs.

For example, the Taskforce heard that the labour and civil engineering costs associated with building overhead transmission and interconnectors make up a significant proportion of the costs. Estimates provided to the Taskforce suggested that labour and civil engineering costs could make up about 25% of the cost of an overhead transmission build, with the bulk of this in managing easements and clearing (GE, 2017).

There could be an opportunity to harness the significant expertise in NSW universities in field robotics to reduce the civil engineering costs of these investments. For instance, the Australian Centre for Field Robotics at the University of Sydney focuses on research, development and application of autonomous and intelligent robots and systems for use in outdoor environments such as mining, transport and logistics, agriculture and marine systems. This includes the Rio Tinto Mine of the Future, an autonomous mine in Western Australia, and the automation of the Patrick Terminal at the Port of Brisbane. These previous successful developments could be leveraged to trial the effectiveness of alternate approaches to transmission line construction, maintenance and serviceability through field robotics, autonomous systems and prefabricated developments in order to reduce costs.

Electricity system modelling is another area where the capabilities within universities can be leveraged to create greater transparency about the NEM and proposed changes to it. Full models of the NEM have been developed and are held within a small number of consulting firms and cannot be interrogated more broadly by researchers when they are used to support particular policy proposals. Discussions with the Centre for Energy and Environmental Markets at UNSW highlighted the need for energy models that are open source, transparent and able to be validated so that governments, the public and other researchers can understand the assumptions and constraints applied in the model design, and can readily test options and policy proposals.

The history of geothermal energy R&D in Australia also provides a useful case study of an intensive R&D effort that has been largely abandoned, despite the promise of the technology to provide a source of dispatchable renewable energy. Australia has a strong history in geothermal research and development. In fact, for a time (~2010-14) it was leading the world in enhanced geothermal research primarily through work in firms supported by government grants and through working with universities, CSIRO and Geoscience Australia. However, now there is practically no geothermal research being carried out in Australia.

The most advanced enhanced geothermal energy project in Australia was undertaken by Geodynamics Ltd (now ReNu Energy) in the Cooper Basin in South Australia. Geodynamics Ltd successfully commissioned a 1 MW power plant which ran from April to October 2013.

Another important geothermal research project including researchers from many disciplines and organisations was led by what was then the National Information Communications Technology Research Centre of Excellence (NICTA) (now Data 61 in CSIRO). The project used data analytics over a variety of heterogeneous data sources to build a geothermal 3D subterranean map of Australia. This allows targeting of more accessible geothermal resources.

The Taskforce understands that these industry efforts were largely abandoned because the technology was seen as uneconomic, and drilling costs are generally prohibitive. However, research continues internationally that could be leveraged, including through the US Department of Energy Geothermal Technologies Office.

Fusion is another technology on the horizon. The Director General of ITER, an international consortium researching fusion power, has stated that "when we prove that fusion is a viable energy source, it will eventually replace burning fossil fuels" (ITER, 2017).

Generally, there are a number of Commonwealth funding sources that can be leveraged to strengthen the focus of the research community on the energy sector including through ARENA and the Australian Research Council. Governments can consider how to use R&D programs more strategically to encourage advances in identified areas of need for the energy sector.

3.7 SKILLS FOR A FUTURE ENERGY SYSTEM

As the electricity system changes so do the skills required to operate and manage it. Historically, there was a need for specialist power and control engineers to plan and operate the system. However, in the period 1990-2010 very little new large generation was added to the system and accordingly very few new power engineers were trained. Given this and the retirement of a large number of the cohort of power engineers trained in the period to the mid-1970s, there is now a shortage of power engineers to manage the technical challenges associated with the NEM at present. So there is now a need to build up power system engineering capability at universities and technical colleges to supply appropriate numbers of graduates and tradespeople.

Domestic energy companies need to identify the changing skills needs in the sector and work with universities and vocational education and training providers to build the capabilities of the local workforce.

A good example of TAFE responding to the changing needs of the energy sector can be found in Goulburn. Touie Smith runs a small business in Yass that installs shallow geothermal systems in residential and commercial buildings for heating and cooling. Given the need for specialised skills to install this technology, Mr Smith has been instrumental in shaping the training modules and syllabus of Goulburn TAFE so that the required capability is being developed locally.

The sections above outlined a series of areas where the NSW Government can encourage innovation to support future reliability and security of the electricity system, which lead to the following recommendations.

Recommendation 5

That the Government encourage innovation in the energy sector by focussing on: product and safety standards; removing regulatory barriers; open access to data; leveraging current research expertise and building research capacity further; and the workforce skills needed for a changing energy system.

This should include:

a) **standards:** that Government ensure safety and product standards keep up with emerging energy technologies and international best practice, and are appropriately designed to protect consumers and enable more efficient and effective technologies to be developed and commercialised, including for export
b) **regulatory barriers**: that Government identify regulatory barriers at all levels for new generation or network technologies, or new business models that will contribute to greater security and reliability. For example, the Government should review regulatory arrangements at the NSW level to ensure efficient regulation of network innovations such as microgrids and other forms of embedded networks which have the potential to improve resilience of the NSW electricity system. This should have a particular focus on consumer protections, accessibility for regional communities, reliability and performance requirements, and safety issues

c) **energy data:** that Government facilitate more easy, open access to electricity data to inform decision making by governments and market participants at all levels from households to large organisations. This would be complementary to data provided to the market by AEMO and other market bodies

d) **research and development**: that Government encourage and promote dynamic and long-term partnerships between Government, industry and universities and other research institutions to support the NSW energy sector to remain at the cutting edge of technological developments in energy. This should have a particular focus on getting costs down, building on the research strengths of the state, and leveraging funding from the Commonwealth and other sources

e) **skills:** that Government encourage employers to partner with and leverage universities and vocational education and training providers to develop curricula that will deliver the targeted pipeline of skills and capability required to meet the future needs of the energy system.

3.8 TRANSMISSION AND INTERCONNECTION

One of the options for improving resilience, reliability and security in the NEM may be greater interconnection between regions and/or new transmission to connect areas of high renewable resource.

The AEMC has previously conducted reviews related to the coordination of generation and transmission investments, including interconnectors. It is very challenging to manage the staging and location of new generation and transmission investment particularly as generation investment is generally a private commercial decision and transmission assets are regulated infrastructure.

There will likely be significant amounts of new transmission, generation and storage investment coming into the market with the retirement of large thermal generators. However, it is difficult to forecast and determine what suite of options would result in lowest costs for consumers.

There is also uncertainty about the technology type and location of future investment, including that the best locations for new renewable generation may be at a distance from existing transmission infrastructure. Accordingly, the shape of the transmission network will need to change in order to supply consumers reliably (AEMC, 2017i).

The increasing installation of distributed energy resources including solar PV and battery storage by households and businesses will also affect electricity demand and network requirements. The AEMC notes that the impact of these new business models on transmission and generation investment is hard to assess (AEMC, 2017i).

This tension between central planning approaches, and allowing the market to determine the appropriate location for new investment, was discussed in the Finkel Review which concluded that a stronger planning approach was needed (Commonwealth of Australia, 2017). That review included a recommendation to create “an integrated grid plan to facilitate the efficient development and connection of renewable energy zones across the National Electricity Market” (Commonwealth of Australia, 2017).

This section outlines some of the issues around interconnection and transmission that need to be worked through collaboratively between NEM jurisdictions through COAG Energy Council.

Potential benefits from greater interconnection

The AEMO National Transmission Network Development Plan (2016b) suggests that the following interconnector developments would be beneficial if competitively priced, and subject to the relevant regulatory processes:

- a new interconnector linking South Australia with either New South Wales or Victoria from 2021
- augmenting existing interconnection linking New South Wales with both Queensland and Victoria in the mid to late 2020s
- a second Bass Strait interconnector from 2025, when combined with augmented interconnector capacity linking NSW.

The AEMC recognises interconnectors as increasing the efficiency of the NEM by:

- allowing electricity from lower priced regions to be used in higher priced regions
- contributing to reduced price volatility in regions
- potentially deferring the need for investment in generation or additional transmission (AEMC, 2017h).

The AER has noted that the duration of congestion on the NSW-Vic and Vic-SA interconnectors has risen in recent years (AER, 2017h). During the 2017 February heatwave, outages and reduced output of generators in NSW contributed to an overload at the interconnections with Queensland and Victoria (AEMO, 2017l).

Various recent studies have looked at the potential benefits of new or augmented interconnectors and the changing role they might play as the generation mix in the NEM changes:

- KPMG (2016) identified that interconnection can mitigate energy security risks; ameliorate price differentials influenced by changes in the generation mix; and manage the geographic separation of renewable energy supply and demand
- Jacobs, in a report for the Clean Energy Finance Commission, generated models that suggest that inter-regional transmission upgrades were required to allow effective use of available renewable resources (Gerardi & Gawler, 2016)
- modelling for the Electricity Network Transformation Roadmap found that with increasing intermittent generation interconnectors may have a stronger role in ensuring supply during peak summer and winter periods and that greater competition between sources of generation would deliver better prices for customers (Energy Networks Australia & CSIRO, 2017)
- AEMO (2016b) modelling of potential interconnector developments indicated that interconnection results in fuel cost savings by facilitating a greater level of geographic and technological diversity which “smooths the impact of intermittency”, improving system resilience and reducing the reliance on gas-powered generation to provide a fast response to gaps in renewable energy supply.

Decision making for transmission investments

Interconnectors can be expensive assets that consumers will pay for over many years once built. Therefore, there is a rigorous and public assessment process that is required to make it more likely that the assets will add value for consumers. The assessment is referred to as the Regulatory Investment Test for Transmission or RIT-T.[9]

A recent review of the RIT-T by COAG Energy Council concluded that the RIT-T remains an appropriate method for decision making to ensure efficient investment in infrastructure to protect consumers from overpaying for electricity. While improved communication of the process was recommended, the review did not recommend shortening the test or changing the categories of costs and benefits considered in the RIT-T (COAG Energy Council, 2017c).

[9] There is one unregulated interconnector in the NEM - Basslink, between Tasmania and Victoria (AEMO, 2016a).

The AEMC has a function called the Last Resort Planning Power. Under the NER, this Power allows the AEMC to direct registered participants to apply the RIT-T to a potential transmission project with the intention to ensure timely and efficient investment in inter-regional transmission (AEMC, 2017h).

Although regularly reviewed, the Last Resort Planning Power has never been enacted in the NEM (AEMC, 2017h; COAG Energy Council, 2017c). In its 2017 report, the AEMC found that the requirements for interconnector investment are being adequately addressed by TNSPs and it was satisfied that identified constraints are being managed (AEMC, 2017h). The report notes that the three interconnector development options judged by AEMO to have positive market benefits are being progressed by the relevant TNSPs.

If a more centralised planning process is adopted, as per the recommendation from the Finkel Review, this may change the role and use of the RIT-T. This needs further discussion through COAG Energy Council. The Finkel Review stated that the RIT-T process "or its successor" should be used to evaluate augmentations in line with an integrated grid plan, and that while time should be allowed to determine efficiency of the recently proposed COAG Energy Council changes, the RIT-T should be reviewed again within the next three years (Commonwealth of Australia, 2017).

Intra-regional transmission

Transmission networks that were typically designed to supply power generated by coal thermal plants will likely need augmentation to take advantage of renewable energy sources (AEMO, 2016b).

In NSW, TransGrid states that all new connection enquiries to its network are for wind and solar generation, but the best wind and solar resources are generally not near existing generation plant and are in areas with limited transmission capacity (TransGrid, 2017a). The Taskforce heard from TransGrid and the NSW distributors that greater locational signals for new renewable energy investments would help to manage the network more effectively.

TransGrid is identifying locations for renewable energy precincts that it argues will minimise unnecessary network investment and provide commercially viable opportunities for renewable energy investment (TransGrid, 2017a). TransGrid also suggested to the Taskforce that, rather than only thinking about interconnectors as facilitating flows between states, they should be seen as an extension of the network that can also facilitate the connection of new renewable generation along the way.

The Taskforce heard that, over time, there is potential for conflict between large scale renewable energy projects and other land use such as agriculture and residential development, because currently the location of new renewable investments is partly determined by ability to access transmission and distribution infrastructure which has been built to serve existing demand in those areas.

In the US, the state of Texas provides an example of how to address locational signals for new renewable energy investments. Competitive Renewable Energy Zones direct renewable generation developers to geographic locations most suitable in terms of resources and transmission connection (Bebon, 2013). The identification of suitable locations considered renewable energy potential, land use, environmental constraints, and cost of augmenting the network (Du, Baldick, & Tuohy, 2017).

Regardless of the method adopted to plan for and coordinate future transmission and generation investment, the issue of land reservation and acquisition for both potential transmission corridors and potential renewable generation zones will likely be important and will need to be planned for well in advance within jurisdictions.

Recommendation 6
That the Government encourage COAG to ask the Energy Security Board to unpack the Finkel Review recommendation to develop “an integrated grid plan to facilitate the efficient development and connection of renewable energy zones across the National Electricity Market” and provide advice to jurisdictions about the role of land reservation for transmission corridors or renewable generation zones across jurisdictions.

3.9 CYBER SECURITY

Cyber security is an increasing risk to electricity networks all over the world. There are several components of cyber security that are relevant to the electricity system in NSW and the NEM more broadly (Energy Networks Australia, 2017a):

- grid systems and platforms that make up the energy network, which include technology providers
- control systems to monitor and control the network
- data and safeguards for accessing confidential information
- distributed energy resources.

The Finkel Review identified the need for “a stronger risk management framework to protect against natural disasters and cyber security attacks” and recommended that the Energy Security Board develop an annual report into the cyber security preparedness of the NEM, with the initial report to be completed by the end of 2018 (Commonwealth of Australia, 2017).

The exposure of the electricity network to cyber security risks was raised by several stakeholders consulted by the Taskforce. This included concerns about:

- the relatively unsecured nature of the network given the significant proportion of communications in the electricity network that are cloud based
- the scale of damage that could be caused to the network by penetrating through a relatively benign component of the system e.g. through a smart meter
- the pace at which the cyber security risks are changing and shifting
- the interdependency between physical damage to the network and cyber penetration
- phishing and the customer information and data that could ‘leak out’ of the system
- the need for audits and greater compliance of the measures used by participants in the sector to mitigate against cyber risks
- whether a commercially pragmatic solution exists to mitigate cyber risks, particularly for smaller participants in the sector given the disproportionate administrative and cost burden that new systems and processes place on their business when compared to a large business.

The Taskforce also heard about the challenge in balancing cyber security protections and effective operation of the network, and ensuring that cyber protections do not in practice reduce the capacity of network operators to respond to and recover from a major power outage.

Due to the evolving nature and understanding of cyber security risks over time, the Taskforce understands that each of the network service providers have different obligations in their licences regarding cyber security mitigation. These were developed at the time of leasing. Therefore, there is an opportunity to review and harmonise these requirements.

Australia has considerable capability in cyber security research and development which should be leveraged by participants in the NEM to assist the sector to implement measures to mitigate against cyber security risks. A new resource in NSW is the NSW Cyber Security Network, comprising various NSW universities and Data61. The Network acts as a broker to find solutions to cyber security issues facing industry, the NSW Government and community and it connects these end users to cyber security capability across NSW's universities and research institutions. Participants in the energy sector in NSW could engage the Network to conduct penetration testing on their systems, for example, or to address a specific problem that the participant may be facing.

The Taskforce suggests that the NSW Government encourage COAG Energy Council to focus particularly on cyber security issues.

Recommendation 7
That the Government encourage COAG to commission ongoing studies on cyber risks and possible responses right across the system including transmission, distribution, retailers' communication platforms, smart meters and other customer-facing demand management technologies and address any identified risks.

4 EXTENDED OUTAGES AND BLACK SYSTEM EVENTS

Several stakeholders raised concerns about potential black system events and system restart procedures. While a black system event in NSW was generally considered to be highly unlikely, there were concerns raised about the black start arrangements and the time that a full system restart might take to see electricity restored to major population centres and time-sensitive industrial and commercial users.

This chapter examines the risks to NSW and specifically the Sydney CBD of a black system event or widespread extended blackout. It considers how well prepared NSW is for such an event and what the potential social and economic impacts could be if NSW or a region of the state is without power for an extended period of time.

Also, the chapter considers the potential impacts to the public and private sectors of controlled power outages due to load shedding that may be directed by the market operator and the need to manage this carefully in order to minimise disruptions to essential services and the community.

This analysis highlights some gaps and vulnerabilities that require more attention to reduce risks and ensure our essential services are well prepared in the unlikely event of a state-wide blackout.

4.1 MANAGING THE IMPACTS OF LOAD SHEDDING

The deliberate cutting of power to various users, referred to as manual load shedding, can occur when supply and demand is imbalanced due to a capacity shortfall through transmission or generation. The manual load shedding guidelines are designed to avoid shedding load to critical services such as transport. However, automatic load shedding, which may result from damage to the network and is unplanned, could affect these critical loads.

The JSSC advises AEMO on both sensitive and priority (top, medium and low) loads for NSW which are then translated into the load shedding guidelines for TransGrid and the distribution business.

When the Taskforce consulted several essential services, it found that they were not aware of the methodologies used to determine load shedding procedures and may not fully understand how load shedding might affect their services.

For example, the Office of the State Health Services Functional Area Coordinator (State HSFAC) advised the Taskforce that it was not certain of how load shedding might affect health services and whether the methodology used to develop the load shedding guidelines factored in the electricity configuration of hospitals and their risks and vulnerabilities. Of greatest concern was the need for advance warning, where warning was feasible, if load shedding was to happen.

Some organisations, particularly those representing key participants in the financial services sector like the ASX and the Reserve Bank of Australia (RBA), raised concern that there is currently no planned communication mechanisms with the Energy and Utility Services Functional Area Coordinator (EUSFAC) after automatic load shedding or an understanding that notice would be provided ahead of manual load shedding, both of which may have serious economic impacts on their operations and the broader economy.

The EUSFAC could leverage the Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience, coordinated by the federal Attorney-General's Department to communicate with critical industries. For example, the Finance and Banking Sector Group in the TISN could facilitate information sharing with the businesses in its sector.

These examples highlight the need for more proactive communication between the EUSFAC and essential services and key private sector groups regarding potential load shedding events and how these events might affect their services. There should also be communication procedures for early warning if load shedding is imminent.

4.2 BLACK SYSTEM EVENTS

Put simply, a black system event is “a large scale blackout of the power system” (AEMC, 2016a). A black system event can be across an entire sub-network, such as the blackout in South Australia on the 28 September 2016 or a significant region within a sub-network.

The AEMC explains that the sudden, unexpected loss of a major supply source can lead to rapid changes in system frequency, and networks and generators will automatically disconnect to protect people and equipment from harm (AEMC, 2016a).

While black system events are rare, with the last black system event occurring in NSW in 1964, the consequences for businesses and the community can be considerable. The 1964 black system event occurred in winter during an electrical storm and the shutdown happened at around midnight and by 7am power was fully restored. Due to the timing of the event, most residents of NSW were not aware of the loss of power.

The black system event in South Australia on 28 September 2016 was the result of severe storms damaging three transmission lines which caused them to trip and create faults in the system. The number of faults then caused many of the wind farms in South Australia to shut down unexpectedly, resulting in the overload and subsequent trip of the interconnector with Victoria. While power restoration to parts of Adelaide began within three hours of the state-wide blackout, parts of the state to the north affected by damaged transmission lines did not regain power for eight days with the final load restored to the state only after 13 days (AEMO, 2017b).

4.2.1 General consequences of widespread blackouts

Widespread power outages can have significant impacts on businesses, health services, water supply, sewage treatment, food supply and transport (Byrd & Matthewman, 2014; Klinger, Landeg, & Murray, 2014; Royal Academy of Engineering, 2014).

There are several examples of large-scale power disruptions internationally that highlight the extent of the consequences for essential services. For example, the 2003 Eastern US/Canada blackout lasted for up to four days and affected 50 million people. Total economic loss due to the blackout is estimated to have been US$4.5-8.2 billion (Anderson & Geckil, 2003). During the blackout, mortality due to accidental deaths increased by 122% from normal conditions and non-accidental deaths by 25% (Anderson & Bell, 2012).

4.2.2 Potential impacts in NSW

It is generally understood that in the event of a black system in NSW the Sydney CBD could be without power for at least 9 to 15 hours and up to several days depending on the severity and cause of the event.

While the Taskforce was able to ascertain the current preparedness of several essential services and key private sector entities for such an outage, it was widely recognised that there are significant gaps in knowledge, preparation and planning for a black system event in NSW.

In particular, it was noted that in many cases business continuity plans may not be able to be sustained beyond six hours of interrupted electricity supply (with a few exceptions that have resilience beyond this point) which falls well short of the anticipated timing for a system restart. There was concern about the ability to secure fuel supplies in an extended black system event.

This reinforces the importance of the Electricity Supply Emergency Sub Plan, under development by DPE, which will address these issues by providing a clear and effective mechanism to coordinate the planning, preparation, response and recovery from power outages across all essential services.

4.2.2.1 Potential economic impact

The Taskforce found that there are no reliable estimates of the potential economic cost of a black system event in NSW. As Sydney CBD is major financial and business hub for Australia and the Asia-Pacific and a densely populated region, the economic impact would be significant.

Business SA estimated the total cost to South Australian businesses of the September 2016 black system was $367 million (Business SA, 2016). Using a VCR figure of $170/KWh for the value of unserved energy for the Sydney CBD (TransGrid & Ausgrid, 2016), TransGrid estimates a cost of $136 million for every 200 MW of load shed in the CBD for four hours (TransGrid, 2017c).

Tomago Aluminium Smelter

The Tomago Aluminium Smelter in the Hunter Valley is a large contributor to the NSW economy with revenues of approximately $1.5 billion (Tomago Aluminium Smelter, 2017). Loss of power for 3-4 hours to a potline during an extended outage or black system could result in severe plant damage and the loss of more than one potline could have a significant impact on the future viability of the smelter (Tomago Aluminium Smelter, 2017).

Financial services

Consultation with representatives from the Banking and Finance Sector TISN, the major banks, the RBA and the ASX indicated that during an extended power outage these entities have uninterrupted power supply (UPS) and/or back-up generators that are capable of providing a power supply for between three days and three weeks depending on the individual business. The key focus during this time is supporting high value transactions and maintaining stability in the finance and payments system.

The RBA, ASX and major banks have a strong ability to maintain operations during power outages and have structured their communications platforms so that they are not reliant on the NBN and would still be operational during a black out. The finance and banking sector have invested significantly in business continuity management. The majority of entities in the sector have separate back-up data centres and recovery centres at multiple locations across the state and nation which provide redundancy.

While most bank branches do not have back-up power supplies, they do have procedures in place for maintaining offline transactions. In some circumstances mobile ATMs can be deployed if back-up power is available.

4.2.2.2 Risks to health and safety

A range of risks and vulnerabilities exist for the State’s essential services during a black system or extended outage that need to be planned for and managed. These include:

Hospitals

- public hospitals in NSW have back-up diesel generators with fuel that would last a variable amount of time, but would need new fuel delivered after six hours

- back-up generators would only be used to supply electricity to run core functions (ventilators, monitors, primary lighting). All elective surgeries would be cancelled, food and laundry services would cease, diagnostic equipment would not be used, healthcare records would not be fully accessed and the sterilisation processes would take up to three days to complete
- hospitals are reliant on air-conditioning systems for ventilation of the buildings, with many having fixed windows. In extended power outages, the room temperature in hospitals would increase and patients may need to be evacuated should conditions get critical for patient care and comfort
- hospitals would be under significant strain due to an increase in patients seeking services that may be unavailable elsewhere
- while the functions of hospitals would be reduced when operating on back-up generators, community expectations do not change. Communications would be needed to explain to the public that hospitals would be under significant strain and only urgent and life-threatened patients would be the priority.

Transport

- a widespread outage would halt all rail services in the Sydney Trains managed network (extending to Kiama, Macarthur, Broadmeadow and Lithgow) due to the fact the rail network is electric. Light rail services would also cease operation. During peak commute periods, there can be as many as 10,000 people on underground trains who may need to be evacuated. Assistance for evacuations from the rail network would be required from NSW Fire & Rescue and NSW Police. However, these emergency services may also be responding to other emergency situations such as people stuck in lifts in buildings
- road traffic will be affected as road tunnels would be closed and all tunnel traffic redirected to surface roads. Select CBD traffic lights would initially operate on UPS, with key metropolitan intersections connected to deployable generators. The road network would be very congested which would place added stress on emergency services responding to incidents. Buses would provide a limited train replacement service. Buses would also be reliant on access to fuel during longer outages
- ferry services would be operable and could be used to move people from CBD areas. Ferries would have between 12 hours and one week’s fuel on board.

Water and sewerage

- Sydney Water uses energy to pump water to local reservoirs where gravity feeds allow the water to be distributed to retail customers. Local reservoirs are able to run without power, although reservoirs would not be topped up from the main supply
- short outages would be manageable, however supply to customers will start to tighten for outages greater than one day. Sydney Water would then need to consider other options including sourcing power generators and/or applying water restrictions
- there is the potential for sewerage to overflow which may have human health and environmental impacts. Many sewerage treatment plants have back-up power generators although not all do.

National Broadband Network (NBN)

- equipment connected to the NBN would not be operational during power outages (e.g. landline telephones connected through the NBN requiring power at the exchange and the residence/business; medical equipment; lift emergency phones; and EFTPOS terminals)
- customers with Fibre to the Premises and a power supply with battery back-up will be able to operate their devices for approximately five hours. Customers can extend this by purchasing separate UPS devices
- customers with Fibre to the Node, Fibre to the Building, Cable, and Fixed Wireless will not have operable internet or phones. Mobile phones will work but will be

dependent on the battery life and back-up power at the mobile transmission towers to operate.

4.3 SYSTEM RESTART

The National Electricity Rules outline the process for restoring power after a black system. This is led by AEMO and involves transmission, distribution businesses and generators (AEMC, 2016a).

It would take quite some time to restore load to major population centres in NSW and the ACT, especially the Sydney CBD. The restoration process is usually described through three stages as shown in Figure 4.1.

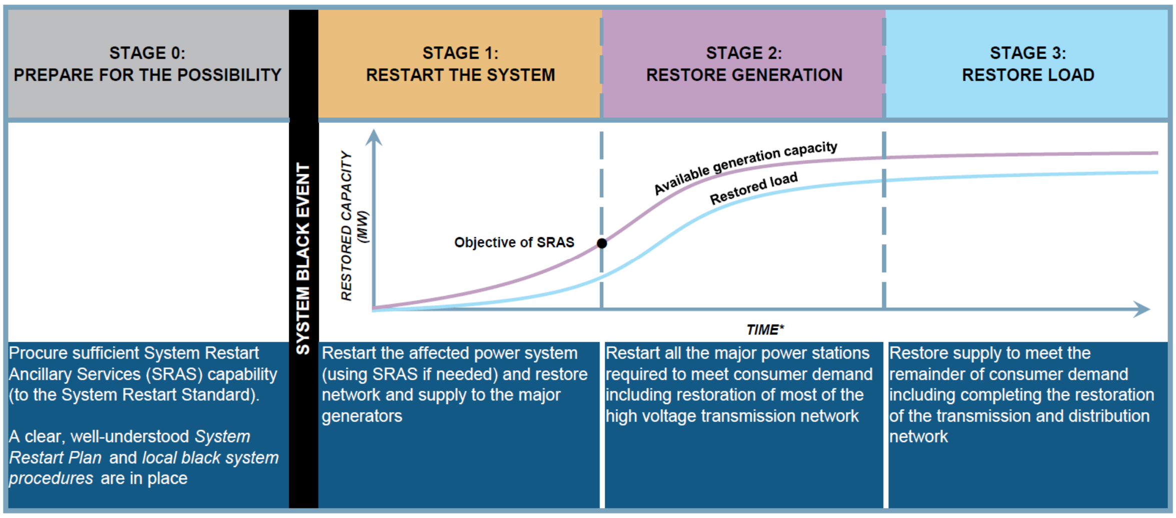

Figure 4.1: Overview of stages in preparing for and responding to black system
Source: AEMC (2016b)

In the event of full power loss to NSW, only some generators have the ability to start without power. Generators with black start capability can be used to provide power to other generators and together restore electricity to the network and finally to customers.

The process of re-energising the system needs to occur piece by piece. To manage stability of the network, the operators re-energise a portion of the energy network (generators, transmission and distribution providers) before reconnecting blocks of customer load. This needs to be managed carefully because reconnecting load may damage the equipment or result in equipment failing. Also, the response of equipment starting from a 'down state' can be hard to predict.

Anecdotal information to the Taskforce suggests that in a black system Sydney would be without power for at least nine to fifteen hours, likely longer, and would be one of the last parts of the state to have power restored to customers. One of the main reasons for this is that the CBD physically lies at the edges of the network in relation to the main generators. Restoring the power back to Sydney is also complicated by a network of underground power cables, which take longer to re-energise than overhead wires.

The time to restore power to customers depends on a number of factors, which can include:

- cause of power loss – if equipment is damaged, power restoration is likely to take longer. If the cause cannot be identified it may take longer to resolve the issue e.g. because of the need to inspect lines physically
- extent of power loss – a state-wide power loss is likely to take longer to recover from than a regional outage

- location of the units used to restart the system and availability of power through the interconnectors
- success of the restart units – from past experience, both nationally and internationally, System Restart Ancillary Services (SRAS) may not start as expected resulting in longer time for restoration
- configuration and characteristics of the network
- operator training and availability of staff (critical incident readiness of parties)
- effectiveness of communications.

4.3.1 System Restart Standard

The first stage of restoration from a black system is guided by the AEMC Reliability Panel's System Restart Standard (the Standard) which defines the time, level and reliability of generation and transmission capacity that should be available for the restoration process (AEMC, 2016b). In December 2016, the Panel published a new Standard which will take effect from 1 July 2018.

The new Standard for NSW is to:

- restore 1,500 MW of supply[10] within two hours at an aggregate reliability of 90%
- north of Sydney at least 500 MW of supply must be restored within four hours with an aggregate reliability of 75%.

The Standard provides the guide for AEMO to procure appropriate SRAS in each of the NEM's sub-networks. AEMO has updated its Guidelines for procuring new SRAS units across the NEM which will commence on 1 July 2018.

Concerns have been raised that the Standard and subsequent procurement of SRAS do not take into account the restoration of load to customers, including sensitive loads and the economic impact that a black system would have on NSW due to the time it would take to restore load to the Sydney CBD. Recognising this concern, the Reliability Panel in its final determination on the new standard made several additional recommendations that the Taskforce supports, in particular:

- that AEMO, TNSPs, DNSPs and the JSSC develop comprehensive plans for the complete restoration process from a black system declaration through to full restoration of all consumers' load and that this should include simulation and training exercises
- that the JSSC proactively communicate the expected load restoration timeframes to relevant stakeholders, which will be crucial for emergency management planning.

The Taskforce also notes the Finkel Review included recommendations to improve black system restart plans and testing of restart equipment and processes.

If the NSW Government deems that the risk posed to certain priority loads (such as Sydney CBD, major industrial users and essential services) by the time required for load restoration after a black system event is too great, there may be opportunity to consider new approaches that may allow parts of the network to be re-energised separately or earlier than is possible through the restart process. This could involve strategic placement within the network of small generators with self-start capacity, which might be able to create an emergency grid, for example in the Sydney CBD.

A full assessment of the grid distribution capacity, substation locations, technical limitations, cost benefit analysis and possible business models would be needed to determine what options are feasible. Any alternative approach would need to integrate with existing system

[10] Note that supply in the context of a black system event means supply available to restart generation, that once restarted is then ready to restore load.

restart procedures. This detailed assessment could form part of the NSW Government's broader analysis for the electricity strategy proposed in Recommendation 2.

4.4 OVERARCHING RISKS AND VULNERABILITIES

While there are many systems in place to support essential services during power outages, some risks and vulnerabilities remain.

Critical infrastructure work programs at the state and federal level will go some way to addressing many of the issues raised with the Taskforce, including the NSW State Level Emergency Risk Assessment, the proposed NSW Critical Infrastructure Resilience Strategy and the draft Commonwealth *Security of Critical Infrastructure Bill 2017*.

Two key issues that need further attention in NSW are government business continuity planning and the management of back-up power supplies and fuel.

4.4.1 Back-up generators and fuel supplies

The availability of back-up fuel supplies during an extended widespread blackout was repeatedly raised by stakeholders and needs greater focus by the NSW Government.

Back-up generators and adequate fuel supplies can ensure services are able to continue to operate during power outages. Many essential services have their own generators and fuel on site, while other services may need to source back-up generators and additional fuel when needed. It is important to note that fuel supplies need to be regularly tested and replenished in order to start back-up generators successfully.

It is not known how back-up generators and fuel supplies would be made available and/or prioritised during an extended outage, or whether critical infrastructure and essential services would have priority access to fuel. Further it is difficult to ascertain the volume of fuel that may be available, or how it would be paid for given EFTPOS would most likely not be working.

4.4.2 Business continuity

Not all NSW Government departments have developed and implemented a business continuity program and a whole-of-government business continuity plan does not exist. During an extended power outage it would be expected that the business of government continues. It is therefore important for all parts of government to consider how they would continue to operate.

As identified in the NSW Critical Infrastructure Resilience Strategy discussion paper, business continuity across NSW needs resourcing to ensure public, private and community services are able to be sustained in the event of a power outage. The Taskforce supports the recommendations[11] made through the State Level Emergency Risk Assessment and further recommends developing a timeframe for implementing these recommendations as soon as possible.

Recommendation 8
That the Government improve communications and more proactively drive processes to ensure essential services and sensitive loads are managed effectively in an energy emergency.

[11] Recommendations being:

- a review of government (local and state) business continuity planning and the extent of testing and exercises
- a business continuity planning toolkit for business and community be developed
- best practice business continuity planning advocated across government and the private sector.

This should include:

a) **load shedding procedures and communications**: that Government through the Jurisdictional System Security Coordinator make sure load shedding protocols minimise impact on sensitive loads such as essential services and central business districts and that the Energy and Utilities Services Functional Area Coordinator be more proactive in communicating to the public and private sectors (leveraging the Trusted Information Sharing Networks) any new information about load shedding
b) **impacts of a black system:** that Government get a better understanding of the potential economic impact of an extended black system event and identify the risks and vulnerabilities within the public and private sectors that need to be planned for and managed to minimise impacts on the economy and the health and safety of the community
c) **system restart procedures:** that the Government:
    - proactively work with AEMO, TransGrid and the distribution businesses to enhance the black start load restoration plan for NSW so that it prioritises load of strategic importance and estimates likely timeframes for load restoration
    - coordinate regular black start exercises between relevant NSW and ACT Government energy and emergency management representatives, AEMO, TransGrid, distribution businesses and generators
    - highlight at COAG Energy Council the need to assess the adequacy of the existing system restart procedures in each state and territory with specific consideration being given to the time anticipated to bring major economic centres back online
d) **back-up fuel supplies**: that Government develop an internal NSW Government register of back-up generation fuel supplies in NSW and the ACT to identify where supplies would come from, how they would be prioritised, and how long they would last during a black system event
e) **NSW Government Continuity Plan**: that Government, through the Office of Emergency Management, the Department of Premier & Cabinet, and the Department of Planning & Environment, develop a whole-of-government business continuity plan for responding to longer-term, widespread power outages and/or black system events.

4.5 GOVERNANCE AND INFORMATION SHARING

Concerns were raised with the Taskforce regarding emergency management approaches now that several network businesses have been fully or partly leased in NSW.

The Taskforce heard that when network businesses were publicly owned there was an expectation that they would act in the public interest during an energy emergency. Further, it was commented that the processes governing this may therefore not have been explicitly defined or codified within the organisations post leasing.

The motivations and priorities of the leased businesses are likely to align generally with those of Government during the management of an energy emergency. However, comments were made to the Taskforce suggesting that in some circumstances, for example, when an action may be expensive, the leased business may be driven to make different decisions than they may have previously when government operated.

The Taskforce understands that the administrative location of the Jurisdictional Responsible Officer (JRO) and the implications of it moving to a private organisation may not have been explicitly considered in the leasing process. The JRO is a key role involved in the management of energy in each state of the NEM and is responsible for implementing the NEM Emergency Protocol. It is the prime management level contact between the jurisdiction and AEMO on operational issues. In NSW the role is held by a designated person(s) in TransGrid. Aside from ActewAGL in the ACT, NSW is the only other jurisdiction where the role does not sit in a government entity.

While the Taskforce acknowledges that TransGrid undertakes functions and has expertise that make it an appropriate organisation to host the JRO role, it is important to note that the dynamic post leasing suggests a need for Government to re-engage with the leased transmission businesses to make sure these issues are considered. This should include reviewing whether there are any strategically important information sources that the Government previously had access to before the leasing of the distribution and transmission businesses, but now does not. This may then need to be captured in additional licence conditions or through a Memorandum of Understanding or appropriate protocol.

Recommendation 9

That the Government identify any gaps in emergency response/management arrangements post-leasing of transmission and distribution businesses. Government should give consideration to the role of the Jurisdictional Responsible Officer and determine whether any additional emergency management or information sharing protocols need to be put in place given the role now sits within a leased entity, and not within a Government organisation.

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Acronyms

Acronym	Definition
ACCC	Australian Competition and Consumer Commission
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AEST	Australian Eastern Standard Time
ARENA	Australian Renewable Energy Agency
ASX	Australian Stock Exchange
BOM	Bureau of Meteorology
CAPEX	capital expenditure
CMCRC	Capital Markets Cooperative Research Centre
COAG	Council of Australian Governments
DNSP	distribution network service providers
DPE	NSW Department of Planning & Environment
EAAP	Energy Adequacy Assessment Projection
ESOO	Electricity Statement of Opportunities
EUSFAC	Energy and Utility Services Functional Area Coordinator
GFC	global financial crisis
GW	gigawatt
IPART	Independent Pricing and Regulatory Tribunal
JRO	Jurisdictional Responsible Officer
JSSC	Jurisdictional System Security Coordinator
LOR	Lack of reserve
MW	megawatts
MWh	megawatt hour
NARCliM	NSW and ACT Regional Climate Modelling
NEM	National Electricity Market
NER	National Electricity Rules
NSW EPA	NSW Environment Protection Authority
OEH	Office of Environment and Heritage
OPEX	operating expenditure
PASA	Projected Assessment of System Adequacy
PHES	Pumped hydro energy storage
POE	Probability of Exceedance
PV	Photovoltaic
RBA	Reserve Bank of Australia
RERT	Reliability and Emergency Reserve Trader
RET	Renewable Energy Target

RIT-T	Regulatory Investment Test for Transmission
SRAS	System Restart Ancillary Services
TISN	Trusted Information Sharing Network
TNSP	transmission network service providers
UPS	uninterrupted power supply
VCR	Value of Customer Reliability

APPENDICES

APPENDIX 1 TERMS OF REFERENCE ENERGY SECURITY TASKFORCE

Extreme weather events, such as the heatwave conditions across NSW over January and February 2017, place significant demands on the State's electricity infrastructure. They highlight the need for best practice long term planning, as well as the need to ensure that the State is well placed to prevent, respond and recover from events when they occur.

The planning and management for extreme weather events is complex. There is the interaction between national and State energy regulatory frameworks and responsibilities, as well as the need to ensure coordination across all elements of the supply chain – market operator, transmission and distribution networks, retailers and customers. The complexity of arrangements for managing high risk events across the national electricity market, networks and jurisdictions has been highlighted by the Reliability Panel in its recent Review of the System Restart Standard.

Energy plays a key role in NSW's State Emergency Management framework. The Review will need to complement work taking place in this area.

Scope of review
The review will:

- assess the risks to and resilience of the NSW electricity system (including the transmission and distribution networks), from extreme weather events in the context of a changing climate
- review the adequacy of the State's management of electricity system security events including prevention, preparedness, response and recovery
- make recommendations on actions to address any vulnerabilities identified and/or opportunities for improvements in current practices

In undertaking this work, the Taskforce will have regard to NSW and ACT Regional Climate Modelling projections. The Taskforce will consider the costs and benefits of any recommendations.

Process
The review is to provide a draft report by the first half of 2017 and a final report by the end of 2017. The review should complement any broader emergency management work being undertaken across the NSW Government.

There is significant work being undertaken by the COAG Energy Council, Australian Energy Market Commission, Australian Energy Market Operator and Australian Energy Regulator. The Taskforce draw on this work and focus on areas particularly related to NSW which are not the remit of these other work programs.

The Taskforce should draw on the expertise of a wide range of stakeholders including the NSW transmission and distribution network businesses, AEMO (Australian Energy Market Operator), AEMC (Australian Energy Market Commission), and other National Electricity Market state and territory regulators.

APPENDIX 2 STAKEHOLDER MEETINGS AND SUBMISSIONS

Table A.1: Stakeholder meetings and teleconferences

Stakeholder group/s
TasNetworks
Water NSW
Sydney Water
Professor Paul Simshauser, Director General Queensland Department of Energy & Water Supply
TransGrid
EnergyAustralia
Dr Kerry Schott, (then) Chair TransGrid
Australian Energy Regulator
Office of Emergency Management, Department of Justice
Australian Energy Market Operator
Briefing - Security of Critical Infrastructure - Critical Infrastructure Centre (Commonwealth)
AGL
Professor Andy Pitman, Director ARC Centre of Excellence for Climate Extremes
Sunset Power International t/as Delta Electricity
Chair, Reliability Panel, and CEO, Australian Energy Market Commission
NSW Parliamentary Counsel
Sydney University
Tasmanian Energy Security Taskforce
Department of Planning & Environment
SnowyHydro Ltd
NSW Crown Solicitor
Associate Professor Iain Macgill, UNSW Australia
Bureau of Meteorology
NSW Health
Ms Audrey Zibelman, CEO AEMO
Mr Terry Effeney, formerly CEO of Energex in Qld and a member of the Expert Panel for the Finkel Review
Mr Trevor Armstrong, COO Ausgrid
Department of Premier & Cabinet
Transport for NSW
Hunter Water
Ms Helen Bennett, Office of Energy Security, Commonwealth Department of Environment
EnergyAustralia
Property NSW
GovDC
Mr Andrew Warnes, Critical Infrastructure Security Branch, Attorney General's Department
Emeritus Professor Jim Galvin
EnergyAustralia
Capital Markets Cooperative Research Centre (CMCRC)
Australian National Low Emissions Coal Research and Development (ANLEC R&D)
Clean Energy Regulator
Tomago Aluminium Smelter
Macquarie Capital
CIM Enviro
Clayton Utz
Finance & Banking Sector Trusted Information Sharing Group (Leanne Herrett, Westpac Group)
Origin Energy Limited
Dr Kerry Schott, (current) Chair Energy Security Board
Energetics

General Electric (Australia/New Zealand)
Office of Environment & Heritage
Endeavour Energy
Essential Energy
Professor Klaus Regenauer-Lieb, UNSW Petroleum Engineering
Professor Thomas Maschmeyer FTSE, University of Sydney Energy Storage Research Network
Climate Risk Pty Ltd
ASX
Reserve Bank of Australia
Mr Rod Simms, ACCC
Reposit Power
Mojo Power
EnergyLab
Independent Pricing & Regulatory Tribunal (IPART)
Mining NSW
Glencore
Yancoal
Centennial Coal
US Department of Energy Geothermal Technologies
Professor Andrew Blakers, Australian National University
Boston Consulting Group
Data61
Professor Mike Sandiford, University of Melbourne
Professor Salah Sukkarieh, Australian Centre for Field Robotics, University of Sydney
Professor Mark Hoffman FTSE, Dean UNSW Engineering
Professor Robin King, Australian Council of Engineering Deans

Note: The Taskforce has been in ongoing discussions with a range of government agencies including the Department of Planning & Environment, the Department of Premier & Cabinet, NSW Health, Transport for NSW, Department of Justice, Sydney Water, Hunter Water, TransGrid, AEMO, AER and AEMC throughout the development of the Initial and Final Report.

Table A.2: Submissions

Ref:	Name	Organisation
SUB001	Mr Aden Ridgeway	Paradigm Resources
SUB002	J F Brett RFD ED	
SUB003	Professor John Quiggin, ARC Laureate Fellow	
SUB004	Mr Rob Murray-Leach	Energy Efficiency Council
SUB005	Mr Roger Whitby	Snowy Hydro Limited
SUB006	Mr Matt Howell	Tomago Aluminium
SUB007	Mr Kevin Ly	Snowy Hydro Limited
SUB008	Mr Rod Howard	Endeavour Energy
SUB009	Submission in confidence	
SUB010	Mr John Griffiths	Gas Energy Australia
SUB011	Mr John Cleland	Essential Energy
SUB012	Mr Warring Neilsen	Elgas
SUB013	Mr Shaun Reardon	Jemena
SUB014	Mr Craig Memery	Public Interest Advocacy Centre
SUB015	Dr Tim Nelson	AGL Energy
SUB016	Mr Rob Sindel	CSR Limited
SUB017	Mr Steve Reid	Origin Energy

Note: Many stakeholders consulted by the NSW Energy Security Taskforce referred to submissions that they had made to the Independent Review into the Future Security of the National Electricity Market (Finkel Review).

Table A.3: Speeches

The Chair of the Energy Security Taskforce also delivered a range of speeches on the work of the Taskforce which included:

Date	Event
1/08/17	Hunter First Forum
3/08/17	CEDA 2017 Energy Series
31/10/17	Legislative Council Select Committee on Electricity Supply, Demand and Prices in NSW
1/11/17	ATSE Energy Symposium

APPENDIX 3 DEMAND PATTERNS

This appendix provides data and examples about demand patters in NSW, further to Section 2.3.1.1.

Changes in demand

Demand (or load) for power from the grid varies on a range of time scales – daily, weekly, seasonally and longer. Demand in NSW generally ranges between 6,000 and 10,000 MW (Figure A.1(A)). It typically varies by about 3,530 MW on a daily basis, but this variation can be up to 7,310 MW or limited to only 1,430 MW (Figure A.1(B)). Weekday demand is typically about 500-1,000 MW or about 10% greater than weekends (Figure A.1(C)).

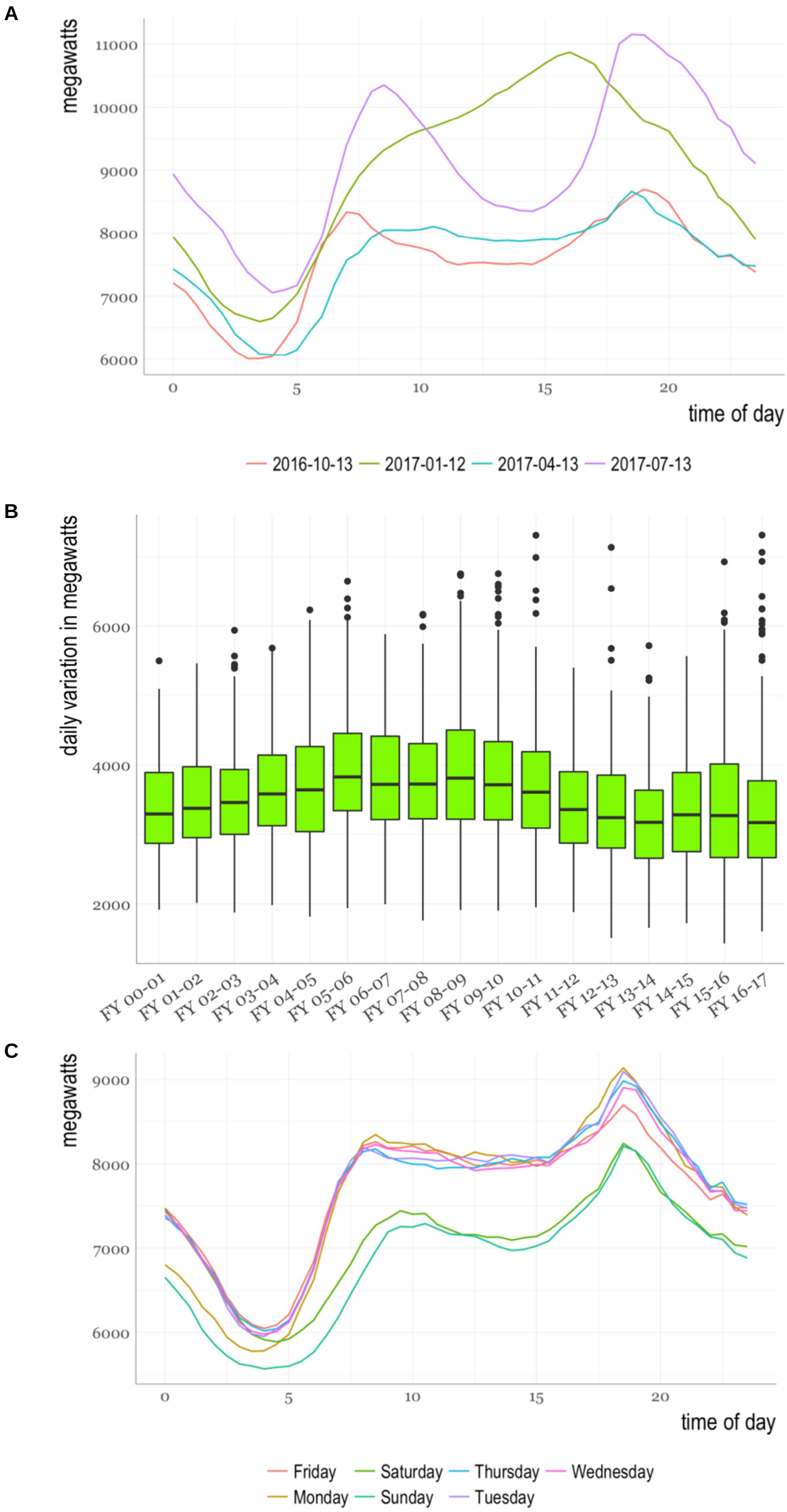

Figure A.1: Variability in demand

A) Example of NSW daily demand trends, for spring (red), summer (green), autumn (blue) and winter (purple days). Note that significant variation occurs on a day-today basis because of weather variability, however in general demand varies from a low in the early morning at 6000-7000 megawatts to a peak in the early evening 8000-11000 megawatts, with a subsidiary low in the mid-afternoon, especially in winter.

B) Boxplots summarising daily variation in NSW power loads in megawatts, aggregated by financial year

C) NSW demand trends for day of the week (02/04/2017 – 08/04/2017)

Source: Sandiford (2017)

As seen in Figure A.2, on daily timescales summer demand tends to peak in the late afternoon between 3:30-5 pm AEST. There has been a slight tendency in recent years for peaks in daily demand for electricity to shift slightly later in the day, at least in part due to the way in which roof top PV reduces demand for grid based power during the day time, but rapidly tails off in the late afternoon when the sun fades and demand for electricity from the grid typically increases due to people turning on their air conditioners as they return home in the evening.

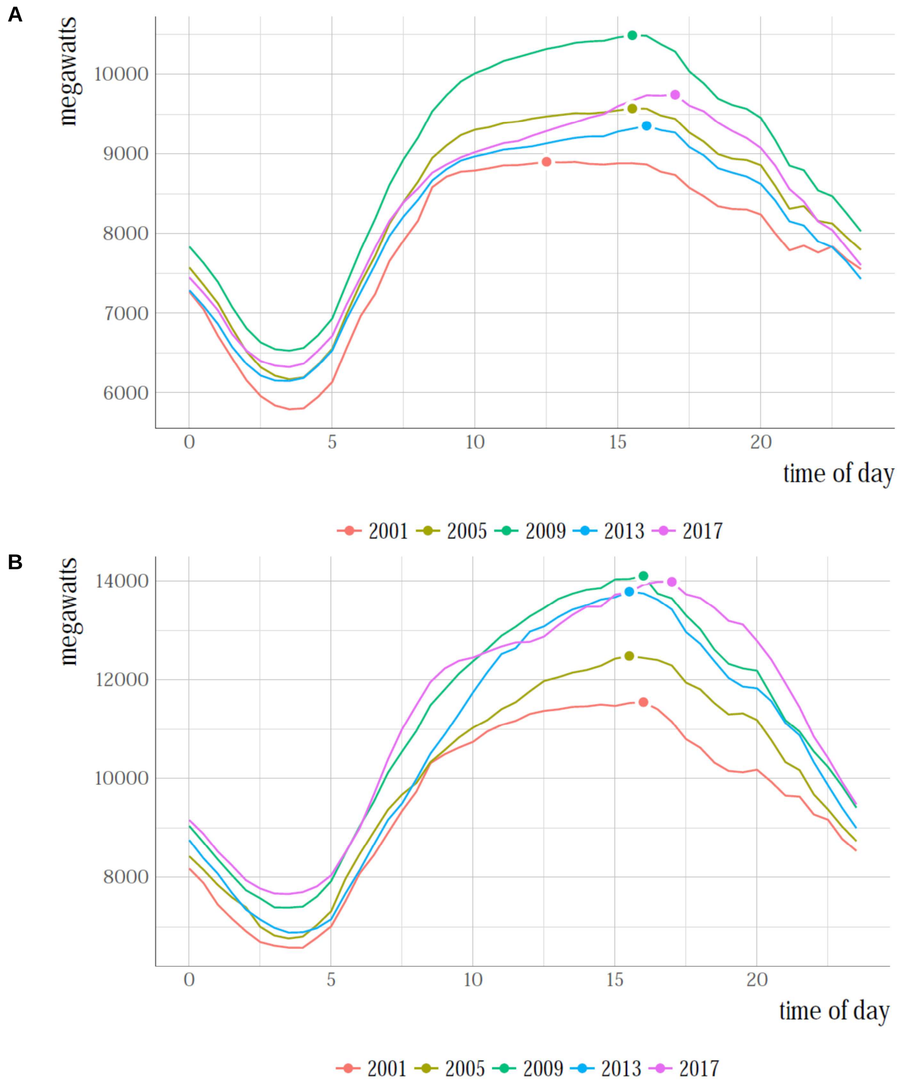

Figure A.2: NSW average (A) and peak demand (B) by time across the first quarter (Jan-Mar) by year.

A) Average demand was highest in 2009, across all hours of the day, and the time of day of maximum demand has shifted slightly later in the day in the last few years.

B) The time of peak demand has shifted slightly later in the day. These shifts reflect, in part, the take up of rooftop solar PV which is reflected in the market as a reduction in demand during daylight hours.

Source: Sandiford (2017)

Demand and temperature

Weather plays a key role in determining electricity demand. The strong ‘boomerang’ correlation between maximum daily temperature and maximum demand is shown in Figure A.3 with a low in demand at ~25°C. The steep rises in demand as the weather gets both progressively colder and hotter indicates the key role that air conditioning (cooling and heating) plays in peak demand. The most extreme demand events (>13 GW) occur in the late afternoon in summer when the temperatures are still rising, household air conditioners are running and before commercial and public sector demand has substantially diminished.

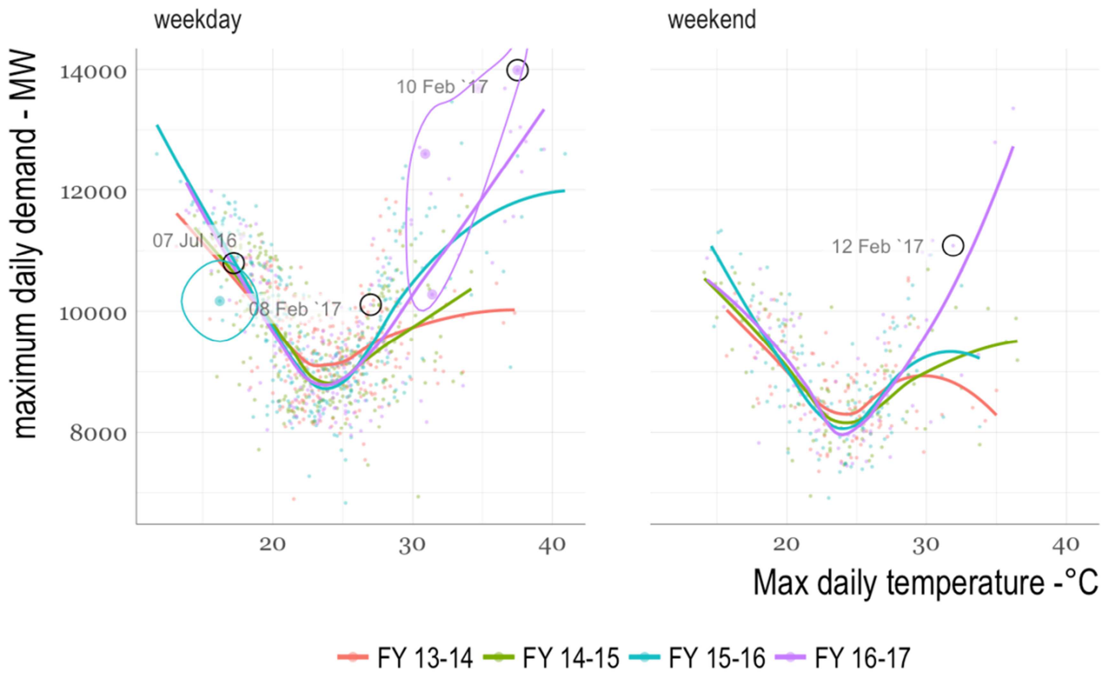

Figure A.3: Boomerang pattern of maximum daily demand in NSW and maximum daily temperature in Sydney (Observatory Hill), by financial year
Days with average spot prices above $500/MWh are identified by larger dots and are encircled. Days of exceptional spot prices across the NEM are also highlighted. The figures discriminate between weekdays and weekend, excluding the Christmas to New Year period, where demand deviates from normal because of low industrial, commercial and public sector loads. Source: Sandiford (2017)

The difference between daily average summer demand profile and extreme daily profiles is shown in Figure A.4, demonstrating the increased generation capacity that is required on peak demand days. In 2017 at the time of peak demand on 10 February, there was an extra ~ 35% of capacity being used compared to the average summer day in that year. This shows the considerable extra capacity that is required to deal with peak events in NSW.

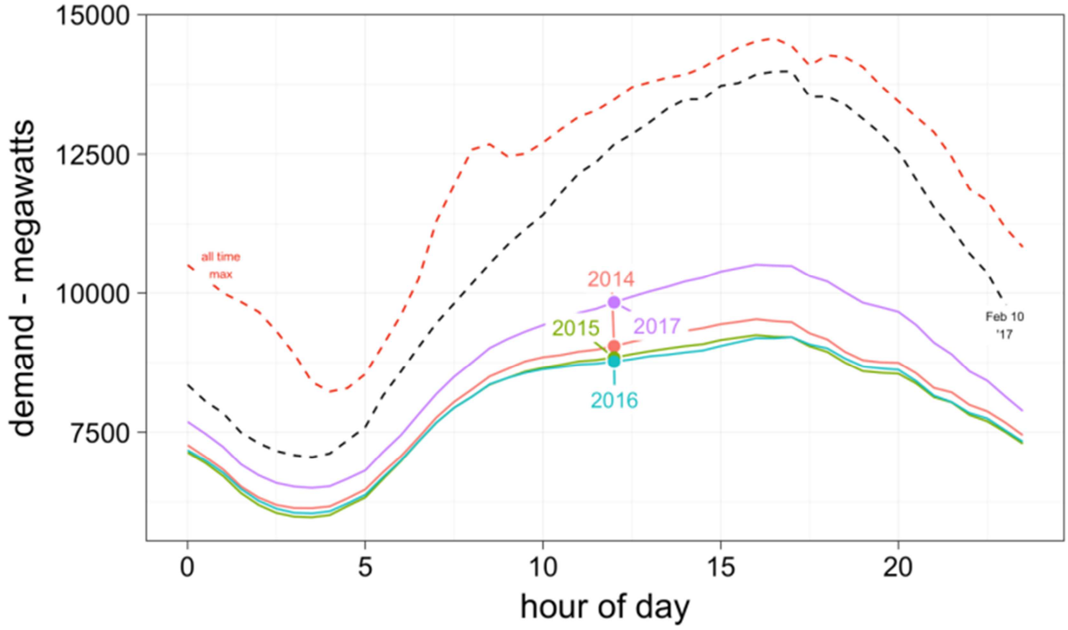

Figure A.4: Average and peak demand, Jan 1 - Feb 14 for the years 2014-2017
The red dashed line represents the all-time maximum demand. The black dashed line represents demand for 10 February 2017. Source: Sandiford (2017)

Duration of peak demand

'Load duration curves' provide another way of visualising the structure of demand over periods of time that cover many different cycles (such as daily and seasonal). Load duration curves are structured with load from highest to lowest plotted from left to right over time (see Figure A.5(A)). The time for which each load applies is typically given as a percentage of total time. With the area under the load duration curve reflecting the total energy demanded in the system, shifts up and down in the load duration curve reflect changes in average energy use. A load duration curve provides a simple illustrative guide to the generating capacity requirements needed to meet demand in terms of peak, load following and baseload.

The left side of the duration curve at low load durations is served by peaking plants (e.g. OCGT and hydro) with the right hand served by baseload plants (e.g. coal). Much of the middle part of the curve requires somewhat flexible or load-following plant, which for NSW includes some coal, as well as gas, and hydro. Wind and solar contribute in a complicated way depending on availability and cause the effective load duration to be shifted downwards, and often skewing it to the left, reducing the requirement for base-load relative to load-following and peaking capacity.

Load duration curves show that load in NSW in 2016-17 was beneath 14 GW 100% of the time, below 12.1 GW 99% of the time and below 8 GW 50% of the time (see Figure A.5(A-B)).[12]

While the position of annual load duration curves moved down and up from 2010-11 through to 2015-16[13], the general shape changed relatively little compared with 2016-17 (shown in Figure A.5(B-C)). Since 2010-11 average demand has reduced, as shown by the downward trend at the 50% duration interval. However, this has stabilised in the last four years.

Peak load fell in the period up to 2014-15, but has risen abruptly since, though has not reached the record of 14.6 GW that was seen in February 2011. The skewing of the 2015-16 and, particularly, the 2016-17 load duration curve to the left reflects the increasingly 'peaky' demand. Marked changes in the shape of the curve, evidenced in the low duration increments in 2016-17, highlight changes in the utilisation rates amongst the available generation types.

[12] Figures based on 30 minute aggregated demand data. The peak 5 minute dispatch interval demand for 10 February 2017 was 14,181 MW.
[13] Note that the shifts up and down between FY2010-11 and FY2015-16 do reflect changes in average energy use.

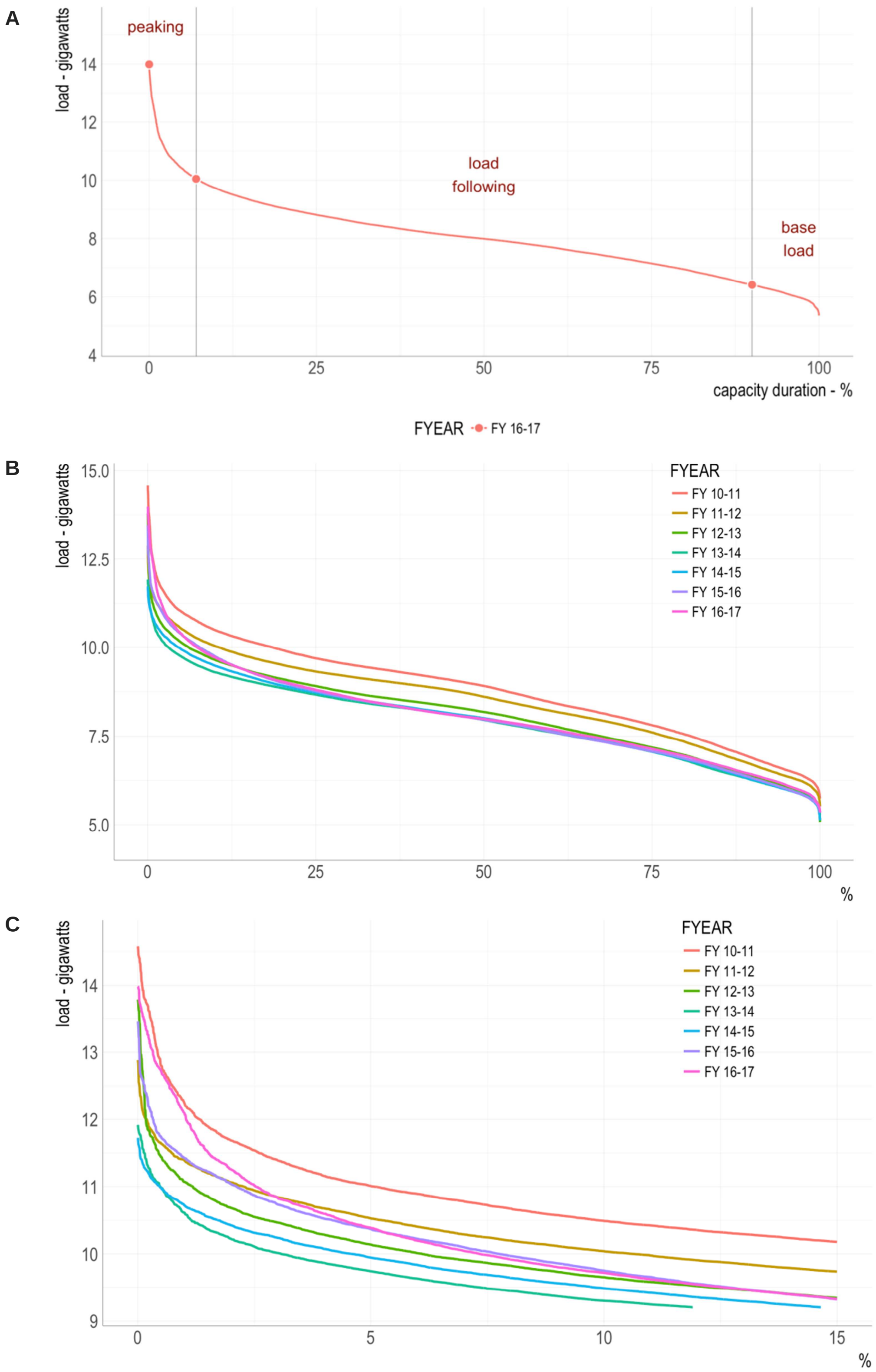

Figure A.5: NSW load duration curves

A) Load duration curve for NSW (2016-17)

B) NSW load duration by financial year. There is a general decline in all years between 2010-11 to 2014-15 and a change in 2016-17 that indicates an increase in peakiness.

C) NSW load duration less than 15% by financial year. The different slope in 2016-17 indicates increasing peakiness.

Source: Sandiford (2017)

Generation for peaking demand

Coal provides the bulk of dispatchable baseload power in NSW. Figure A.6 shows the steady production of coal generation over time. Whilst coal is dispatchable, the nature of some generators does not make them very flexible.

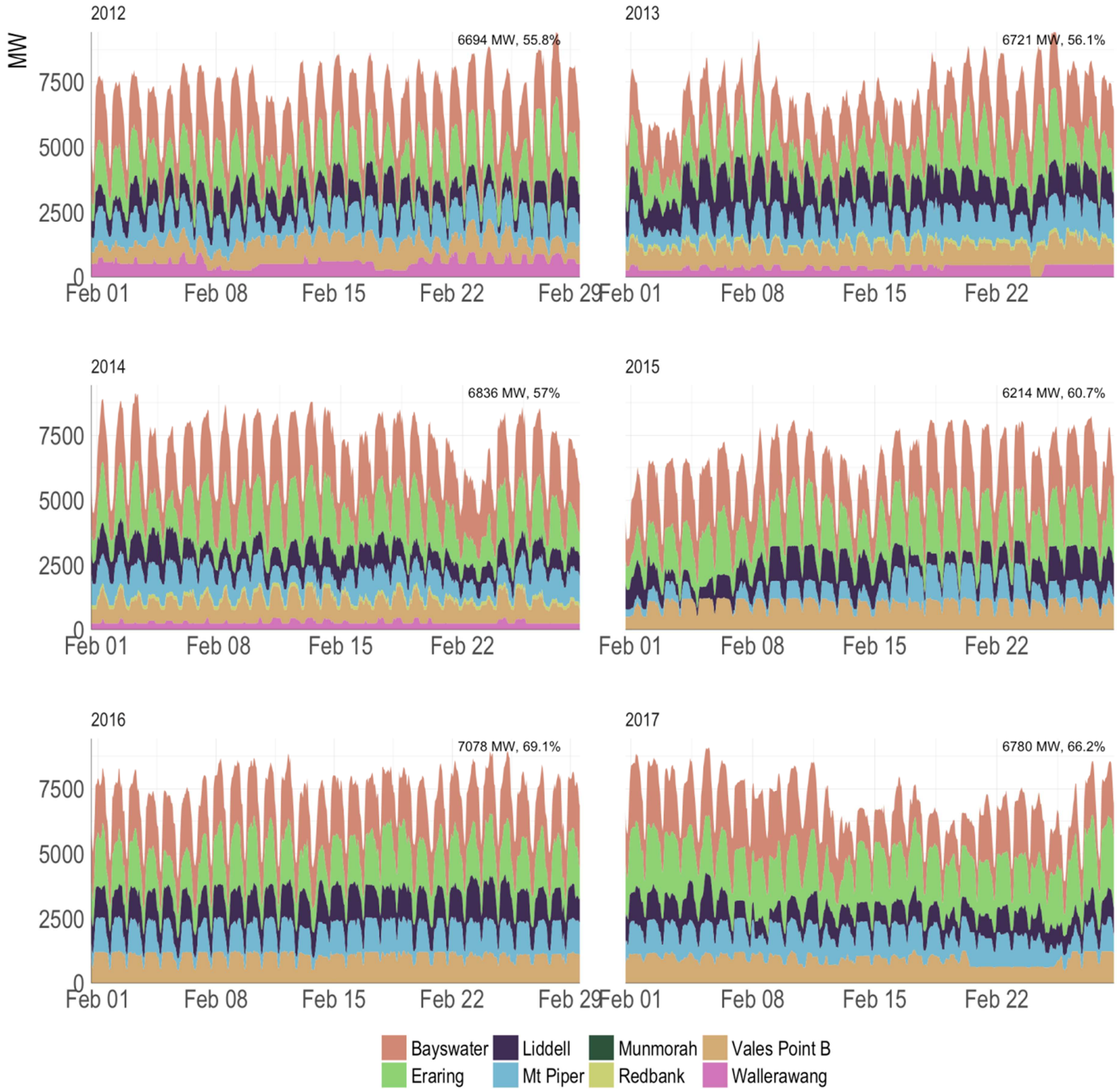

Figure A.6: NSW coal power production by station for the example summer month of February between 2012 and 2017
Average output in megawatts and total coal percentage utilisation rate indicated on top left of each panel.
Source: Sandiford (2017)

The increasing participation of wind can be seen in Figure A.7. Figures A.8 and A.9 show the role of gas and hydro as peaking power in NSW. The figures also show that with increasing gas prices and changing demand profiles, some plants in NSW have become more peak producers. For example since 2016 Tallawarra which typically provided intermediate generation now is a peak generator (Energy Australia, 2017).

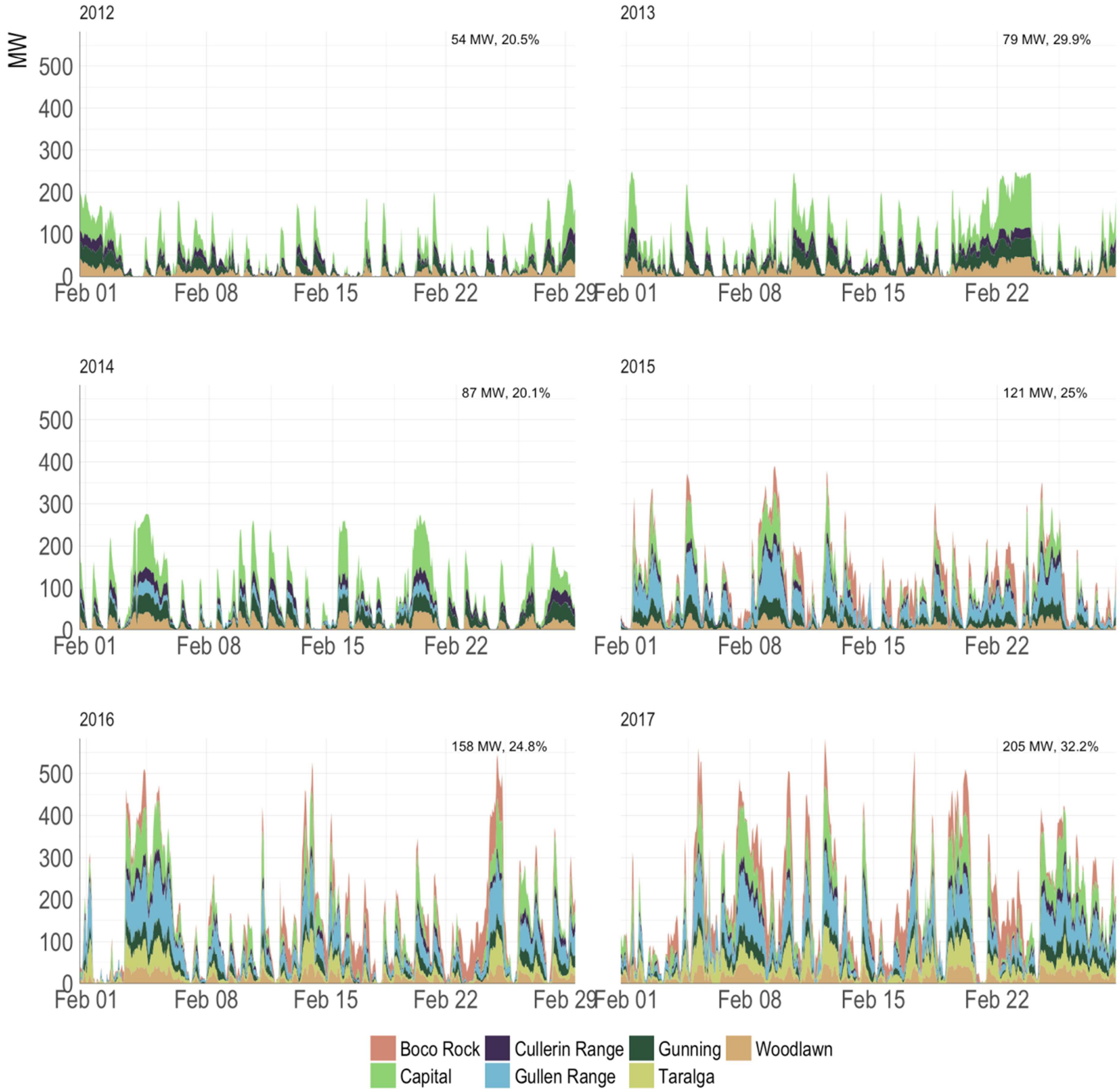

Figure A.7: NSW wind power production by station for the example summer month of February between 2012 and 2017
Average output in megawatts and total percentage utilisation rate indicated on top left of each panel
Source: Sandiford (2017)

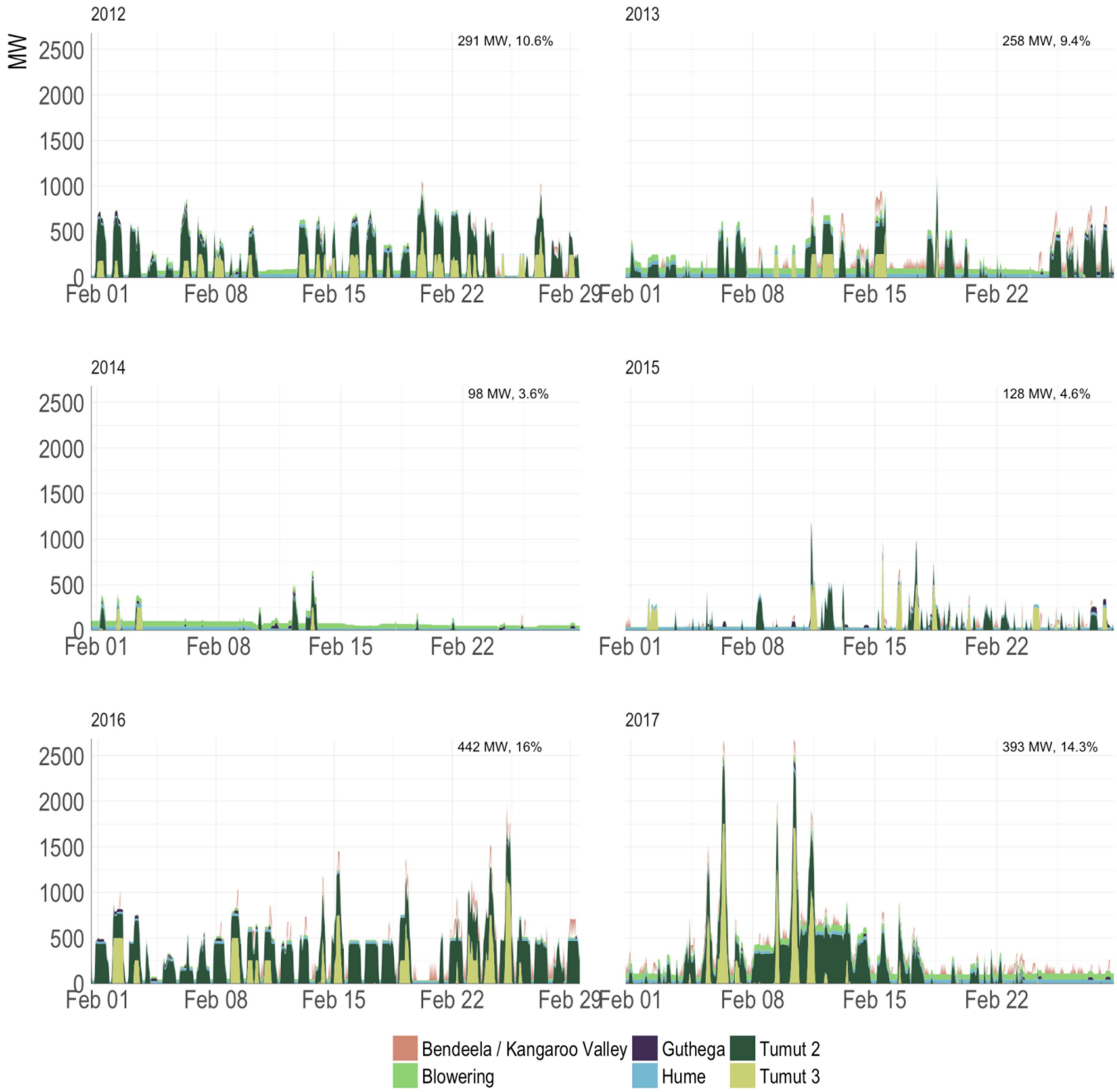

Figure A.8: NSW hydro power production by station for the example summer month of February between 2012 and 2017
Average output in megawatts and total percentage utilisation rate indicated on top left of each panel
Source: **Sandiford (2017)**

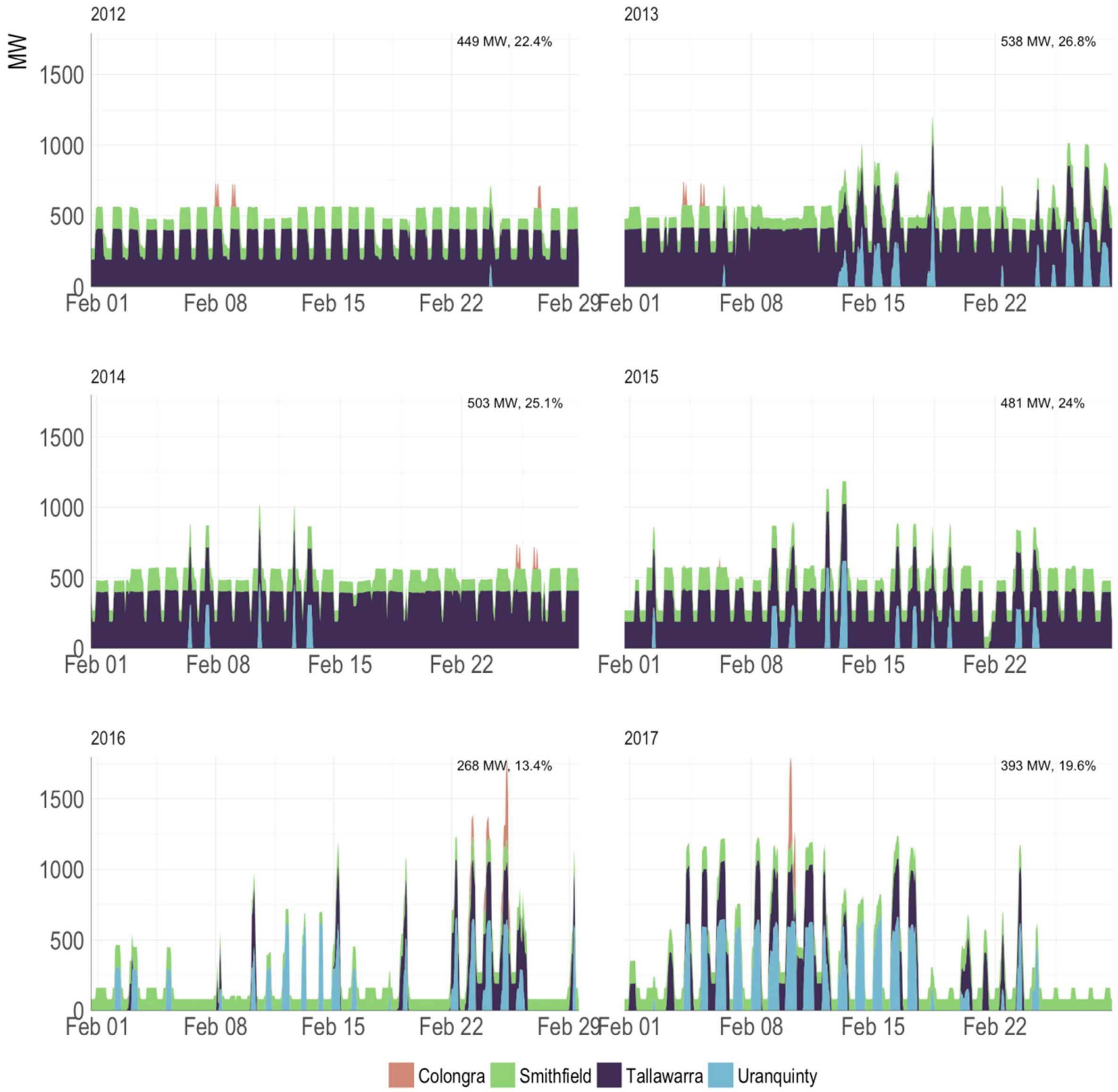

Figure A.9: NSW gas power production by station for the example summer month of February between 2012 and 2017
Average output in megawatts and total percentage utilisation rate indicated on top left of each panel
Source: Sandiford (2017)