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February 2019

Keep calm and carry on

Managing electricity reliability

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Grattan Institute Report No. 2019-01, February 2019

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We would like to thank the members of Grattan Institute's Energy Reference Group for their helpful comments, as well as numerous government and industry participants and officials for their input.

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This report may be cited as: Wood, T., Dundas, G., and Percival, L. (2019). *Keep calm and carry on*. Grattan Institute.

ISBN: 978-0-6483311-8-6

Overview

Australians are questioning the future reliability of their electricity supply. More than two years after the statewide blackout in South Australia, media commentary, political grandstanding and threats of government interventions in the market continue. This report shows that what's needed is not panic and politicking, but cool-headed policy responses to manage reliability without unnecessarily adding to consumer bills.

Political leaders and media commentators have linked the SA blackout with that state's high level of wind power. A false narrative has taken hold: that electricity supply has become less reliable with more renewable energy, and that this is inevitably going to get worse. But overwhelmingly outages are caused by problems in transporting power; it has nothing to do with whether the power was generated from renewables or coal or some other technology.

Over the past 10 years, more than 97 per cent of outages were due to problems with the local poles and wires that transport power to homes and businesses. If we respond to misperceptions, we are likely to add to the cost of electricity while doing little to improve reliability.

Each part of the power supply chain contributes to outages in different ways and requires different management responses. The common thread is to ensure that the benefits to consumers justify the cost of increasing reliability.

A lack of generation capacity on hot days caused only 0.1 per cent of outages over the past decade. But past success does not guarantee future success. Events in Victoria and SA in January 2019 highlighted the current tight balance between supply and demand. As more old coal generators are closed and summer heatwaves become more severe, outages will increase unless investment in new supply follows. A stable policy framework is needed to reduce emissions and encourage investment in new supply so that such outages remain rare. Further reforms, such as a centralised capacity market or direct government intervention to support investment, are not required.

Natural disasters and major equipment failures can destabilise the power grid, leading to large and expensive outages. The 2016 SA blackout demonstrated that the changing shape of the energy system requires changed management practices. The market operator has already implemented such practices, and a combination of regulatory obligations and market mechanisms are being applied to support grid stability as the system continues to evolve.

Equipment failures, falling trees, inquisitive animals and crashing cars can all cause the power to go out in the local distribution network. It would be prohibitively expensive to prevent all these outages. The New South Wales and Queensland governments spent $16 billion more than was needed on distribution networks over a decade, while achieving only very small improvements in reliability. Households and businesses are still paying for this through their power bills. Regulators and network businesses need to balance cost and reliability as weather patterns, technology and consumer preferences change. Consumers will not be happy to pay for another round of network 'gold plating'.

Increasing renewable generation does create challenges for managing the power system. But energy market authorities have taken significant steps since the SA blackout to ready the grid ready for a future with much more wind and solar generation. This report identifies further necessary reforms. But if we keep calm and carry on, these challenges can be met without more big price increases for households and businesses.

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1 Why are we talking about reliability?

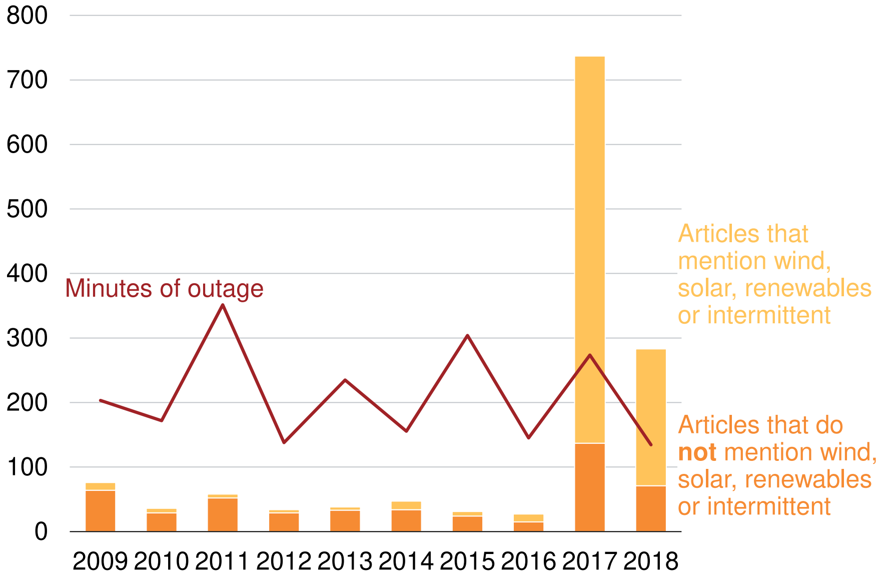
Australians are talking about electricity reliability more than ever. South Australia lost power on 28 September 2016 and media reporting immediately spiked. The number of articles talking about 'blackouts' has been 10 times higher in the two years since than it was in the preceding decade. The SA blackout was a big event, but the increase in media reporting is disproportionate to the increase in overall power outages (Figure 1.1). The number of outages varies from year to year but remains broadly flat.[1]

SA has the highest share of wind and rooftop solar generation in the National Electricity Market (NEM).[2] This led to media reports after the SA blackout linking blackouts to renewable energy (Figure 1.1). Since the SA blackout about 80 per cent of media articles that talk about 'blackouts' mention 'wind', 'solar', 'renewables', or 'intermittent', compared to less than 20 per cent before.[3]

More renewable generation does create challenges for managing the grid. Politicians and the media have been quick to emphasise these challenges (Box 1). But this report shows that these challenges are manageable. There is no reason to panic about wind and solar growing as a proportion of our power supply, nor for Australia to abandon its international commitments to reduce greenhouse gas emissions. Since September 2016 Australia's energy regulators and market operator have made significant progress on the things necessary to manage a renewables-heavy grid. We should keep calm, so they can carry on.

Figure 1.1: Media articles mentioning 'blackouts' have increased; power outages have not

Number of articles in major newspapers, average minutes of outage per customer



Notes: Articles mentioning (blackout or black-out or "black out") *and* electricity *in The Australian, The Australian Financial Review, The Hobart Mercury, The Age, The Herald Sun, The Sydney Morning Herald, Daily Telegraph, The Adelaide Advertiser or The Courier-Mail. The number of articles in these newspapers has remained relatively constant over this time period. Minutes of outage are for customers of all NEM-connected distribution networks and include all sources of outage. Data in financial years. Victorian outage data for July to December 2008 and January to June 2018 was estimated due to unavailability.*

Sources: Grattan analysis of Dow Jones (2018) and AER (2018b).

1. Outages means minutes of outage throughout this report.
2. In 2017–18 wind generation provided 6.3 per cent of electricity across the NEM, but 40 per cent in SA. Rooftop solar provides 3.4 per cent across the NEM, but 8 per cent in SA: AER (2018a).
3. An 'intermittent' generator is one whose output is not readily predictable, such as solar and wind generators.

Box 1: Many politicians and commentators have blamed reliability issues on renewables

'Reliability suffered, most noticeably in South Australia, where their reckless reliance on renewables without storage or firming capacity left their system vulnerable.' – Malcolm Turnbull, then Prime Minister, 11 July 2018

'[The Australian Energy Market Operator's] report [on 8 February 2017 load-shedding in SA] confirms the complexity and fragility of maintaining energy security in South Australia. In particular the difficulty of forecasting and managing high levels of intermittent generation. That is why the Turnbull Government is focused on energy storage and ensuring sufficient baseload power in the system.' – Josh Frydenberg, then Federal Energy Minister, 15 February 2017

'The Australian Energy Market Operator has forecast significant supply shortfalls in Victoria under plausible hot weather conditions this summer. This is a direct result of Victorian Government policies forcing out reliable 24/7 power, and a failure to prioritise firming of heavily subsidised intermittent wind and solar generation.' – Angus Taylor, Federal Energy Minister, 16 November 2018

'Jay Weatherill needs to to abandon his obsession with wind power and admit it has created the most expensive and least reliable electricity in the country. Then he must ensure no more base load generators leave the state.' – Steven Marshall, then SA Opposition Leader, 10 February 2017

'High electricity prices and worsening reliability reflect a woeful failure of planning. First in South Australia and now across the National Electricity Market, the intermittent nature of renewables such as wind and solar is at the centre of the problem. Coal-fired generation has been made less reliable as a result of ill-considered renewable energy targets that have 'hollowed out' the electricity supply.' – The Australian editorial, 15 June 2018

'Nothing might change political fortunes more rapidly than a summer when airconditioners are not working. It will not take long for the public to work out that an over-reliance on clean energy is at the core of their discomfort.' – Graham Richardson, The Australian, 11 October 2017

'The blackout roulette game has been engineered by Victorian State Premier Daniel Andrews and NSW Premier Gladys Berejiklian and her predecessor Mike Baird whose governments vandalised the power system by 'plonking' wind and solar farms in various areas without providing back up for high demand days when the wind doesn't blow and the sun doesn't shine.' – Robert Gottliebsen, The Australian, 18 January 2018

'Victoria sits on vast deposits of coal – enough for electricity for hundreds of years. It also has lots of gas. Yet last Thursday and Friday it somehow managed to run out of electricity, just like some third-world country. Just like South Australia.' – Andrew Bolt, Herald Sun, 29 January 2019

1.1 The South Australian blackout has triggered a national debate about renewables

The SA blackout (Box 2) attracted national media attention. Power reliability used to be seen primarily as a local issue – in the decade before the SA blackout only 25 per cent of articles mentioning 'blackouts' appeared in national newspapers. But since the SA blackout more than 45 per cent of such articles have been in national newspapers.

The national debate was further stoked by the November 2016 announcement that the Hazelwood coal power station in Victoria would close in March 2017, outages in SA (including at BHP's Olympic Dam mine) and Victoria on 1 December 2016 due to a transmission line fault, outages during a heatwave in SA and NSW in February 2017, and again during a heatwave in Victoria in January 2019.

The SA blackout also prompted a policy debate about the robustness of the electricity system. On 7 October 2016 the COAG Energy Council commissioned a review of the security and reliability of the NEM[4] led by the Chief Scientist, Alan Finkel.[5] That review led to the creation of a new market review body, the Energy Security Board, to coordinate the recommended reforms, which include an annual 'health check' of the NEM. The latest check, published in December 2018, reported that the outlook for both the security and reliability of the NEM was 'critical'.[6]

1.2 What really causes power outages?

Outages occur across all parts of the power system. The electricity grid is a large and complex machine that must operate continuously under all weather conditions. Power is transported from distant power stations via high-voltage transmission lines, and then reduced in

4. The NEM covers most customers in eastern Australia, including NSW, Queensland, Victoria, SA, Tasmania and the ACT.
5. Finkel et al. (2017).
6. ESB (2018a).

Box 2: The South Australian blackout

At 4.18pm on Wednesday 28 September 2016 the South Australian grid lost all power supply, causing massive disruption to businesses, commuters and households. About 80-90 per cent of customers had power restored by midnight, but some customers were without power for two weeks. Two separate studies estimated the economic effect of the blackout at about $400 million.[a]

Several factors combined to cause the blackout. First, tornadoes damaged several high-voltage power lines. Nine wind farms were unable to cope with a series of disturbances and disconnected from the system, reducing supply by about 450 megawatts (MW). This sudden loss of supply caused an increase in flow on the Heywood interconnector with Victoria, which disconnected to protect itself. Once Heywood disconnected, the imbalance between supply and demand was too great, and the system shut down.

The impact was compounded by a slow and difficult system restart. Power station damage from lightning strikes meant that power could not be restored locally, and it took more than two hours to establish a secure network connection to Victoria.[b]

a. Parliament of South Australia (2017).
b. AEMO (2017a).

voltage to travel on a low-voltage distribution network to the customer (Figure 1.2). One part or other of this system will fail sometimes.

The three main parts of the grid cause outages in different ways.

Generators can cause outages when there is simply a lack of supply to meet demand, or when a generator suddenly disconnects from the grid ('trips') or fails. One of key factors that caused the SA blackout was the sudden trip of nine wind farms.

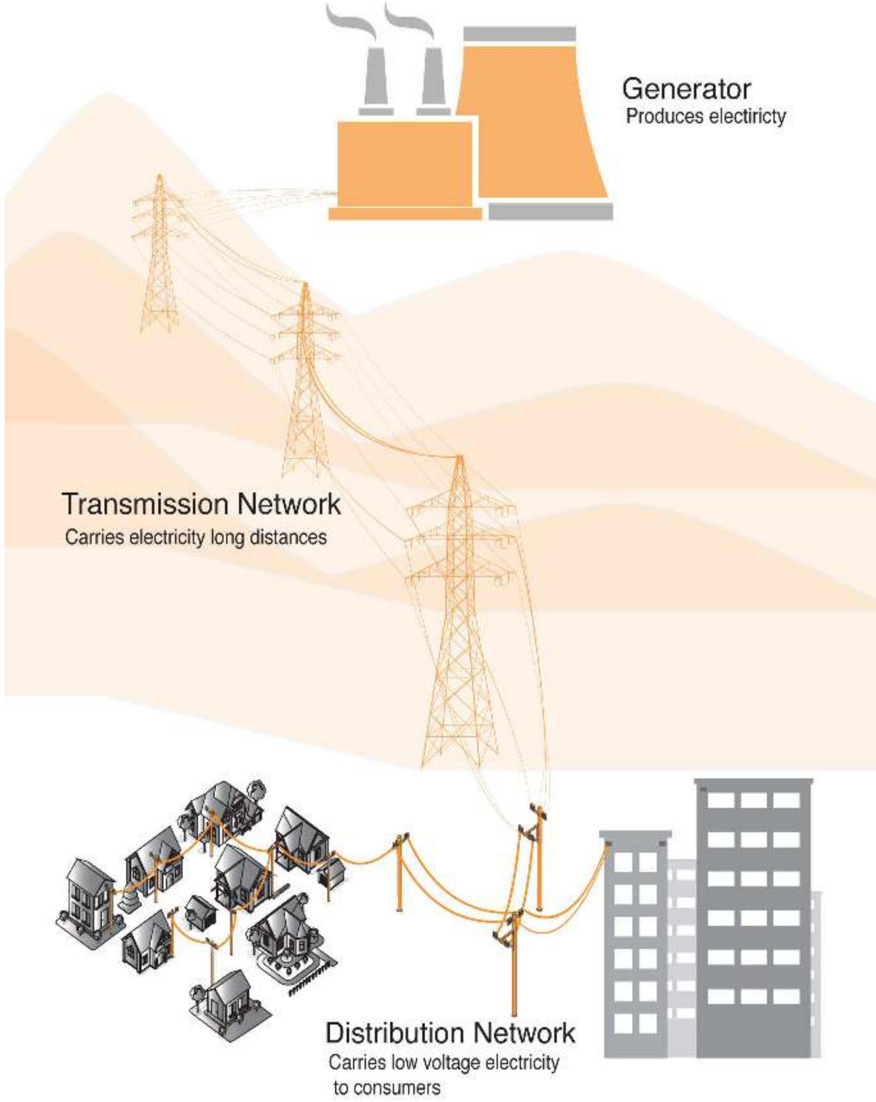
Outages in the transmission network can occur when network equipment fails, or when natural disasters such as bushfires and lightning strikes take out transmission lines.

Finally, a great variety of issues can cause localised power outages in the distribution network – planned maintenance, equipment failures and overloads, natural disasters such as floods and storms, and external factors such as animals and vehicles.

The debate about the effect of renewables on reliability in the wake of the SA blackout is unbalanced. It ignores the fact that most failures occur in transporting power to the customer, and have nothing to do with the source of that power (Figure 1.3 on the following page). Over the ten years to 30 June 2018, only 1.6 per cent of outages were related to generation issues, most of which was the SA blackout.[7] Only 0.1 per cent of outages were due to a lack of power supply.[8] More than 97 per cent of outages occurred in the distribution network.

7. The SA blackout was the only time over the ten years that a generation trip or failure led to distribution-connected customers losing power. A transmission-connected customer, the Tomago aluminium smelter in NSW, lost load on 10 February 2017 due to technical problems with two gas power stations on a hot day with very high demand.
8. This excludes generation shortfalls in Victoria on 24 and 25 January 2019. Comprehensive data is not yet available for this period. Currently available information indicates that the number of customers affected was about half that of the shortfalls in SA and Victoria on 29 and 30 January 2009: AEMO (2019a).

Figure 1.2: The electricity supply chain



1.2.1 Why do people link renewables and reliability issues?

Two main arguments in the public debate link more renewable generation with less reliability.

Wind and solar only provide power when the wind blows or the sun shines

Political and media commentary focuses on the intermittent nature of wind and solar (see Box 1 on page 7). This often involves the rhetorical question: what will happen when the wind doesn't blow and the sun doesn't shine? This simplistic critique has a simple answer: run something else. That something is a 'dispatchable' generator that can increase or reduce its output as required.

A more nuanced concern about wind and solar is that they make it harder to invest in dispatchable generation. They push prices down when it is windy or sunny, and so other generators will need higher prices at other times if they are to be viable. If this price volatility were to make it too risky and difficult to invest in new dispatchable generation, supply and reliability could fall. This concern is considered further in Chapter 2.

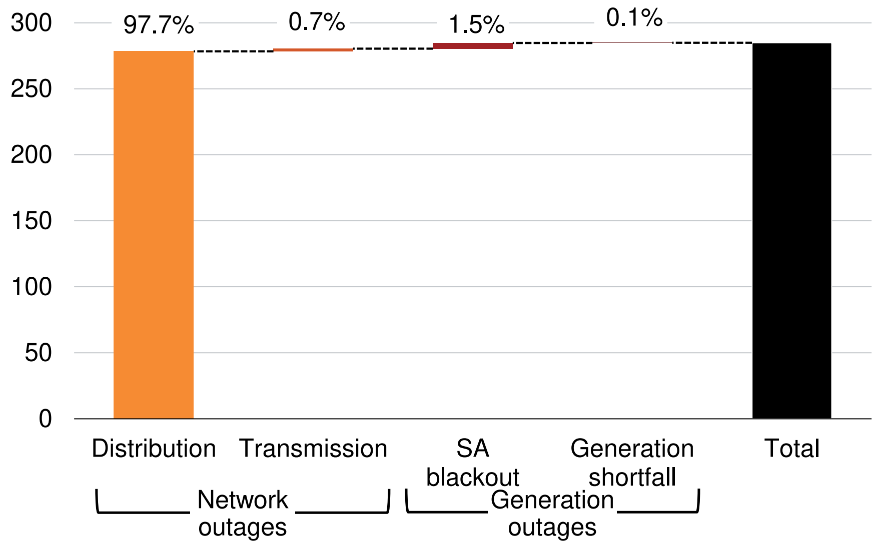
Wind and solar are not 'synchronous'

The intermittent nature of wind and solar is unrelated to the SA blackout.[9] The SA blackout occurred in September on a day where Adelaide's maximum temperature was 20°C and when demand was moderate.[10] A lack of generating capacity – wind or otherwise – was not the issue.

9. AEMO (2016a, p. 21).
10. SA demand at the time of the blackout was about 1800 MW. This is about half SA's maximum demand on 8 February 2017 when available generation was temporarily insufficient to satisfy demand. On that day SA demand (including that supplied by rooftop solar) peaked at 3317 MW: AEMO (2017b, p. 7).

Figure 1.3: Outages overwhelmingly occur in transporting power, not generating it

Average annual minutes of outage per customer by cause, financial years 2009 to 2018



Notes: Covers distribution network-connected customers in supply areas connected to the NEM. This analysis attributes the SA blackout to generation issues – the unexpected tripping of nine wind farms. Throughout this report the Victorian Distribution Network Service Provider (DNSP) data covers the 9 calendar years from 2009 to 2017, all other DNSP data covers the 10 financial years from 2008–09 to 2017–18. This analysis uses a slightly different methodology to that used by the Australian Energy Market Commission (AEMC), see for example AEMC Reliability Panel (2018, p. 53).

Sources: Grattan analysis of AER (2018b) and AEMO (2019b).

The SA blackout and renewable generation are linked because wind and solar are not 'synchronous' generators, like coal, gas and hydro generators. Wind and solar generators do not have pieces of equipment that spin at the same frequency as the rest of the grid (in other words, synchronised with the grid).[11] Synchronous generators have inherent characteristics that support the stable operation of the grid, particularly when it is hit by a shock. Australia's energy market bodies accept that as wind and solar (both large- and small-scale) displace synchronous generators, the grid will become more vulnerable to shocks – unless compensating actions are taken.[12]

Chapter 3 discusses the link between asynchronous generation and grid stability, and examines the technical options available to manage a grid with high levels of renewable generation.

1.3 Should we aim for 100 per cent reliability?

The short answer is no. Increasing reliability costs money, and a trade-off must be made between cost and reliability. Research by Energy Consumers Australia indicates that more customers are concerned about the price they pay for electricity than its reliability.[13] This is unsurprising after a decade in which household electricity prices have increased by 50 per cent more than inflation.[14]

The Australian Energy Regulator (AER) is examining the value customers place on reliability (Box 3). It released a consultation paper in October 2018 and will publish its estimates by December 2019. This analysis will help policy makers and regulators balance cost and reliability.[15]

11. Although wind turbines involve large pieces of rotating equipment, their blades spin at a rate determined by the wind speed, not by the grid frequency.
12. AEMO (2018a, p. 15); AEMC (2017a, p. 2); and AER (2017, p. 56).
13. Energy Consumers Australia (2018).
14. ACCC (2018).
15. AER (2018c).

Box 3: The AER is examining the value customers place on reliability

The AER recognises that the value customers place on reliability varies depending on a range of factors. These include the duration of the outage, when it occurs (during the day, evening, or overnight), and whether it occurs during hot or cold weather.

The AER is examining whether customers are willing to pay more to avoid outages during hot weather than at other times. If they are, this indicates more should be spent to avoid these outages.

The AER's analysis should help networks to manage the timing, frequency and duration of planned outages to reduce their inconvenience to customers.

The AER is also considering whether customers value reliability more than they used to. It notes arguments in both directions.[a] On one hand, people working from home may place a high value on reliability. On the other hand, battery-powered devices such as phones and laptops, and increased affordability of batteries to provide back-up supply, could reduce people's reliance on the grid.

a. AER (2018c, p. 9).

1.4 Rebalancing the debate

Australia needs a cool-headed debate about electricity reliability. The lessons of the SA blackout have been buried in confusing political and media debate. We need to understand whether reducing emissions harms reliability, and what can be done to manage a more renewables-heavy grid. And we need more honesty about what causes outages and what it really costs to avoid them.

Concerns about reliability have caused price increases in the past. Blackouts in 2004 prompted the NSW and Queensland state governments to bolster network reliability standards. As a consequence, networks over-spent by $16 billion, while delivering only modest improvements in reliability.[16] Network costs were the largest cause of increasing residential electricity prices in those states over the past decade. Prices increased more than 50 per cent above inflation in NSW,[17] and more than 70 per cent in Queensland.[18]

A mature debate will help governments and regulators better balance price, reliability and emissions – the so-called energy 'trilemma'.

This report considers what governments should do, and not do, to address different causes of outages. These causes include a lack of power at times of peak demand (Chapter 2), a lack of resilience to major shocks (Chapter 3), and various issues that cause outages in the poles and wires that deliver power to homes and businesses (Chapter 4).

16. Wood et al. (2018a, p. 21).
17. ACCC (2018, p. 14).
18. Ibid. (p. 20).

2 Ensuring we have enough power supply

The NEM has a strong track record in delivering reliable power. But past success does not guarantee future success. This chapter shows arguments that the grid may not be able to maintain reliability into the future are valid, but often over-stated. Generation shortfalls are much less common than other types of outages, and more easily managed. Targeted reform to reduce investor uncertainty will be sufficient to address this risk for the foreseeable future, without redesigning the electricity market or resorting to heavy-handed interventions such as new generation underwritten by government or permanent back-up reserves.

2.1 Is sufficient supply a problem today?

2.1.1 The NEM has delivered sufficient supply to date

NEM-connected customers rarely lose power due to a lack of generating capacity. 'Load shedding' has occurred for this reason on only five days since the start of 2005 – two consecutive days in January 2009, one day in February 2017, and two consecutive days in January 2019 (Box 4).[19] Over the ten years to 30 June 2018, only 0.1 per cent of outages were due to a lack of generation capacity to meet demand (Figure 1.3 on page 10).

This has seen the NEM perform well within its targeted reliability standard that no more than 0.002 per cent of energy consumption should be left unsupplied in any market region[20] due to a lack of generation or transmission capacity.[21] The amount of load lost in Victoria and South Australia in 2009 was greater than 0.002 per cent of that year's energy, but these states have comfortably satisfied the reliability standard over the past decade. This is very likely to remain the case after the lost load in Victoria in 2019 is taken into account, but accurate information on the amount of load lost is not yet available.

The NEM has maintained reliability primarily through commercial incentives. Prices are allowed to rise to very high levels, presently more than 100 times the average annual price.[22] These high prices encourage energy retailers and large energy users to ensure they own, or contract with, enough generation capacity to supply their customers at all times. If they do not, purchasing from other generators at peak times, typically on hot summer afternoons, will be very expensive. Price spikes also encourage users to reduce demand at peak times.

These commercial incentives have brought forward substantial investment when the market was tight, and so maintained reliability. This was most clearly seen between 2005 to 2009. Peak demand grew rapidly during the 2000s, soaking up the market's excess capacity and increasing the risk of summer supply shortfalls. AEMO forecast imminent shortfalls in all mainland NEM regions in 2006, and again in Victoria and SA in 2008 (Table 2.1). But shortfalls did not eventuate in NSW or Queensland, and were experienced only during an exceptional heatwave in Victoria and SA in January 2009 (Box 4). Investors committed 5 GW of new dispatchable generation, reducing these risks. Of this capacity, about 3 GW was driven primarily by market signals rather than various government subsidies that were available at the time and about 4 GW was committed by private investors (Table 2.2).

19. The last such event before January 2009 was on 1 December 2004 in NSW: AEMC Reliability Panel (2006) and AEMC Reliability Panel (2010).
20. NEM regions broadly follow state boundaries. The five regions are Queensland, NSW (including the ACT), Victoria, SA and Tasmania.
21. AEMC Reliability Panel (2018).
22. The NEM's maximum price was $14,200/MWh in 2017–18. In that year the average market price varied between $73/MWh and $98/MWh depending on the region: AEMO (2019c).

Box 4: Load shedding due to a lack of generation

Victoria and South Australia, January 2009

Maximum temperatures in Melbourne and Adelaide exceeded 43°C on Thursday 29 January 2009 and remained very high the next day.

These extreme temperatures drove electricity demand to record levels in Victoria and South Australia.[a] More than 200,000 customers had their power interrupted on a rotating basis on each day to balance supply and demand.[b]

South Australia, February 2017

On Wednesday 8 February 2017 the temperature in Adelaide peaked at 41.6°C, which was higher than forecast. Electricity demand was well above the levels AEMO had forecast the previous day.

About 285 MW of gas generation capacity was unavailable on a long-term basis, and 153 MW of gas and liquid fuel generation capacity experienced technical problems during the afternoon.

These effects, combined with the expected late-afternoon decline in rooftop solar output and unexpectedly low wind generation, saw demand exceed available generating capacity at 6.30pm.[c] The local network operator interrupted the power supply of about 85,000 customers for an average of 34 minutes.[d]

Victoria, January 2019

On Thursday 24 January 2019 the temperature in Melbourne reached 41°C, and on Friday 25 January it hit 43°C before an afternoon cool change. Two coal units were unavailable during Thursday – one due to plant failures and one due to scheduled maintenance – and another coal unit failed around midnight on Thursday night.

AEMO called on back-up reserves, but this did not prevent load shedding. On the evening of 24 January, the Portland aluminium smelter was required to reduce load for almost two hours. On 25 January the smelter was again required to reduce load, and more than 200,000 small customers had their power interrupted on a rotating basis between midday and 3pm.[e]

Adelaide reached 46°C on 24 January, pushing the SA grid to the limit. Back-up diesel generators purchased by the SA Government in 2017 were used, but load shedding was not required.

a. NEMMCO (2009).
b. Grattan analysis of AER (2018b).
c. AEMO (2017b).
d. Grattan analysis of AER (2018b).
e. AEMO (2019a).

Table 2.1: AEMO's forecasting approach often suggests imminent shortfalls, but these do not always eventuate

Years until predicted generation shortfall in AEMO's Electricity Statement of Opportunities (ESOO)

Year	QLD	NSW	VIC	SA	Comments
2005–06	3	3	0		800 MW committed across the NEM
2006–07	2	1	1		400 MW committed in NSW
2007–08	2	6	3	3	1350 MW committed in NSW
2008–09	5	6	0	2	950 MW committed in QLD
2009–10	5	6	4	3	550 MW committed in VIC
2010–11	3	6	5	5	
2011–12	2	7	3	3	
2012–13	8	>10	6	7	Reduced demand forecasts
2013–14	6	>10	>10	>10	
2014–15	>10	>10	>10	>10	
2015–16	>10	7	9	4	Closures in NSW, VIC and SA
2016–17	>10	9	1	1	1600 MW to retire by 2017–18
2017–18	>10	>10	>10	>10	VIC and SA very close to predicted shortfall; RERT employed
2018–19	>10	5	3	6	AEMO adjusts plant failure assumptions; RERT employed

Notes: Years to shortfall are calculated based on 'low reserve conditions' (LRCs) predicted under ESOO central modelling scenario. Near-term LRCs that could be addressed through operational measures, such as rescheduling maintenance, are ignored. The ESOO date represents the coming summer at the time of release. The 2016–17 ESOO is the November 2016 update, after Hazelwood's closure announcement. Darker colours indicate a shorter time before a predicted shortfall. Black cells indicates an actual shortfall in that year. Committed generation capacity in the comments section refers only to dispatchable ('scheduled') capacity that was committed in the calendar year prior to the summer in question, i.e. *calendar year 2005 for the 2005–06 ESOO. RERT is the Reliability and Emergency Reserve Trader mechanism.*

Source: Grattan analysis of AEMO (2018b).

Table 2.2: Investors built capacity in response to a tight market

Dispatchable generators committed between 2005 and 2009

Generator	Year committed	Year built	Region	Capacity	Investment driver
Braemar	2005	2006	QLD	504	QGS
Laverton North	2005	2006	VIC	312	Market
Tallawarra	2006	2009	NSW	435	Market, GGAS
Uranquinty	2007	2009	NSW	664	Market
Colongra	2007	2009	NSW	668	Market
Bogong	2007	2009	VIC	140	RET, Market
Quarantine	2007	2009	SA	127	Market
Darling Downs	2007	2009	QLD	630	QGS, 'ramp gas' from LNG project
Braemar 2	2008	2009	QLD	519	QGS
Mt Stuart	2008	2009	QLD	126	Market
Tamar Valley	2008	2009	TAS	266	Market
Condamine	2008	2009	QLD	140	QGS, 'ramp gas' from LNG project
Yarwun	2008	2010	QLD	160	Cogeneration, QGS
Mortlake	2009	2011	VIC	566	Market

Notes: Grey rows identify generators that were publicly owned when built. All generators are gas-fired except Bogong, which is hydro-electric, and Mt Stuart which uses liquid fuel. Generator 'commitment' is defined consistent with AEMO's ESOO publications. QGS is the Queensland Gas Scheme, which required 13 per cent (later 15 per cent) of generation to use gas as a fuel. GGAS is the NSW Greenhouse Gas Abatement Scheme. RET is the national Renewable Energy Target.

Sources: Grattan analysis of AEMO (ibid.), AER (2009), AER (2010), AER (2011) and AER (2012).

More recently the risk of shortfalls has increased substantially. The closure of the Northern (SA) and Hazelwood (Victoria) coal-fired power stations in May 2016 and March 2017 respectively has greatly tightened the balance between supply and demand.

There was a small generation shortfall in South Australia during the 2016–17 summer, but this was well below the level targeted by the reliability standard. Continuing tight conditions saw AEMO secure back-up reserves through the Reliability and Emergency Reserve Trader (RERT) mechanism (Box 5) for both the 2017–18 and 2018–19 summers.[23]

AEMO used the RERT in SA and Victoria during January 2019. In SA this was sufficient to prevent load shedding, but there were generation shortfalls and load shedding in Victoria on 24 and 25 January (see Box 4).

2.1.2 Generation shortfalls are very rare, even in heatwaves

Generation shortfalls make the headlines because they affect many customers at once, and because they occur on very hot days. Some commentators describe load shedding as a 'third world' solution to managing the grid. But consumers may not want to pay the cost of preventing all generation shortfalls. Given these events are so rare, we should not over-react to them when they do occur. And we should examine shortfalls in the context of other outages that can occur on hot days.

Generation shortfalls are not the most common source of outages on hot days. On days over 35°C in January and February 2009, Victorians and South Australians lost 14 times more power because of network failures and weather damage (particularly bushfires) than generation shortfalls (Figure 2.1).

23. AEMO (2018c); and AEMO (2018d).

Box 5: The Reliability and Emergency Reserve Trader mechanism

The RERT is the NEM's 'insurance policy' to protect against generation shortfalls. AEMO typically only uses the RERT to procure reserves if it forecasts that a NEM region is not expected to satisfy the reliability standard for a given year.

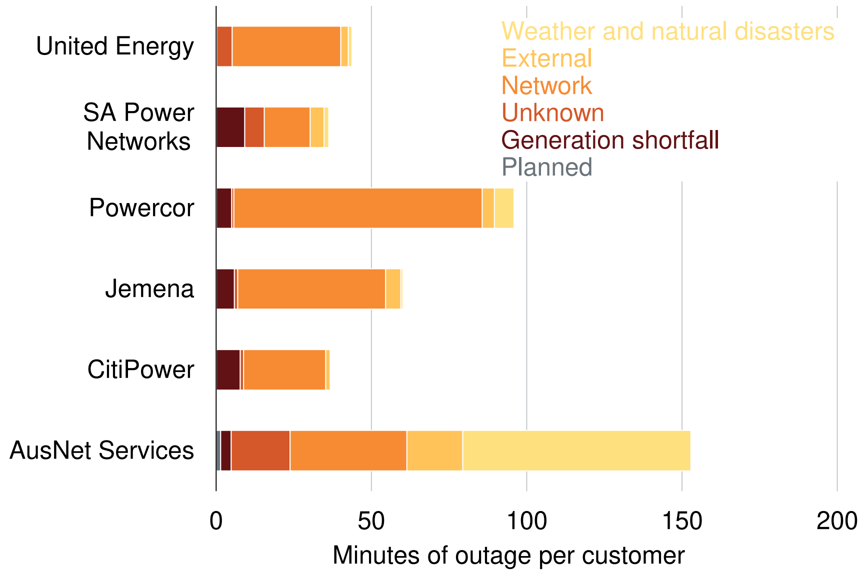
The RERT might be used to procure reserves that turn out not to be required if, for example, summer weather is relatively mild or there are few generator failures at times of high demand. In 2017–18 AEMO procured RERT reserves for the summer and activated some reserves in anticipation of potential shortfalls.[a] But no major generation or transmission assets failed at times of peak demand[b] and so the activated RERT reserves were not needed.

This does not mean that AEMO should not have invoked the RERT last summer, because there was, of course, no guarantee that there would be no extreme hot weather or major plant outages. Those events did coincide during January 2019, and RERT reserves were dispatched to reduce the extent of shortfalls in Victoria.

Like any insurance policy, failure to use the RERT does not mean that it was not valuable. But the price paid for insurance should reflect the impact and probability of the events being insured against.

a. AEMO (2018c).
b. Ibid.

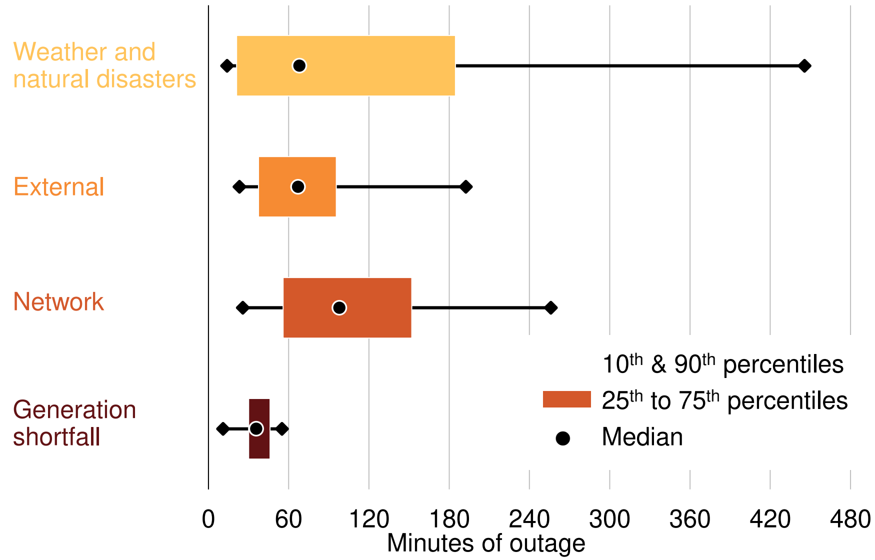
Figure 2.1: Generation shortfalls played little role in the outages on very hot days in Victoria and SA in January and February 2009 . . .
Distribution network



Notes: Cumulative minutes of outage per customer on days over 35 degrees in January and February 2009. Bureau of Meteorology (BoM) data sourced for a single location per Distribution Network Service Provider. Larger DNSP areas are likely to have more varied weather across their network on a given day.

Sources: Grattan analysis of AER (2018b), BoM (2018) and AEMO (2019b).

Figure 2.2: . . . and those blackouts caused by generation shortfalls were the shortest
Outage type



Note: Customer-weighted percentiles.

Sources: Grattan analysis of AER (2018b), BoM (2018) and AEMO (2019b).

Outages caused by generation shortfalls are also easier to manage than network problems. Power can be restored as soon as demand falls or supply increases. And the blacked-out areas can be rotated to reduce the impact on any individual customer.[24] By contrast, customers affected by a network failure or storm damage will be without power until a crew can come out and fix it.

Almost all customers affected by generation shortfalls during the outages in Victoria and SA during January and February 2009 were back on line in less than an hour (Figure 2.2). Similarly, the February 2017 shortfall in SA left customers without power for 34 minutes on average.[25] By contrast, the median outage caused by weather events lasted more than an hour and often much longer. And the median outage caused by network asset failures and overloads was closer to two hours. More than 10 per cent of customers who lost power due to weather events and network asset failures were without power for more than four hours.

2.2 Could generation shortfalls become more common in the future?

Past success does not guarantee future success. There are several reasons the NEM's historic reliability might not continue.

2.2.1 The supply-demand balance is tight and likely to remain so

The NEM is in a phase of rapid change. The generation mix is changing as old coal-fired power stations, such as Hazelwood, reach the end of their technical lives and are closed. Significant investment in new renewable generation, driven by economics and government subsidies, will accelerate this trend.

Continuing retirements of coal-fired power stations mean the present tight balance between supply and demand is likely to persist. The Liddell power station in NSW is scheduled to close in 2022, and more will follow. Reliability risks will be exacerbated by the increasing unreliability of ageing coal generators, and increasing temperatures due to climate change.

These trends have prompted AEMO to forecast a tightening supply-demand balance in Victoria, NSW and SA.[26] In the absence of new generation, AEMO expects those regions will breach the reliability standard in 2021-22, 2023-24 and 2024-25 respectively (Figure 2.3).

Like any forecast, AEMO's supply-demand forecasts become less reliable the further they look into the future. While the stock of generation assets available for the coming summer is effectively fixed one or two years ahead, investors can deliver significant new capacity over a period of three or more years. Plausible levels of investment will see the market satisfy the reliability standard, as shown in AEMO's Integrated System Plan (Figure 2.4).

Further, AEMO's supply-demand forecasts are not designed to predict the most likely market outcome, but rather to signal the need for new generation investments.[27] To achieve this the market rules only allow AEMO to include any generators that are already in operation or classified as 'committed'.[28] This requirement excludes generators

24. Errors can occur in implementing rotational load shedding. During the February 2017 shortfall in SA, AEMO instructed that 100 MW be shed, but the local network operator shed about 300 MW: AEMO (2017b, p. 20).
25. Grattan analysis of AER (2018b).
26. AEMO (2018e).
27. They are called a 'statement of opportunities' precisely because they are intended to highlight opportunities for investors to build.
28. A committed generator must have planning approvals, finance and a firm construction contract, (AEMO (2014a, pp. 31–32)). In some recent cases generators have commenced construction before notifying AEMO that they satisfy all of these conditions, and so have been classified as committed.

that are at an advanced stage of development but do not meet all the commitment criteria.

The outlook can change quickly as projects progress. For example, almost 2 GW of wind and solar generation was committed in NSW and Victoria alone since the August 2018 forecast shown in Figure 2.3 was finalised.[29]

AEMO's current predictions of medium-term shortfalls are not greatly concerning. AEMO's forecasts only predict likely market outcomes in a worst-case scenario of a prolonged investment drought. This is unlikely to occur when the market is tight and prices are elevated, signalling the need for new investment. Present high market prices, along with policy incentives, have already prompted significant investment in wind and solar. And the last time the market was tight, between 2005 and 2009, investors responded strongly, delivering more than 5 GW of new dispatchable generation (Table 2.1 on page 15).

There is ample time for investors to respond with new capacity to address the increasing risk of shortfalls from about 2022 – provided other risks and uncertainties can be managed. These risks and uncertainties, and their potential remedies, are discussed further below.

2.2.2 Increasing wind and solar generation

Higher levels of wind and solar generation do not threaten reliability, provided investors can respond to market requirements and build sufficient dispatchable generation. This is particularly important when existing generators are retired, causing a sudden drop in available capacity.

29. More than 500 MW of wind generation in Victoria and about 1.4 GW of solar generation across both states. While wind and solar have a smaller impact on reducing the risk and size of shortfalls than dispatchable generators per unit of generating capacity, they do reduce expected shortfalls to some extent.

The Finkel Review considered that wind and solar generation created 'challenging conditions for investment in other generators',[30] and that this could compromise reliability. In future NEM prices are likely to be low on windy days and very high on still evenings. Finkel considered that this volatility could make investment risky, and any resulting lack of investment would affect reliability. AEMO has also questioned whether the market will deliver new dispatchable generation, given higher levels of wind and solar.[31]

Volatility caused by wind and solar will affect the viability of baseload generators (Box 6). Baseload generators run continuously and so are exposed to both high and low prices. But not all dispatchable generators are affected in this way.

Box 6: Distinguishing baseload and dispatchable generation

A baseload generator is a dispatchable generator with high capital costs and low operating costs. These characteristics make it economic to run continuously to supply the 'base' (or minimum) load of a power grid.

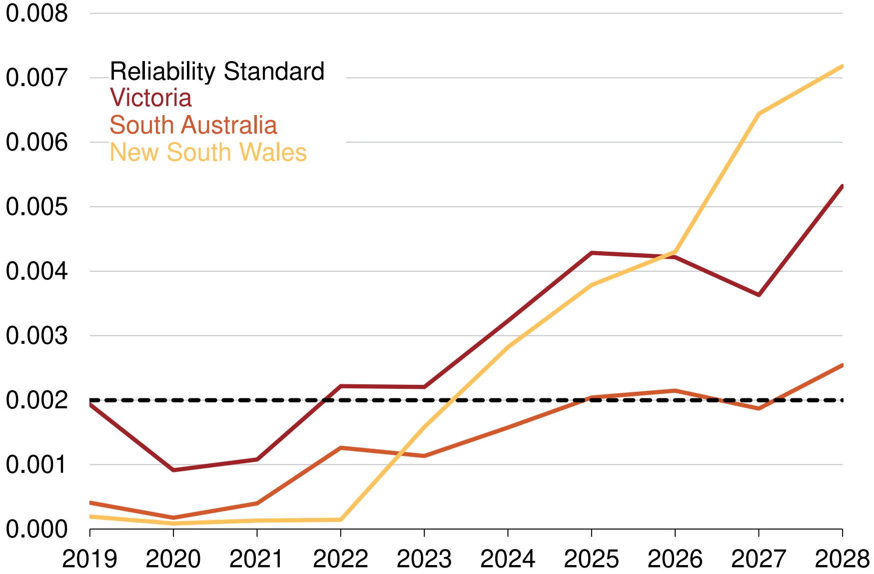
The right level of baseload generation is a question of economics, not reliability. Baseload generators, such as coal generators, are not necessarily more reliable than other dispatchable generators, such as gas and hydro generators. All suffer technical failures.

The electricity system requires dispatchable generation to be reliable, but it does not necessarily require any baseload generation. In principle, a reliable grid can combine wind and solar with sufficient flexible dispatchable generation, such as gas, hydro and batteries.

30. Finkel et al. (2017, p. 17).
31. AEMO (2018f).

Figure 2.3: Without new investment beyond existing and committed generators, there will be chronic shortfalls

Expected percentage of annual consumption not supplied, financial years

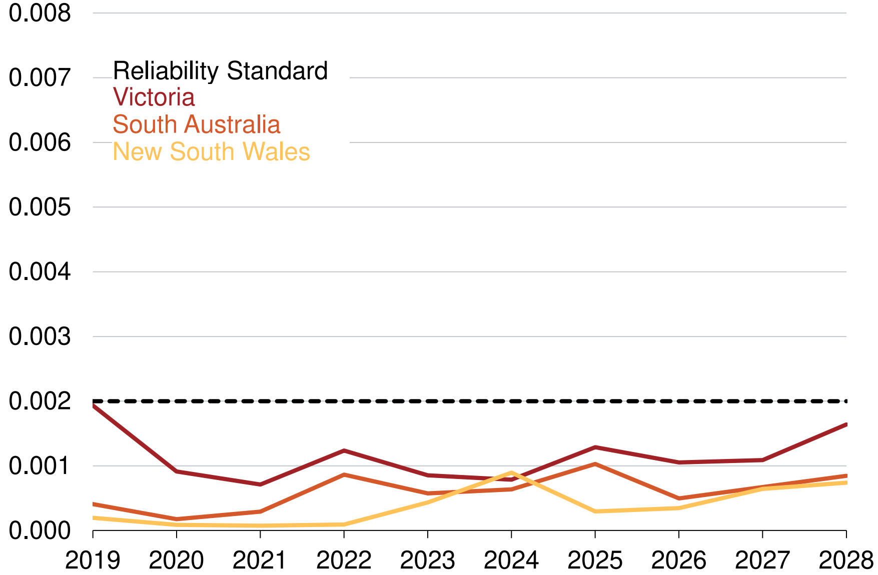


Note: Based on AEMO's Electricity Statement of Opportunities neutral scenario.

Source: AEMO (2018e).

Figure 2.4: With plausible levels of new investment, the market will remain reliable

Expected percentage of annual consumption not supplied, financial years



Note: Based on AEMO's Integrated System Plan neutral scenario, excluding Snowy 2.0 project.

Source: AEMO (ibid.).

More flexible dispatchable generators, such as gas and hydro, can turn off to avoid low prices and on to capture high prices. And dispatchable storage technologies such as pumped hydro and batteries actually benefit from increased volatility – they buy power when prices are low and sell when prices are high.

Volatility itself does not risk reliability. It just means that baseload generators are likely to be replaced with more flexible dispatchable generators, such as gas and hydro. In fact, the possibility of very high market prices at peak times is a key reason the NEM has historically delivered new investment to maintain reliability.

2.2.3 Gas market uncertainty

Historically, gas-fired 'peaking' power stations have been a common investment to help meet peak demand. But the gas market is changing rapidly in response to gas exports from Queensland. Prices have increased substantially and long-term contracting is difficult. Immature gas spot markets compound these difficulties. If investors cannot manage the risks of the evolving gas market sufficiently to invest in gas generation, reliability could be compromised (although demand response and other types of generation would still be available to prevent shortfalls).

Despite the challenges, integrated players with a portfolio of gas resources and contracts are likely to be able to invest. The 'big three' integrated generation and retail companies are all currently planning new gas-fired generation, although it is not yet confirmed if these projects will proceed.[32]

32. AGL plans to replace some of the generation from its retiring Liddell coal-fired power station with gas generation sited next to its Newcastle gas storage facility: AGL (2018a). Origin Energy has approval to expand its gas-fired Quarantine power station in SA by up to 180 MW: Knoll (2018). EnergyAustralia has approvals for two gas-fired power stations in NSW: Energy Australia (2018).

2.2.4 Climate policy uncertainty

Climate policy has been unstable in Australia for more than a decade. A nation-wide carbon price was introduced and then repealed. Other policies have been proposed and abandoned, such as the Finkel Review's Clean Energy Target and the Energy Security Board's National Energy Guarantee. State governments have partially filled this national policy vacuum with an uncoordinated set of renewable energy and emissions reduction targets, few of which enjoy bipartisan support.

A stable climate policy framework is important for both existing and potential new generators. Potential investors try to anticipate their competitors' investment and retirement decisions. For example, investments in gas peaking generation, pumped hydro or other dispatchable generation technologies depend on the rate of investment in wind and solar and the timing of major coal retirements – both of which are affected by climate policy.

This uncertainty is not insurmountable – as noted above, the big three integrated energy companies are each considering new gas power stations – but it does increase the risk that investors will not respond to market signals. Between 2005 and 2009, investors committed to significant new gas generation despite the fact that climate policy was evolving and as uncertain as it is now. We may not be so lucky this time.

2.2.5 Climate change will cause more extreme heatwaves

Climate change is increasing average temperatures in Australia, and with it the severity and frequency of extreme hot temperatures.[33] If extremely high electricity demand and generation failures coincide, there could be very large generation shortfalls.[34]

33. BoM and CSIRO (2018).
34. AEMO (2018g).

With time and perfect foresight, investment can respond to growing peak demand. In this case rising temperatures will primarily affect prices rather than reliability. But we don't have perfect foresight and so it is likely that climate change will increase the risk of generation shortfalls.

2.3 What governments should do to reduce generation shortfalls

Historically, the NEM has maintained reliability and delivered new investment when required. The level of generation shortfalls has been very low, even on hot days where supply is most stretched.

But this analysis does not imply that policy makers should be complacent. The market is tight, and likely to remain so as old coal generators are retired and heatwaves become more severe. The rapidly changing gas market makes the present environment challenging for investors.

Reform is needed to manage the future risk of generation shortfalls.

2.3.1 Provide a stable market platform that addresses emissions

Uncertainty over climate change policy has complicated investment decisions in Australia. In 2017 the Grattan Institute highlighted the need for a stable policy framework within which investors can commit to new generation.[35] Unfortunately, little has changed since.

An explicit carbon price would be ideal, but political realities dictate that a 'second-best' solution is needed. This could take the form of an emissions intensity scheme, the Clean Energy Target proposed by the Finkel Review,[36] or the National Energy Guarantee previously considered by the COAG Energy Council[37] and recently advocated by the NSW Government.[38]

35. Wood et al. (2017a).
36. Finkel et al. (2017).
37. ESB (2018b).
38. Nguyen et al. (2018).

The COAG Energy Council should implement a stable and clear emissions policy. This would signal to investors that the days of ad hoc interventions are over. It would provide clarity for investors in all types of generation, and so support reliability.

2.3.2 Place a reliability obligation on retailers

The COAG Energy Council is developing a retailer reliability obligation to support the reliability of the NEM.[39] This policy was formerly the reliability arm of the now-abandoned National Energy Guarantee, which addressed both reliability and emissions reductions. Under the proposed reliability obligation, AEMO would forecast the market's requirement for dispatchable generation into the future. In the event that this process identified a shortfall three years away, retailers and large customers would be required to hold contracts for dispatchable generation or demand response to meet their share of expected peak demand.

If the market overall remained short of supply one year out, AEMO would act as the 'procurer of last resort' and secure reserves through the RERT (as described in Box 5 on page 16). But unlike the existing RERT mechanism, AEMO's expenditure would be paid for by retailers that failed to comply with their reliability obligation, rather than by consumers at large.[40]

Such a mechanism directly targets reliability, but gives retailers flexibility to achieve this in the most cost-effective way.[41] It gives regulators and governments extra surety that potential shortfalls are identified three years out, and that energy companies will respond. And by making the entities that increase the risk of shortfalls pay for back-up

39. COAG Energy Council (2018).
40. ESB (2018b).
41. Wood et al. (2017b).

reserves, rather than putting the cost on customers at large, it sharpens the NEM's existing reliability incentives.

Governments should continue to implement the retailer reliability obligation. It will reinforce the inherent commercial incentives of the market that support reliability, without disrupting the existing market structure and contracting practices.

2.3.3 Use short-term back-up reserves when cost-effective

Investors have responded to expected generation shortfalls in the past, and are likely to do so again in a clear policy environment. But it is difficult for investors to respond to unexpected shortfalls. They are unlikely to anticipate and build ahead of a sudden closure of a large coal plant, as occurred in the case of Hazelwood (Box 7).

The AEMC recently ruled that generators must give at least three years' notice before closing.[42] This reduces the risk of sudden and unexpected closures increasing prices and reducing reliability. But it does not eliminate it. The AEMC allows the AER to provide exemptions, recognising that generators may be forced to close for reasons beyond their control, such as a major technical failure.[43] This is appropriate, given that the cost of refurbishing an old generator that has suffered a major failure would almost certainly not be justified.

The main measure currently available to manage the risk of sudden changes in the supply-demand balance is the RERT. Hazelwood's sudden closure made the market tight, and investors had little time to respond. AEMO has used the RERT to manage the risk of shortfalls in the two summers since, and this action reduced the amount of load shedding necessary in Victoria and avoided the need for load shedding in SA in January 2019.

42. AEMC (2018a).
43. Ibid. (p. 7).

Box 7: The retirement of Hazelwood

In November 2016 Engie and Mitsui announced that they would close Hazelwood, a 1600 MW brown coal generator in Victoria's Latrobe Valley, in March 2017. Engie said it was not viable to spend hundreds of millions of dollars required to enable the plant to keep operating safely.[a]

Because Hazelwood closed with less than six months' notice, other investors had no time to respond with new capacity. This contributed to a large jump in wholesale market prices in Victoria. The average price for the three months after the closure (April to June 2017) was more than 60 per cent higher than for the same months in 2016.[b] Although some of this increase was probably due to increases in fuel costs.[c]

a. Engie (2016).
b. Grattan analysis of AEMO (2019c).
c. Wood et al. (2018c).

There is a strong case for AEMO to have access to back-up reserves under some circumstances. A mechanism that can procure reserves at a cost less than the value of increased reliability to customers, but higher than what those reserves would earn in the market, will cost-effectively improve reliability.

This must be balanced against the risk that providers of back-up reserves will draw resources out of the general market, seeking more generous payments from AEMO, which would undermine the market's incentives for reliability and shift risk to consumers. For example, the AER has expressed concerns that the RERT may crowd out market-driven demand response.[44]

44. AER (2018d, p. vi).

Back-up reserves can be very expensive. For the summer of 2017-18, AEMO spent about $51 million to guard against expected shortfalls of almost 1 gigawatt-hour. This cost is fairly modest in aggregate, at about $6 per household,[45] but it is high per unit of expected consumption not supplied, at about $57,000 per megawatt-hour.[46] This is more than 60 per cent higher than AEMO's estimate of the value of customer reliability,[47] and four times the market price cap in that year. RERT costs and usage for the 2018-19 summer are not yet known.

The AEMC is considering a rule change proposed by AEMO to 'enhance' the RERT.[48] The market operator wants a longer lead-time to procure reserves (one year rather than the present nine months), and an option to procure reserves for three consecutive years at a time. And it has requested more flexibility on when to use the RERT and how much reserve to purchase – this would be based on a broad risk assessment, rather than by reference to the reliability standard. As part of the rule change, the AEMC has also proposed options that would reduce AEMO's discretion on when it can use the RERT, and how much reserve it can purchase.

An appropriate balance would allow AEMO to procure reserves when they will benefit consumers, but would not cause the RERT to draw resources out of the market. Given more discretion, AEMO is likely to err on the side of caution and procure more reserves. And the possibility of earning prices higher than the market price cap may cause reserve providers to avoid the market and focus on the RERT.

45. AEMO (2018c, p. 32).
46. Grattan analysis based on AEMO (ibid.) and AEMO (2018e). Skinner (2018) estimated the cost of activating the RERT in 2017-18 at $62,000 using a slightly different methodology.
47. $33,460/ megawatt hour (MWh) in 2014 dollars (AEMO (2014b, p. 5)), or about $35,400/MWh in 2017-18 dollars.
48. AEMC (2018b).

The balance between these risks varies depending on the amount of time between when reserves are procured and when they will be needed. Reserves procured six or more months out carry the greatest risk of drawing reserves from the market. AEMO should be able to procure these reserves only when the reliability standard is expected to be breached. But greater flexibility is appropriate for reserves procured weeks or days out from a potential shortfall. AEMO should be able to procure these without explicit reference to the reliability standard, but it should also ensure value for money by only paying when the reserves are actually used, and capping the price at the value of customer reliability.

2.3.4 Support demand response

Demand response is often a cost-effective way to maintain reliability. There are likely to be many energy users for whom reducing power use is more attractive than paying high market prices at times of peak demand, or paying generators to protect them from those high prices. But demand response has only played a small role in the NEM to date, often as part of the RERT rather than the normal operation of the market. Contracts typically shield users from the true cost of their power use at peak times, so demand response only works when electricity retailers share the benefits with users. This appears to happen only rarely.

The AEMC is considering a rule change to unlock more demand response.[49] It is considering mechanisms that would allow users and third-party aggregators to capture the benefits of demand response independently of retailers.

Though it will take time for demand response to mature and become widespread, the proposed rule change is a step in the right direction. It, and broader efforts by users, aggregators and retailers to identify

49. AEMC (2018c).

opportunities for demand response, will reduce the costs of maintaining reliability into the future.

2.3.5 Transmission between NEM regions can play a supporting role

Transmission plays an important role in preventing generation shortfalls. If two regions experience peak demand at different times, transmission can allow them to share capacity, boosting reliability and reducing costs.

AEMO's Integrated System Plan sets out potential transmission investments to connect new renewable generation and share power efficiently across the NEM. It foreshadows potential transmission upgrades, which are then evaluated and progressed by transmission network businesses under the scrutiny of the AER. These processes, though slow, can contribute to the future reliability of the NEM, and should remain a focus.

But more transmission is unlikely to dramatically improve reliability. If transmission lines bring cheap power into a region at peak times they will depress price. Over time that will either cause existing generators to retire, or delay investment in new generation. And if a reliability problem already exists, generation or demand response will generally be able to address the issue more quickly than transmission, which takes a long time to develop.

Transmission lines can help, but reliability ultimately requires flexible power stations that are ready to run for a few key hours each year, or users willing to reduce their demand at those times.

2.4 What governments should not do

Investment supported by stable emissions policy, the retailer reliability obligation and sound transmission planning are key to long-term reliability. These measures will be sufficient to manage expected risks to reliability for the foreseeable future. Other proposed reforms are likely to prove costly or counterproductive. Several possible reforms that governments should not implement are discussed below.

2.4.1 Implement a centralised capacity market

The NEM is an 'energy only' market. This means that generators are paid for energy delivered, but not for making capacity available which may or may not be used. This contrasts with centralised 'capacity markets', where a regulator determines a capacity requirement and then allows generators and demand response providers to bid to supply that capacity. Such capacity markets are used around the world, including Western Australia, Great Britain, Ireland and the north-eastern United States.[50]

Such centrally planned capacity markets can increase reliability if the market operator sets a high capacity requirement. But this reliability comes at a cost, in the form of significant capital expenditure on generators that are rarely, if ever, used. Western Australia's capacity market adds about $100 million per year to the cost of supply, and in the US capacity markets generally have higher costs than energy-only markets.[51]

A capacity market could reduce the risk of unexpected closures. Generators that were at risk of closure would be less willing to offer capacity to the market operator, signalling the possibility of closure to potential investors. But a generator with a capacity contract could still suffer a major failure, causing it to close unexpectedly.

50. The PJM grid serving part or all of 13 states in the eastern United States plus the District of Columbia.
51. The pattern is clear and persistent, but market structure is not the only driver of system costs: Wood et al. (2017b, pp. 36–37).

The Finkel Review did not recommend a centralised capacity market for the NEM,[52] but it recognised views for and against. It described an international view that capacity markets are politically necessary, because politicians are unwilling to wait for prices to increase to a level necessary to motivate new investment, and so would intervene in the market.[53]

Politicians should stay calm and resist the temptation of large, but risky, reforms. Redesigning the structure of the NEM in the middle of a period of rapid technology-led change would create a new source of uncertainty for investors. It would be a disproportionate response to a manageable problem. These risks, and the high cost of a capacity market, mean it should only be implemented in the NEM if other reforms have been tried and found wanting, and significant risks of generation shortfalls remain.[54] With the retailer reliability obligation still under development, and generation shortfalls far from chronic, it is clear that these conditions have not been met.

2.4.2 Place a reliability obligation on new generators

The Finkel Review proposed a 'generator reliability obligation' on new wind and solar generators.[55] These generators would need to include some dispatchable generation to 'firm' their variable output. The amount of firming would be determined based on a general assessment of regional capacity requirements and the size of the project.

But reliability is a function of the overall market and the balance between supply and demand, not just the actions of new entrant generators. Unlike a retailer reliability obligation, which obliges all major retailers and customers to contribute to reliability in proportion to their demand for electricity at peak times, a generator reliability obligation focuses only on investors in new wind and solar power. For example, it ignores the impact on reliability of other generators withdrawing capacity. It would blur, rather than reinforce, the commercial incentives for reliability built into the market, which has allowed the NEM to successfully deliver new capacity when required.

2.4.3 Underwrite or sponsor new generation

Governments should not underwrite or sponsor investment in new generation capacity, or to extend the life of existing generators, on the grounds of reliability. Government-subsidised capacity is likely to displace private investment, potentially harming rather than helping reliability.

Various governments and oppositions in Australia have proposed such interventions. Examples include the Federal Government's proposal to underwrite new generation, the Federal Government's development of the 'Snowy 2.0' pumped hydro project,[56] the SA Government's investment in temporary diesel generation,[57] the former SA Government's proposal to build and own a permanent gas-fired generator,the Queensland Government's proposed renewable investments through a new 'CleanCo',[58][59] and the Victorian Opposition's policy to contract for new supply.[60]

52. Finkel et al. (2017, p. 85).
53. Ibid. (p. 84).
54. Wood et al. (2017b, p. 37).
55. Finkel et al. (2017, p. 23).

56. While the project is notionally a commercial project undertaken by a private company, Snowy Hydro, the fact that Snowy Hydro is wholly-owned by the Federal Government and that the project has been promoted as a government initiative suggests that this project is effectively government-driven: Turnbull (2017).
57. Livesey (2018).
58. Queensland Government (2019).
59. Livesey (2018).
60. Guy and Southwick (2018).

But these projects could compromise reliability by spooking genuine commercial investors. If government-supported projects displace private investment, they won't improve reliability. For example, the former SA Government justified its plan to build and own a gas-fired generator or the grounds that 'the private sector is not building new generation'.[61] But AGL Energy argued this could cause them to cancel their own plans for a new generator.[62] Since then, the SA Government has abandoned its plan to build and own a permanent gas-fired generators, and AGL has committed to build the new Barkers Inlet power station.[63]

Government-sponsored projects are also often not tailored to the needs of the market. For example, Snowy 2.0 will provide significant new capacity, but won't arrive until after the closure of the Liddell power station in 2022 and indeed after the summer of 2023-24, when AEMO forecasts shortfalls could arise. So the prospect of Snowy 2.0 could harm, rather than help, reliability in the intervening period.

Government interventions can be very expensive. The SA Government spent $111 million to lease 276 MW of diesel generation for two years.[64] This generation was used for about four hours on 24 January 2019 and avoided load-shedding – but the cost to taxpayers was equivalent to more than $100 per SA household. It is unlikely that SA taxpayers would consider this insurance worth the cost.

2.4.4 Require permanent back-up reserves

The RERT is used when the near-term risk of shortfalls is high. An alternative approach would be to maintain back-up reserves at all times.

61. Chang (2017).
62. Macdonald-Smith (2017).
63. AGL (2018b).
64. The SA Government spent a further $227 million to purchase the generators at the end of the lease period, and will incur significant further operating and relocation costs: Livesey (2018).

For example, California requires retailers to maintain a permanent 15 per cent reserve above their forecast capacity requirements.[65] In Australia, AEMO has proposed turning the RERT into a permanent 'standing reserve'.[66] Another approach would be to implement a centralised capacity market with a significant reserve above what is forecast to be required.

Any approach that maintains permanent reserves above what is required will improve reliability, but at a potentially significant cost.

65. Wood et al. (2017b, p. 42).
66. AEMO (2018g, p. 3).

3 Keeping the grid resilient to shocks

The electricity grid, particularly large generators and the transmission lines that connect them, can be destabilised by natural disasters and equipment failures. Such shocks cause about 2.2 per cent of all customer outages (Figure 1.3 on page 10), but can be dramatic when they occur, as highlighted by the SA blackout in September 2016. This chapter highlights the significant progress made since then to make SA's grid stable and more resilient to shocks.

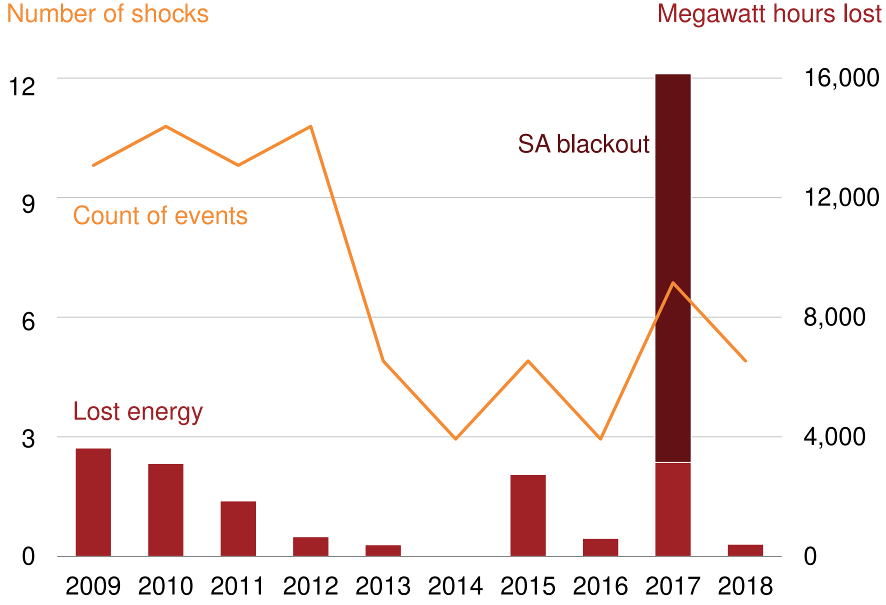
The SA blackout shocked Australia's energy market authorities into action. Their hard work since means that technologies and techniques needed to manage a grid with more wind and solar are now being deployed in SA, and they will be ready to apply across the NEM in future. Governments should not see the risk of power outages as a barrier to achieving ambitious emissions reductions in Australia's electricity sector.

3.1 Is the grid vulnerable to shocks today?

Shocks to the grid regularly cause some customers to lose load (Figure 3.1). There have been 70 instances of load shedding in the NEM in response to sudden shocks to the high voltage grid (generators and transmission lines) over the decade to June 2018.[67] Forty-five were caused by failures of network equipment. Twenty-three were caused by natural events such as lightning strikes, bushfires, storms and, on one occasion, an earthquake. Only two were triggered by issues with generators, one of which was the SA blackout.[68]

67. This excludes load shedding due to generation shortfalls, which were covered in Chapter 2.
68. As explained in Chapter 1, we have classified the blackout as resulting from a generator failure because the unexpected loss of nine wind farms was crucial to the subsequent trip of the Heywood interconnector. The other shock caused by a generation failure in the past decade was the failure of all four units at the Colongra gas power station in NSW on 10 February 2017 due to a lack of gas pressure in its pipeline: AEMO (2017c).

Figure 3.1: Shocks regularly cause customers to lose load, but the SA blackout was unusually large



Note: NEM events only.

Sources: Grattan analysis based on unpublished AEMC analysis, AEMO incident reports and AEMC Reliability Panel (2010).

Shocks occur across the NEM and are not specific to any one region. Twenty of the grid shocks originated in Queensland, 17 in NSW, 14 in Tasmania, 12 in Victoria and seven in SA (for details, see Appendix A).

Events of this kind rarely occur on the scale of the SA blackout, which was by far the largest such event of the past decade. Such a widespread loss of power must be prevented by quickly stabilising the grid after a shock. Generators are designed to disconnect from the grid ('trip') if frequency or voltage goes outside safe operating levels. And transmission lines will disconnect if they are suddenly over-loaded to compensate for the loss of other equipment. If the initial shock causes other equipment to trip, it can quickly 'cascade' and become a much larger problem.

3.1.1 How AEMO guards against sudden shocks

The loss of a generator or transmission line will cause a rapid change in the grid's frequency. The loss of a generator (or its connecting transmission line) will cause a sudden fall in frequency, and the loss of a transmission line supplying customers will cause a sudden rise in frequency.

Australian grid frequency is 50 hertz (Hz) – 50 cycles per second. Generators are designed to trip off in response to very low or very high frequencies – generally below 47 Hz or above 52 Hz – to protect themselves from damage.[69]

If AEMO cannot stop frequency from falling below 47 Hz or rising above 52 Hz, it risks a widespread blackout. It procures enough 'frequency control ancillary services' (FCAS) to keep frequency within acceptable bands after a range of potential shocks, and to manage frequency more generally (Box 8). But for very large shocks FCAS will not be sufficient and rapid load shedding is required to stabilise the grid.

A property of the grid called 'inertia' plays a crucial role in slowing the rate at which frequency changes after a shock. Inertia is provided only by 'synchronous generators' – those that spin at grid frequency. It is not provided by wind and solar generators, which are 'asynchronous'. Box 9 explains this distinction.

69. AEMC Reliability Panel (2017).

Box 8: Managing grid frequency

If a shock occurs and frequency moves outside the normal operating band of 49.85 to 50.15 Hz, AEMO uses 'contingency' frequency control ancillary services' (FCAS) to limit the effect of the shock.

If frequency falls, AEMO uses 'raise' contingency services to increase it. This normally involves generators increasing output to rebalance the system. If frequency increases, AEMO uses 'lower' contingency services to reduce it, normally by requiring generators to reduce output.

In the past the grid has had lots of synchronous generation and AEMO has not needed to actively manage the level of inertia on the system. But in recent years asynchronous generation has displaced synchronous generation, reducing inertia. This has happened especially quickly in SA. This increases the risk that a small shock will lead to a big blackout.

Another property of the grid, known as 'system strength', helps to prevent some shocks from becoming widespread. System strength refers to how robust voltage is to a shock. Voltage can fall rapidly if lines clash with one another or become electrically connected to the ground,[70] because current flows through the fault (a short circuit) rather than to customers. The rapid flow of current to a fault is called 'fault current', and is used to detect faults and trigger protection mechanisms.

A strong system generates high levels of fault current, which reduces the effect of a fault on the voltage in its vicinity. As low voltages can

70. This is most commonly caused by lightning or wind, or when when transmission towers are damaged and fall.

cause generators to trip, this reduces the number of generators that might disconnect in response to the fault, and so the risk of load shedding. A strong system also makes it more likely that protection systems will correctly isolate faults, reducing the duration and extent of voltage dips.

Synchronous generators support system strength better than asynchronous generators, because they produce large volumes of fault current. Increasing levels of asynchronous generation has reduced system strength, particularly in SA.

3.1.2 What caused the SA blackout?

The SA blackout started as a weather event, but the widespread loss of load would not have occurred without multiple wind farms unexpectedly tripping, destabilising the system and overloading the Heywood interconnector. But trips are not unique to wind farms. Synchronous dispatchable generators can also trip and destabilise the grid. For example, the simultaneous trips of both units of the coal-fired Northern power station caused the Heywood interconnector to disconnect in December 1999, March 2004 and March 2005.[71] In each case many customers lost power.

But even though the amount of generation tripped was greater than in the case of the SA blackout, none of these disconnections caused a state-wide blackout. The key difference was the low level of inertia provided by SA generators in the 2016 event.[72] This meant frequency fell too rapidly for emergency load shedding to be triggered, and so the SA grid could not be balanced.

The lesson from the SA blackout is that the SA grid needs to be managed in a way that either prevents Heywood from disconnecting, or

Box 9: Synchronous generation provides inertia, but asynchronous generation does not

Synchronous generators spin at a rate synchronised to the system frequency. The most common types in Australia are coal, gas and hydro generators. These generators involve a large turbine that is propelled by hot steam, hot exhaust gases or water.

Once spinning, a synchronous generator's turbine will tend to keep spinning. This inertia acts as a store of kinetic energy, and means that a synchronous generator will slow the rate at which grid frequency changes. If frequency falls, the turbine will release some kinetic energy. If frequency increases, the turbine will absorb additional kinetic energy. Both of these effects cause frequency to change more slowly in response to a shock.

Wind and solar generators are asynchronous because they do not involve equipment that spins at system frequency (wind turbines spin at a rate determined by wind speed rather than grid frequency). Wind and solar generators do not naturally absorb or release energy in response to a change in grid frequency, and therefore do not inherently slow the rate at which system frequency changes. They can be engineered to mimic the properties of synchronous generators – sometimes called 'synthetic inertia' – but these techniques are not yet widely used and, in any case, cannot fully replace physical inertia.

71. AEMO (2017a).
72. Ibid. (p. 55).

that ensures there is sufficient inertia to allow time for emergency load shedding. And system strength needs to be high enough to reduce the risk of widespread generator trips.

3.1.3 What has been done since the SA blackout?

The SA Government reacted quickly to the blackout, requiring AEMO to restrict flow over the Heywood interconnector.[73] Reducing SA's dependence on power from Victoria makes it easier for SA to maintain stable power supply after any sudden loss of Heywood.

But restricting flow from Heywood also makes it harder for SA to access cheap power from Victoria. During 2017 and 2018 AEMO and ElectraNet, the SA transmission network operator, developed a scheme to reduce the risk of the Heywood interconnector disconnecting as it did during the SA blackout, but without restricting flows. If a large volume of generation trips in SA, this scheme will trigger the rapid injection of power by a large battery connected to the grid. If that is insufficient, the scheme can also trigger rapid load shedding.[74]

AEMO has also taken steps to increase SA's system strength. Since November 2016 AEMO has curtailed wind generation in SA at times to maintain sufficient local synchronous generation.

The AEMC has also made rules providing AEMO with new tools to keep the grid resilient to shocks.[75] Since September 2017 AEMO is required to assess the minimum levels of fault current and inertia in each part of the grid so as to maintain resilience to shocks.

If AEMO finds a shortfall in either fault current or inertia it can direct the relevant transmission network operator to procure the required services. In June 2018 AEMO found a system strength shortfall in SA, and used the new rules to require ElectraNet to fix the problem.[76] In December 2018 AEMO found an inertia shortfall for SA and called on ElectraNet to fix it.[77]

3.2 Could shocks become a problem in the future?

If no action is taken, an increase in the share of asynchronous generation would make the grid less resilient to shocks. Less synchronous generation means less inertia, making it harder to keep the grid within an acceptable frequency band in the event of sudden loss of supply or demand. Similarly, it would reduce system strength, increasing the risk that grid faults will cause generator trips and load shedding.

The share of asynchronous generation on the NEM will increase over the coming decades. The cost of wind and solar generation has fallen dramatically, leading to strong investment in these generators. Government policies, including the national Renewable Energy Target, and Victorian and Queensland renewable targets, further support this investment. Even in the absence of emissions reduction policies, renewable investment will continue because wind and solar cost less than the prices they can earn in the wholesale market. And low costs, government subsidies and high retail prices are likely to see households and businesses continue to take-up rooftop solar in large amounts. AEMO's Integrated System Plan forecasts a strongly growing share of wind and solar (large-scale and rooftop) generation, increasing from about 16 per cent today to 40 per cent by 2030 (Figure 3.2 on the next page).

The growth of small asynchronous generation, such as rooftop solar, creates particular challenges. Grid-scale asynchronous generation can be curtailed by the market operator to manage system strength

73. This was initially done through a Ministerial direction: AEMO (2016b). The SA Government subsequently formalised the requirement through a regulation under the *Electricity Act 1996 (SA)*: AEMO (ibid.).
74. ElectraNet (2017); and ElectraNet (2018a).
75. AEMC (2017b).
76. AEMO (2018h, p. 4).
77. AEMO (2018i, p. 5).

and inertia, but small-scale generators cannot. And while rooftop photovoltaic solar systems can adjust their output in response to a disturbance to frequency and so help stabilise the grid, they do not always perform according to required standards.[78]

3.3 Options to address the problem

Increased asynchronous generation creates new challenges for grid management. But what the public debate since the SA blackout has not recognised is that a range of measures are available to address these challenges. Far from representing a canary in the coal mine, SA provides a template for other parts of the NEM with increasing renewable generation, such as Victoria and Queensland.

In the past synchronous generators provided inertia and system strength for free. In the future we may need to pay for these services explicitly through regulated network investments or markets for new ancillary services. But the tools are available, and the price is likely to be worth paying to keep the grid stable.

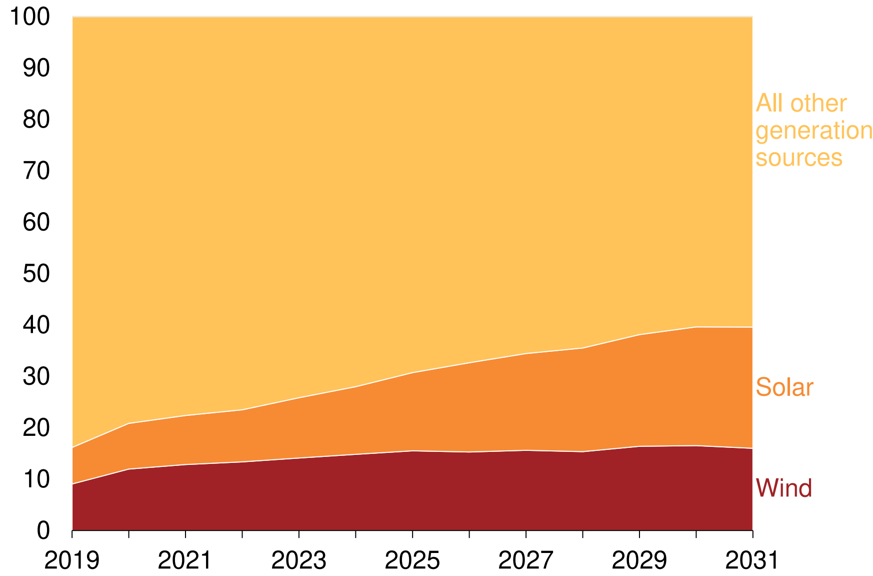
3.3.1 Limiting the output of asynchronous generators

When it is windy or sunny, asynchronous generation will tend to displace synchronous generation, reducing system strength and inertia. This is particularly difficult to manage when demand is low.

The market rules allow AEMO to curtail large-scale wind and solar output if necessary to keep the grid stable. As discussed above, since November 2016 AEMO has targeted a minimum level of synchronous generation in SA at all times.

78. For example, about 15 per cent of rooftop solar systems in Queensland and 30 per cent in SA did not respond to a grid shock on 25 August 2018 in a manner consistent with the required Australian standard, (AEMO (2019d)). In response the Clean Energy Regulator is reviewing its processes for approving solar inverters: Williams (2019).

Figure 3.2: AEMO predicts increasing renewable generation
Share of NEM generation, financial years, percentage



Notes: Based on AEMO's Integrated System Plan neutral scenario. Solar includes both large-scale and rooftop solar.

Source: Grattan analysis of AEMO (2018j).

This requirement costs money because it results in more expensive gas generation running instead of zero marginal cost wind generation. ElectraNet estimates the cost at about $50 million to $70 million per year.[79] But given that the SA blackout cost customers about $400 million,[80] the cost of this requirement may well be justified, at least as an interim measure.

3.3.2 Synchronous condensers

Machines called 'synchronous condensers' (Box 10) can also provide system strength and inertia. Synchronous condensers do not generate electricity, and so they complement, rather than compete with, asynchronous generators.

ElectraNet is currently procuring synchronous condensers to address the SA system strength shortfall identified by AEMO.[81] This will be cheaper than AEMO's current approach of constraining wind generation and requiring gas to run instead. ElectraNet estimates that it will cost between $80 million and $140 million to purchase enough synchronous condensers to meet AEMO's requirements,[82] or about $5 million to $8 million per year[83] – far less than the cost of AEMO curtailing wind generation.

AEMO has recommended that ElectraNet consider using synchronous condensers to address the recently identified inertia shortfall in SA.[84]

79. ElectraNet (2018a, p. 87).
80. Parliament of South Australia (2017).
81. ElectraNet (2018a).
82. Ibid. (p. 86).
83. Constant inflation adjusted price to recover the capital cost over an asset life of 25 years (GHD (2017)) while earning ElectraNet's present regulated rate of return (AER (2018e)).
84. AEMO (2018i, p. 5).

Box 10: Synchronous condensers

Like a synchronous generator, a synchronous condenser has a heavy metal rotor that spins at grid frequency. Both will release energy if grid frequency drops, or absorb it if grid frequency increases. In other words, both provide inertia to the grid.

A synchronous generator spins because it is connected to a turbine driven by hot steam, hot exhaust gases or water, which allows it to send electricity into the grid. By contrast, a synchronous condenser spins by drawing power from the grid.

The physical inertia of a synchronous condenser means that, if grid frequency drops, it will release some stored kinetic energy and slow the rate of frequency decline. Conversely, if frequency increases, a synchronous condenser will draw more energy from the grid to accelerate it to the new grid frequency. By drawing energy, the synchronous condenser will cause frequency to increase more slowly.

A synchronous condenser also provides large amounts of fault current and so helps to maintain system strength.

3.3.3 Purchasing inertia and fast frequency response services

Historically, the NEM had sufficient inertia from synchronous generation, and fast frequency response technologies were not available. But because of the increase in asynchronous generation and the emergence of new technology. The AEMC has considered whether markets for inertia and fast frequency response should be established to help maintain frequency and manage shocks.[85] In February 2018 the AEMC found that a market for inertia was not justified for the

85. AEMC (2018d); and AEMC (2018e).

time being, in part because its September 2017 rule change ensures minimum levels of inertia to guard against major shocks.[86] But the AEMC believes further inertia and fast frequency response reforms are likely to be needed in coming decades.[87] Ongoing work is required to design and implement new markets and procure new services needed to efficiently manage the grid in the future.

3.3.4 Increased transmission interconnection

Transmission interconnection can help to manage the effects of frequency disturbances. Frequency is constant across a synchronised grid, so a shock will change frequency in all parts of the grid simultaneously.[88] This means that power will naturally flow to or from areas with low inertia, to keep them synchronised with the rest of the grid. Provided this flow does not overload the transmission connection, it will allow parts of the grid with low inertia to 'free ride' on the inertia of others.

But there are limits to this. The SA blackout showed that a lack of local inertia can result in high power flows, disconnecting interconnectors and causing very large disturbances. And a grid-wide reduction in inertia cannot be overcome through more interconnection. A longer-term, grid-wide increase in asynchronous generation must be managed in other ways.

Similarly, transmission cannot greatly increase system strength because it is specific to each part of the power system. Generators have less effect on voltage at more distant parts of the network. More transmission cannot increase system strength than in the same way as local synchronous generation or condensers.

86. AEMC (2018e).
87. AEMC (2018d, pp. 81–82).
88. Tasmania is not synchronised with the mainland parts of the NEM, as it is connected by a direct current, rather than alternating current, interconnector.

4 Managing outages in the distribution network

Some level of distribution outages is inevitable. Equipment failures, falling trees, inquisitive animals, lightning strikes and crashing cars can all cause the power to go out (Figure 4.1). The distribution network accounts for over 97 per cent of customer outages (Figure 1.3 on page 10) and about a third of a typical household's bill,[89] so balancing reliability and cost in this part of the supply chain is crucial. This chapter outlines how network businesses and regulators tackle this task. It shows that distributed generation and new storage technologies offer opportunities to improve reliability – especially for rural customers – at reasonable cost.

4.1 Are distribution outages a problem today?

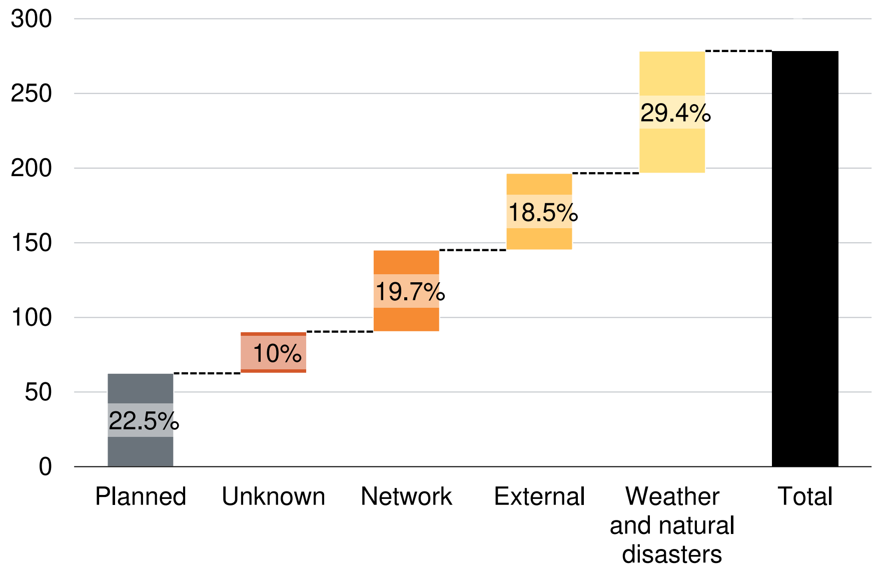
4.1.1 How the networks are performing

Australia's distribution networks are incrementally improving reliability over time. As Figure 4.2 shows, distribution outages across the NEM vary significantly from year to year, but there is no clear trend up or down. Spikes are mainly caused by natural disasters such as severe storms and bushfires. When uncontrollable events are excluded, the underlying ('normalised') level of outages declines, from about 133 minutes per customer in the six years from 2006 to 2011 to 116 minutes in the subsequent six years.[90] This pattern is true of all but two distribution networks.[91]

89. Grattan analysis based on AEMC (2018f, p. ix).
90. Grattan analysis of AER (2018f). Victorian data are for calendar years 2006 to 2011 and 2012 to 2017. Other networks' data are for the periods July 2005 to June 2011 and July 2011 to June 2017.
91. The two exceptions are CitiPower and United Energy. Both networks serve the Melbourne metropolitan area, and have very low overall outage levels. CitiPower's outages increased from 24 minutes to 27 minutes per customer over the two periods analysed. United Energy's outages increased from 59 minutes to 66 minutes per customer.

Figure 4.1: A range of largely unavoidable things cause outages in the distribution network

Average annual minutes of distribution outage per NEM customer by cause, 2009 to 2018



Notes: 'External' includes outages caused by vehicles, animals or vegetation. 'Network' includes equipment failures and overloads. Weather and natural disasters includes storms, lightning, floods, bushfires and earthquakes. There may be some inconsistency in reporting between categories, e.g. vegetation damage due to a storm.

Source: Grattan analysis of AER (2018b).

Historically, new technology has enabled networks to dramatically improve reliability over time. For example, Victoria had about 510 minutes of outages per customer in 1989-90 (including major storm events).[92] New technology and management practices in the early 1990s reduced outages to less than 300 minutes per customer in 1993-94.[93] A key source of improvement was the roll-out of auto-reclose devices that restore power automatically after transient faults, such as those caused by lightning or animal contact.[94] Since then, total outages in Victoria have reduced to about 150 minutes per customer per year[95] – a 70 per cent reduction in less than 30 years.

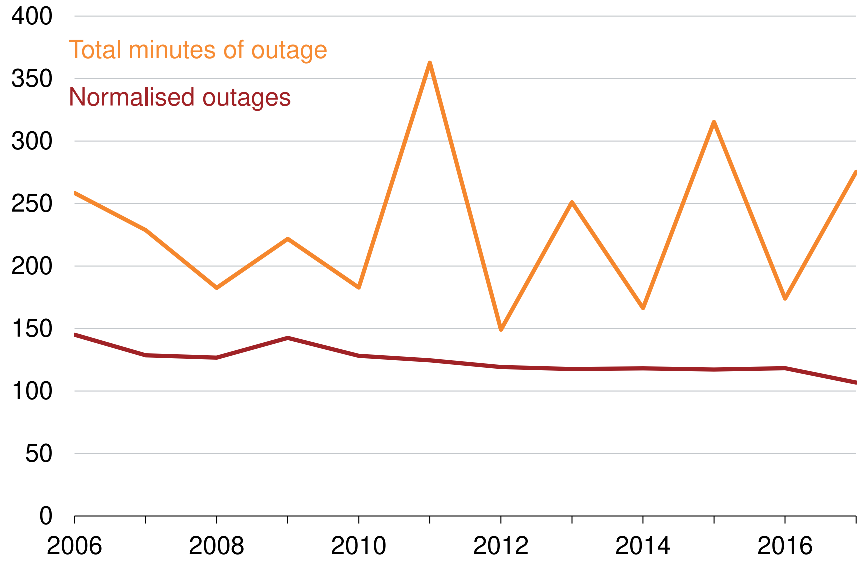
4.1.2 How the regulatory framework supports reliability

The AER typically allows the networks to make investments that are deemed necessary to safely maintain supply – it would be unacceptable to leave some customers without supply, or to continue to operate unsafe equipment. But the AER requires networks to justify discretionary investments. Ideally this is done by showing that they improve reliability enough to justify the additional cost.[96]

92. Office of the Regulator-General (1997, p. 10).
93. Ibid. (p. 10).
94. Ibid. (p. 11).
95. Grattan analysis of AER (2018b). Calculated for the six years to the end of 2017, excluding the CitiPower network. CitiPower was excluded because the 1989-90 data is for the former State Electricity Commission (SEC) supply area. The SEC's supply area excluded several municipally operated service areas in central Melbourne, which after restructuring of the industry formed a significant share of the current CitiPower supply area. Therefore the SEC is more comparable to the other four Victorian distribution areas.
96. This is not specified in the market rules, but is commonly adopted as good practice by both transmission and distribution networks, see for example AusNet Services (2018a, p. 57) and AEMO (2016c, p. 4). Networks currently use a value of customer reliability estimated by AEMO. The AER is conducting its own analysis of the value customers place on reliability. See Box 3 on page 11 and AER (2018c) for more detail.

Figure 4.2: The underlying rate of outages is declining, but natural disasters cause fluctuations year-to-year

Average minutes of outage per customer



Notes: 'Total minutes of outages' is the average minutes of unplanned outages per customer per year across the NEM. 'Normalised outages' excludes 'major event days' and upstream transmission and generation failures. The data excluding these sources is 'normalised' to control for these large, but random, events. Due to different reporting time frames, year is calendar year for Victorian data from 2006 to 2017, year is financial year for other networks' data from July 2005 to June 2017.

Source: Grattan analysis of AER (2018b).

The AER also manages the Service Target Performance Incentive Scheme (STPIS), under which networks can earn additional revenue if they improve their performance.[97] Broadly, the AER scrutinises networks' discrete investments and overall operational spending to ensure they are cost-effective, while the STPIS provides an incentive for the networks to improve reliability through refinements that don't explicitly require new spending.

In addition to the NEM-wide regulatory framework, most states and territories impose their own reliability standards on the distribution networks, with penalties for non-compliance.[98]

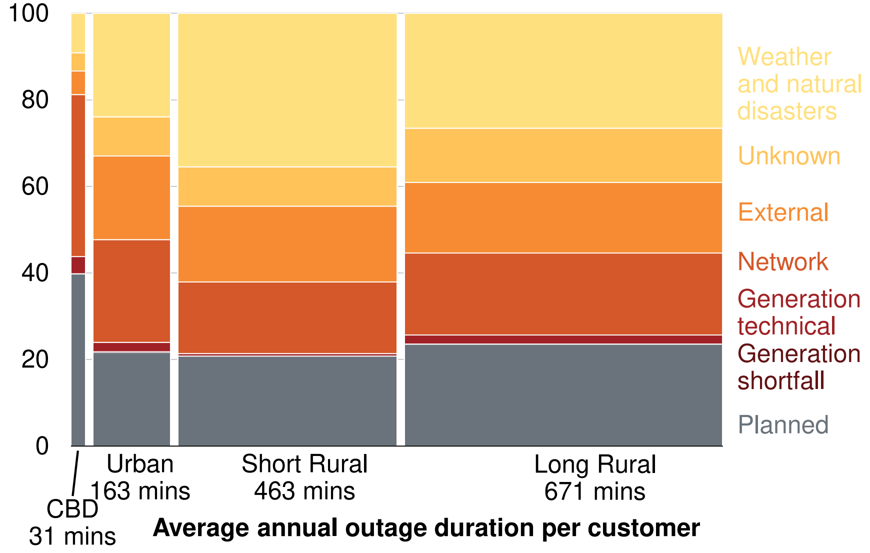
4.1.3 Where you live affects your reliability

Network reliability is improving overall, but the level of outages increases with distance from the major cities. CBD customers on average have 31 minutes without power each year, but other urban customers experience almost three hours on average. Rural customers on 'feeder' lines less than 200 kilometres long have nearly eight hours and those on feeders more than 200 kilometres long have about 11 hours without power (Figure 4.3). CBD customers are less likely to be affected by weather events and more by planned outages, but the causes of outages are similar for urban (but non-CBD) and rural customers. All types of outage increase with the distance over which power is transported.

This pattern is consistent across all NEM-connected distribution networks (Figure 4.4). The longer distances between rural customers mean that network infrastructure is more costly to maintain and more

97. National Electricity Rules, cl. 6.6.2 and AER guidelines. The STPIS creates an implicit target for each network of its performance in the previous five-year period, adjusted for improvements in reliability expected due to specific expenditure allowed in its revenue determination.
98. Victoria and the ACT allow networks to apply their own standards.

Figure 4.3: The further from the CBD, the less reliable your electricity
Outages by feeder type, 2009 to 2018, percentage



Note: Customer-weighted annual averages. 'CBD feeder' means a feeder in the CBD area of State or Territory capital that has been determined by the relevant participating jurisdiction as supplying electricity to predominantly commercial, high-rise buildings, supplied by a predominantly underground distribution network containing significant interconnection and redundancy when compared to urban areas. 'Urban feeder' is a feeder which is not a CBD feeder and has a 3-year average maximum demand over the feeder route length greater than 0.3 MVA/km. 'Short rural' feeder means a feeder with a total feeder route length less than 200 km, which is not a CBD feeder or urban feeder. 'Long rural' feeder means a feeder with a total feeder route length greater than 200 km, which is not a CBD feeder or urban feeder, AER (2018g).

Source: Grattan analysis of AER (2018b).

exposed to weather and other external disruptions than for urban customers. This in turn suggests that dramatically improving the reliability of their electricity would be very costly using conventional network approaches. But distributed generation and storage technologies may overcome the tyranny of distance, as discussed below.

4.2 Could distribution outages get worse in the future?

4.2.1 Temperature increases make the grid more prone to failures

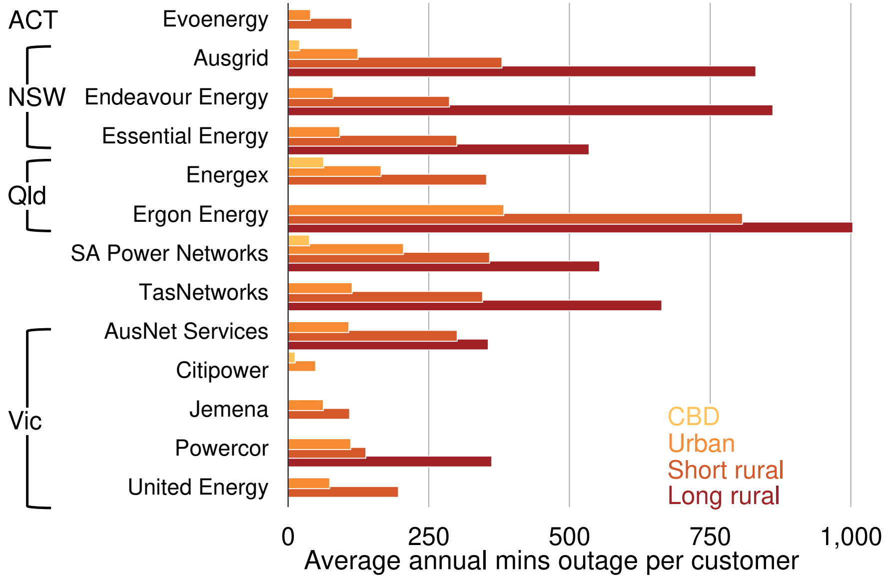
Historically, Australian networks have improved their reliability over time as technology and management techniques have improved (Figure 4.2 on page 36). But climate change will increase temperatures and place additional strain on the grid.

Distribution outages are more likely on hot days. The average rate of outage is more than 3 times higher on days over 35 degrees than on days below 35 (Figure 4.5 on the next page).

Networks are sensitive to temperature for several reasons. On hot days wires sag due to heat expansion, increasing the risk of shorting. Transformers overheat and fail, and fuses are more likely to blow. High demand and high temperatures work together to increase the risk of equipment failures. And natural disasters such as cyclones and bushfires are more common on very hot days.

It follows that climate change will harm network reliability if nothing is done. If networks continued to spend what they spend today on maintenance and investment, global warming of 1 degree would indicatively increase average outages by 26 minutes per customer per year (Figure 4.6 on the following page). By contrast, if today's network was operating in the lower temperatures of the 1980s, we would expect 10 minutes fewer outages for the same network cost. Additional network investment would limit the increase in outages

Figure 4.4: Where you live affects your reliability
Distribution network by feeder type, 2009 to 2018

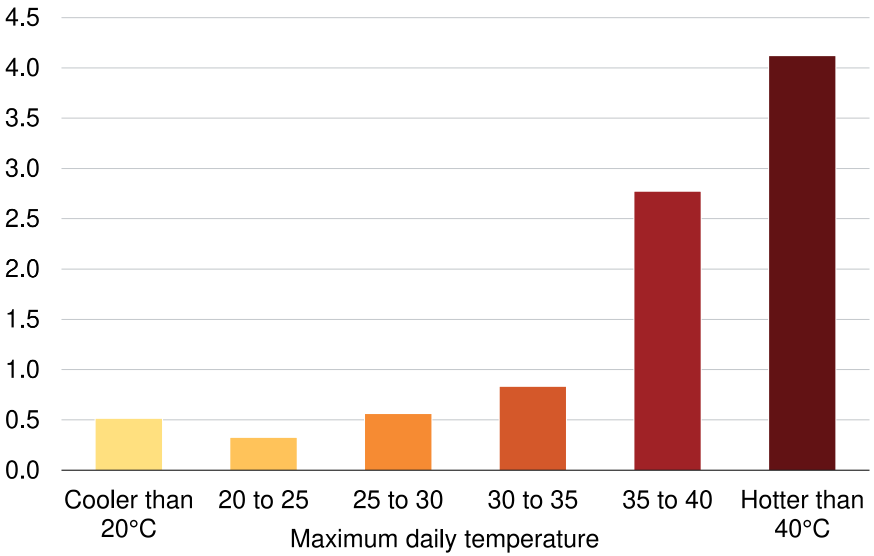


Note: Customer-weighted annual averages.

Source: Grattan analysis of AER (2018b).

Figure 4.5: Networks are highly sensitive to temperature

Average daily minutes of outage per customer, 2009 to 2018

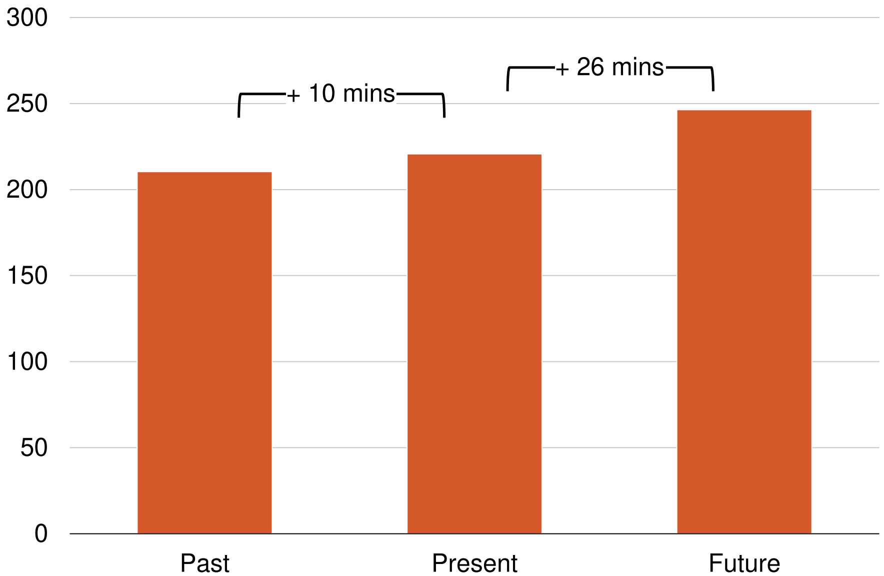


Notes: BoM maximum daily temperature data sourced for a single location per DNSP. Estimates are conservative as larger DNSP areas are likely to have more varied weather across their network on any given day. Weather station data were sourced for Canberra Airport for Evoenergy, Newcastle Nobbys Signal Station for AusGrid, Essendon Airport for CitiPower, Campbelltown (Mount Annan) for Endeavour Energy, Brisbane for Energex, Townsville Aero for Ergon Energy, Tamworth Airport for Essential Energy, Melbourne Airport for Jemena, Ballarat Aerodrome for Powercor, Adelaide Airport for SA Power Networks, Wangaratta Aero for AusNet Services, Hobart (Ellerslie Road) for TasNetworks, and Moorabbin Airport for United Energy. Weather stations were chosen based on a combination of population centres and data availability.

Sources: Grattan analysis of AER (2018b) and BoM (2018).

Figure 4.6: Rising temperatures will mean more outages in the future, unless networks spend more

Average annual minutes of outage per customer



Notes: This estimate assumes no additional investment to improve network resilience to increased temperatures. In practice it is likely that increased network investment will offset part of the effect estimated here – but at a cost. Estimates calculated by mapping representative yearly temperature distributions to the average outages by temperature per customer by distribution network. The present is the typical daily temperature distribution for a year between 2008 and 2017 by DNSP. The past is the average temperature distribution in the 1980s where data is available, or the present minus one degree for each day. The future is the present temperature distribution plus one degree.

Sources: Grattan analysis of AER (2018b) and BoM (2018).

caused by hotter temperatures. Customers would likely be willing to spend a significant amount of money to avoid these additional outages – potentially as much as $450 million.[99] But even this level of expenditure may not be sufficient to avoid any worsening of reliability. And whatever the outcome, it still represents a cost to consumers – whether through higher prices, lower reliability or a combination of both.

Regulators and network businesses will need to carefully balance cost and reliability as increasing temperatures put pressure on the grid. This requires regularly updating estimates of the value of reliability to customers, and using this to determine the right level of investment in response to these pressures.

4.2.2 Distributed energy creates new challenges

The grid was not designed for two-way flow of electricity. When the grid was built, power was supplied by large power stations and then delivered to customers through the transmission and distribution networks. Now, customers are increasingly installing generation at their premises, particularly solar on household and commercial rooftops, and sending power back into the grid. This makes managing the network more complicated.

Uncontrolled distributed generation could increase voltage and make voltage control more difficult,[100] although new inverters are required to reduce output when voltage gets too high. And high levels of rooftop solar exports could exceed the capacity of transformers or other network equipment.[101]

Controlled distributed energy (sometimes known as 'virtual power plants') could also create challenges. Sudden charging or discharging in response to market price signals could overload the local network. This was seen in a small-scale virtual power plant trial in Salisbury, SA, when a number of batteries were charged simultaneously to prepare for a storm, pushing the local network to its thermal limits.[102]

4.3 Options to address the problem

It would be prohibitively expensive to prevent all outages in the distribution network. Many things that cause these outages, such as storms, fires, tree falls, animal and vehicle impacts, and equipment failures, are difficult to prevent. Trying to do so could lead to a 'gold-plated' system that provides a little more reliability but at great cost to customers.

Research by Energy Consumers Australia indicates that more customers are concerned about the price they pay for electricity than its reliability.[103] About 70 per cent of customers are happy with the reliability of their electricity, but only about 40 per cent are happy with the overall value for money.[104] This is unsurprising given that inflation-adjusted household electricity prices have increased by more than 50 per cent in a decade,[105] but outages have been broadly flat.

Simply building more poles and wires promises to be a very expensive way to improve reliability. Smarter approaches are needed. The rapidly reducing cost of distributed renewable energy and storage technologies offers new ways to improve reliability at lower cost – but the network regulatory regime must be reformed to accommodate the cost-effective application of these new approaches. And these new approaches raise difficult questions about how should pay for some network services. Smearing the cost of projects with very localised benefits across all customers may not be appropriate, and fairer ways of funding these projects may need to be found.

99. Based on current estimates of the value of customer reliability: AEMO (2014b).
100. AEMO and ENA (2018, p. 14).
101. Ibid. (p. 14).
102. Ibid. (p. 20).
103. Energy Consumers Australia (2018).
104. Ibid. (pp. 15–16).
105. ACCC (2018).

4.3.1 Repeal or reform state and territory reliability standards

The existing national regulatory regime for distribution networks, though not perfect, guides networks towards the right balance between cost and reliability. It is sufficiently flexible to adjust as technology and consumer preferences change. But state and territory reliability standards have not always found this balance. This was particularly true of standards imposed in NSW and Queensland between 2005 and 2014.[106] Past Grattan analysis estimated the value of reliability improvements to customers in these two states as between $2 billion and $4.8 billion – substantially less than the $16 billion in excess capital expenditure on distribution networks in those states.[107]

State and territory standards are rarely determined based on how much customers are willing to pay for more reliability. If implemented correctly these regimes would simply reinforce incentives already present in the national regime. Implemented incorrectly, they impose inconsistent and potentially costly requirements. They should be repealed – or at least transferred to the AER or another body operating under the national rules, as recommended by the ACCC.[108]

4.3.2 Better manage distributed energy resources

The Open Energy Networks project run by AEMO and Energy Networks Australia is investigating models for managing distributed energy resources (generation and storage installed at customer premises or in low voltage parts of the network).[109] Options include a centralised model under AEMO's control, or a two-tier model where distribution networks ensure local resources operate within network limits and manage their interaction with AEMO and the large-scale grid.

106. Wood et al. (2018b).
107. Wood et al. (2018a, p. 21).
108. ACCC (2018, p. 192).
109. AEMO and ENA (2018).

Box 11: Mini-grid case studies

Mooroolbark, Victoria: linking suburban houses

AusNet Services trialled a mini-grid in eastern Melbourne involving 14 households with solar and batteries.[a] It showed that individual houses, and the linked mini-grid, could successfully supply power independently from the grid.

Mallacoota, Victoria: reinforcing a long rural feeder

The eastern Victorian town of Mallacoota often suffers long outages because it is supplied by a long feeder that is regularly damaged by weather and vegetation. AusNet Services expects to reduce outages by about 90 per cent when it installs a battery and diesel generators at Mallacoota in 2019.[b] The project's main funding source will be additional revenue under the STPIS.[c]

Dalrymple, SA: local supply from a grid-scale generator

AGL, ElectraNet and ARENA are together trialling a grid-scale battery at Dalrymple on the Yorke Peninsula, charged from AGL's Wattle Point wind farm.

The project will benefit the grid in multiple ways, including by directly supplying customers in the event that the transmission line supplying Dalrymple fails.[d] The AER allowed ElectraNet to recover a share of the project costs. The project will not fully pay for itself and so required ARENA funding, but this approach may become economically viable as batteries become cheaper.

a. AusNet Services (2018b).
b. Utility Magazine (2018).
c. AusNet Services, personal communication with the authors, 23 November 2018.
d. ElectraNet (2018b, p. 18).

The AEMC has also implemented a rule to require a register of distributed energy resources, to help with planning for the effects of increased distributed generation.[110]

Connection standards can make it easier to manage distributed energy resources. Measures such as export or capacity limits on rooftop solar are blunt instruments, but may be necessary while more sophisticated approaches are developed. And updated standards for rooftop solar inverters should mean that future installations do not contribute to excessive voltages. Since late 2016, rooftop solar systems are required to stop producing if grid voltage is persistently high.[111] But not all systems respond as required, so performance will need to be monitored and managed. Ongoing work is required to balance the cost of managing distributed resources between those installing them and customers at large.

4.3.3 Support customers investing in back-up supply

Rather than leaving it to networks to improve reliability, customers can invest in their own back-up supply. Hospitals, high-rise office buildings and others have done this for years. But the practice is likely to become more prevalent as distributed energy and storage technologies become cheaper, potentially extending to organisations sensitive to outages such as nursing homes and shops, and even to some households.

This trend should be recognised and reflected in network investment decisions. In particular, networks should not aim to achieve a level of reliability that customers could achieve more cheaply through their own back-up supply. And calculations of the value of customer reliability used to assess network investments must reflect this.

110. AEMC (2018g).
111. See for example Energex (2017) and SAPN (2017).

4.3.4 Reinforce the grid with distributed resources

Like individual customers, groups of customers can improve the reliability of their power supply using distributed technologies. A localised 'mini-grid' combining generation and storage can guard against grid failures. Network companies are testing various forms of mini-grids (Box 11). The trials are promising, but mini-grids won't provide value-for-money for large numbers of electricity customers until battery costs fall substantially.

Because a mini-grid must interact with the main grid, it is not straightforward to work out who should pay for increased reliability. In the Mallacoota and Dalrymple case studies (Box 11) reliability will be improved for a small number of customers but a much larger group will pay for it. This approach may not be sustainable – or regarded as fair – on a larger scale.

Box 12: Western Power's stand-alone power systems trial

In 2016 Western Power began a two-year trial of stand-alone power systems for six remote farming properties near Ravensthorpe, 500km south-east of Perth.

The properties had on average 75 hours fewer outages each year than would have been expected had they not been on stand-alone power.[a] This dramatic success has prompted Western Power to expand the trial to 60 more properties in 2019.[b]

a. Western Power (2018a).
b. Western Power (2018b).

4.3.5 Use stand-alone power to supply remote customers

Improved technology means that it is now likely to be cheaper to serve many remote customers using a stand-alone power system rather than continuing to supply them from the grid.

As well as reducing costs, stand-alone power systems will improve reliability for many edge-of-grid customers. A stand-alone system is less exposed to the elements. A Western Power trial of this approach dramatically improved reliability for participating properties (Box 12). Other networks are considering similar approaches; for example, Ergon Energy is planning to trial a stand-alone 'power pod' on a remote grazing property in Queensland.[112]

Yet despite the potential cost and reliability benefits of replacing grid connections with stand-alone power systems, regulatory barriers prevent this from occurring in many cases. Specifically, distribution networks are not allowed to use stand-alone power systems as an alternative to grid-connected supply, even where it would be cheaper to do so. And customers that move to a stand-alone system today would lose protections available to grid-supplied customers.

The COAG Energy Council has asked the AEMC to review how the current regulatory framework would need to change to support the use of stand-alone power where appropriate. Issues that need to be addressed include how costs are shared between customers with stand-alone power systems and remaining grid-connected customers, and how to ensure that off-grid customers have adequate guarantees on reliability and price.[113]

The COAG Energy Council and the AEMC should accelerate these reforms, which have great potential to reduce network costs for all customers and to improve reliability for remote customers.

112. Vorrath (2018).
113. AEMC (2018h); and AEMC (2018i).

Appendix A: High-voltage events

Table A.1: Generation and transmission events that have led to loss of supply – July 2008 to June 2018

Date	Originating region	Other regions affected	Energy lost (MWh)	Cause category	Detailed cause
18/8/2008	NSW	–	57	Network	Directlink interconnector control system fault
27/11/2008	QLD	–	2	Network	Line faults
8/12/2008	QLD	–	79	Weather and natural disasters	Lightning
29/12/2008	NSW	–	24	Weather and natural disasters	Lightning
22/1/2009	QLD	–	330	Network	Line fault
29/1/2009	VIC	–	807	Generation shortfall	Generation shortfall
29/1/2009	SA	–	160	Generation shortfall	Generation shortfall
30/1/2009	VIC	–	1071	Generation shortfall	Generation shortfall
30/1/2009	SA	–	263	Generation shortfall	Generation shortfall
30/1/2009	VIC	–	2783	Network	Line trip
8/2/2009	VIC	–	252	Weather and natural disasters	Bushfires and unrelated line faults.
8/3/2009	QLD	–	75	Weather and natural disasters	Lightning
3/4/2009	VIC	–	10	Network	Line fault
9/6/2009	SA	–	13	Weather and natural disasters	Hailstorms
2/7/2009	NSW	All NEM regions	515	Network	Circuit breaker failure at Bayswater Power Station switch yard
23/7/2009	QLD	–	64	Network	Line fault

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Table A.1 – *continued from previous page*

Date	Originating region	Other regions affected	Energy lost (MWh)	Cause category	Detailed cause
8/10/2009	VIC	–	310	Network	Busbar fault
13/10/2009	QLD	–	373	Network	Busbar trip
21/11/2009	QLD	–	0	Network	Busbar trip
28/11/2009	NSW	–	1700	Weather and natural disasters	Bushfire
14/2/2010	QLD	–	11	Weather and natural disasters	Lightning
16/2/2010	QLD	–	1	Weather and natural disasters	Lightning
17/2/2010	QLD	–	1	Weather and natural disasters	Lightning
29/4/2010	TAS	–	115	Network	Busbar trip
17/6/2010	NSW	–	22	Network	Busbar trip
7/7/2010	NSW	–	636	Network	Substation fire
29/7/2010	VIC	–	30	Network	Busbar trip
26/9/2010	SA	–	15	Network	Busbar trip at Osborne Power Station
29/9/2010	QLD	–	39	Weather and natural disasters	Lightning
24/10/2010	NSW	–	277	Network	Line fault
3/1/2011	QLD	–	760	Network	Circuit breaker failure
10/1/2011	NSW	–	0	Network	Busbar fault
4/2/2011	VIC	–	2	Weather and natural disasters	Lightning
11/2/2011	SA	–	35	Weather and natural disasters	Lightning
2/5/2011	QLD	–	63	Network	Circuit breaker fault

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Table A.1 – *continued from previous page*

Date	Originating region	Other regions affected	Energy lost (MWh)	Cause category	Detailed cause
5/7/2011	NSW	–	7	Weather and natural disasters	Strong winds cause line fault
26/11/2011	TAS	–	0	Network	Busbar fault
1/12/2011	QLD	–	169	Network	Protection system fault
12/12/2011	VIC	–	292	Network	Under-frequency load shedding system fault
17/12/2011	SA	–	24	Weather and natural disasters	Lightning
28/1/2012	QLD	–	4	Weather and natural disasters	Lightning
22/3/2012	QLD	–	6	Network	Busbar trip
28/3/2012	NSW	–	30	Network	Circuit breaker failure
6/4/2012	TAS	–	38	Weather and natural disasters	Lightning causes line trip and disconnects Woolnorth wind farm
27/5/2012	NSW	–	27	Network	Protection system fault
19/6/2012	VIC	TAS, QLD, SA	67	Weather and natural disasters	Earthquake in Victoria causes generator trips in Victoria and SA. Industrial load in Tasmania is shed. Small amounts of load shed in Queensland.
5/7/2012	TAS	–	56	Network	Basslink trip due to temperature sensor
18/12/2012	NSW	–	180	Network	Circuit breaker failure
9/2/2013	QLD	–	2	Network	Unintended disconnection during maintenance
15/2/2013	SA	–	44	Network	Protection system fault

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Table A.1 – *continued from previous page*

Date	Originating region	Other regions affected	Energy lost (MWh)	Cause category	Detailed cause
21/3/2013	TAS	–	107	Weather and natural disasters	Lightning
1/10/2013	TAS	–	2	Weather and natural disasters	Lightning
15/1/2014	VIC	–	18	Weather and natural disasters	Bushfire smoke causes fault
16/1/2014	VIC	–	8	Weather and natural disasters	Bushfire smoke causes fault
10/12/2014	TAS	–	466	Network	Basslink inverter failure
11/12/2014	NSW	–	26	Weather and natural disasters	Storm debris causes Directlink interconnector trip
16/12/2014	TAS	–	335	Network	Basslink inverter failure
13/2/2015	VIC	–	1560	Network	Protection fault at Heywood interconnector
23/2/2015	TAS	–	356	Network	Basslink inverter failure
2/8/2015	TAS	–	212	Weather and natural disasters	Lightning causes line trip and disconnects Reece generator
1/11/2015	SA	–	186	Network	Protection system fault at Heywood interconnector
20/11/2015	NSW	–	207	Network	Transformer and circuit breaker fault
28/9/2016	SA	–	13,000	Generation trip/failure	Tornadoes cause line faults, which cause multiple simultaneous wind farm trips and overloads Heywood interconnector. Attributed to generation as the wind farm trips were unexpected.
1/12/2016	VIC	SA	2562	Network	Line fault in Victoria causes load shedding in SA and Victoria

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Table A.1 – *continued from previous page*

Date	Originating region	Other regions affected	Energy lost (MWh)	Cause category	Detailed cause
20/12/2016	TAS	–	28	Network	Protection system fault.
8/2/2017	SA	–	170	Generation shortfall	Generation shortfall
10/2/2017	NSW	–	334	Generation trip/failure	Failure to start of all four Colongra gas units due to low gas pipeline pressure.
12/3/2017	TAS	–	170	Network	Basslink converter cooling system failure
29/3/2017	QLD	–	48	Network	Busbar trip
3/6/2017	NSW	–	2	Network	Busbar trip
24/10/2017	QLD	–	57	Network	Busbar trip
13/11/2017	TAS	–	149	Network	Under-frequency load shedding system fault
15/2/2018	NSW	–	59	Network	Protection system fault
17/2/2018	QLD	–	143	Network	Protection system fault
28/2/2018	TAS	–	1	Network	Lightning

Notes: 28/09/2016 event estimate based on Grattan analysis of SA demand patterns in September 2016. Small events are rounded down to zero.
Sources: Grattan analysis of AEMO (2019b) and AEMC Reliability Panel (2010).

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