Chapter 2
Background

Introduction

2.1 This chapter begins with a brief outline of Australia's warming climate and the extreme weather events associated with climate change. It then looks at the implications of climate change and extreme weather events for Australia's electricity infrastructure. Australia's commitments under the Paris Climate Agreement are outlined, followed by a summary of the emissions in Australia's electricity sector. This is followed by a section on the main generation technologies currently used in Australia. The chapter then examines the National Electricity Market (NEM) and its regulatory framework, before concluding with a summary of the challenges facing the NEM as it moves towards a low and ultimately zero emissions energy future.

A warming world

2.2 Australia's climate is warming. The average air temperature has increased by around 0.9 degrees Celsius since national records began in 1910. Since the 1950s, each decade has been warmer than the preceding decade.[1]

2.3 The Australian Academy of Science explains that human activities are amplifying the 'greenhouse effect' that is causing global warming:

> Human activities are increasing greenhouse gas concentrations in the atmosphere. This increase is extremely likely to have caused most of the recent observed global warming, with CO_2 being the largest contributor. Some observed changes in Australia's climate, including warming throughout the continent and drying trends in the southwest, have been linked to rising greenhouse gas concentrations.[2]

2.4 The Australian government recognises the scientific evidence that the warming climate is predominantly due 'to the observed increases in human activities such as the burning of fossil fuels (coal, oil, and natural gas), agriculture and land clearing'.[3]

2.5 Nevertheless, during the course of the inquiry, witnesses were required to explain that the scientific academies of the world, including the United States, Britain, Germany, France, all the countries of Europe, Russia, China and India, as well as Australia, are 'clearly of the view that the link between carbon dioxide and other

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1 Australian Government, Department of Environment and Energy, *Understanding climate change*, https://www.environment.gov.au/climate-change/climate-science/understanding-climate-change (accessed 16 March 2017).

2 Australian Academy of Science, *The science of climate change: questions and answers*, 2015, p. 5, available at https://www.science.org.au/files/userfiles/learning/documents/climate-change-r.pdf (accessed 16 March 2017).

3 Australian Government, Department of Environment and Energy, *Understanding climate change.*

greenhouse gas emissions and climate is a real one, and that humans have contributed the major part of the increase in greenhouse gases in the atmosphere over recent times'.[4]

2.6 Australia's warming climate has brought an increase in the severity of extreme weather events such as flooding, fire and drought. Indeed, Australia has already experienced the effects of climate change, particularly 'increases in extreme weather including longer and more severe heatwaves, increased bushfire weather, increased intensity of extreme rainfall events'.[5]

2.7 According to the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Bureau of Meteorology, under all future emissions scenarios, Australia will experience, amongst other effects of climate change, more heat extremes, more intense extreme rainfall events, a greater proportion of high intensity storms, more extreme fire-related weather in southern and eastern Australia, and a greater frequency of extreme drought.[6]

Committee view

2.8 The overwhelming weight of scientific evidence from around the world indicates that human activities are, in large measure, driving climate change. Furthermore, the scientific evidence indicates that climate change has already caused an increase in extreme weather events in Australia and will do so to an even greater extent in the future.

2.9 That the committee feels compelled to reiterate these basic facts about the scientific evidence is a damning indictment of the dire state of political discourse on the science of climate change in this country.

Implications of climate change for electricity networks

2.10 The economic consequences of extreme weather events are already substantial, and these negative impacts and economic costs are predicted to become vastly larger as the effects of climate change intensify. The committee received evidence from a range of submitters and witnesses, including electricity network providers, that a warming world poses significant challenges to the security and resilience of Australia's electricity infrastructure.

2.11 The CSIRO set out the enormous increase in the damage wrought on critical infrastructure by the rise in extreme weather events:

> About $450 million has been spent each year by governments on critical infrastructure restoration, which could rise to $17 billion by 2050…the total

4 Professor Ross Garnaut, private capacity, *Committee Hansard*, 7 March 2017, p. 25.

5 Australian Government, *National Climate Resilience and Adaptation Strategy Summary*, 2015, p. 10, available at https://www.environment.gov.au/system/files/resources/3b44e21e-2a78-4809-87c7-a1386e350c29/files/national-climate-resilience-and-adaptation-strategy.pdf (accessed 16 March 2017).

6 Australian Government, *National Climate Resilience and Adaptation Strategy Summary*, 2015, p. 10.

> economic costs…of natural disasters in Australia in 2015 exceeded $9 billion, which is expected to double by 2030 and reach $33 billion per annum by 2050…Both historical climate observations and climate projections into the future indicate that the frequency and intensity of many extreme weather events are on the rise. For this reason, there are likely to be significant benefits in directing investments towards mitigation efforts including improving infrastructure resilience to extreme weather events.[7]

2.12 The Electrical Trades Union drew attention not only to the impact of extreme weather events on electricity infrastructure, but also to the interdependency of electrical and other critical infrastructure:

> The economic threat posed by the impacts of natural disasters to the Australian economy is staggering. More than a fifth of Australia's economic output is at high or extreme risk of disruption from cyclones, while more than a quarter of national gross domestic output is located in areas with high to extreme risk of flooding. Analysis undertaken by SGS Economics & Planning found that 11 per cent, or $175 billion of national GDP, is located in areas subject to bushfire. Natural disasters and other large scale events that impact on electricity networks affect not only the electrical infrastructure in communities, but also many other infrastructure sectors, which are all interdependent with the electrical system…and often span several states and/or regions.[8]

2.13 Energy Networks Australia is the association that represents Australia's energy grid, supporting over 900,000 kilometres of electricity transmission and distribution lines. Mr John Bradley, Chief Executive Officer of Energy Networks Australia told the committee that:

> Implications of climate change for our networks are significant, with potential for sea level rise, increased frequency and severity of extreme weather events and related events, including storms, cyclones, heat waves and bushfires. Given the long life of energy network assets, investment decisions made today must incorporate risk assessments from a whole diverse range of factors, including future climate change.[9]

2.14 Professor Ross Garnaut reminded the committee that the impact of extreme temperatures on electricity infrastructure can have disastrous consequences:

> In the state of Victoria, the formal conclusions of the inquiry into the bushfires noted not only the role of extreme heat but also that developments through the interactions of extreme heat with electricity transmission contributed to the bushfires themselves.[10]

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7 Commonwealth Scientific and Industrial Research Organisation (CSIRO), *Submission 23*, p. 3.

8 Electrical Trades Union of Australia, *Submission 53*, p. 14.

9 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 30.

10 Professor Ross Garnaut, private capacity, *Committee Hansard*, 7 March 2017, p. 20.

2.15 The Northern Alliance for Greenhouse Action pointed out that higher temperatures would place a greater burden on electricity networks as they work to meet a projected increase in peak demand:

> …the cost to energy networks from climate change is estimated to be $2.5bn over the next five years…the largest proportion of this cost arises from the requirement to augment networks to accommodate the increase in peak demand largely associated with air-conditioning use [although] this is likely to be a conservative estimate as the past few years have seen increased bushfire activity, increased intensity of storm events, and hotter and drier conditions.[11]

Paris Climate Agreement

2.16 There is now global recognition of the catastrophic effects that will result without concerted efforts to dramatically reduce greenhouse gas emissions resulting from human activity.

2.17 The Paris Climate Conference (COP21) in December 2015 involved 195 countries signing the 'first-ever universal, legally binding global climate deal' setting out a global action plan to limit global warming to below 2°C.[12]

2.18 For the Paris Agreement to enter into force, at least 55 countries representing at least 55 per cent of global emissions were required to deposit their instruments of ratification. This was achieved when the European Union formally ratified the agreement, and it entered into force on 4 November 2016.[13]

2.19 Following a recommendation by the Joint Standing Committee on Treaties,[14] the Prime Minister the Hon Malcolm Turnbull MP announced on 10 November 2016 that Australia would ratify the Paris Agreement:

> The negotiation of the Paris Agreement was a turning point in the global transition to a lower emission future. Australia was one of more than 170 countries to sign the Agreement when opened for signature at the United Nations in New York in April 2016
>
> …
>
> Ratification of the Agreement confirms Australia's ambitious and responsible target to reduce emissions by 26 to 28 per cent below 2005 levels by 2030. This target is comparable with other advanced economies

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11 Northern Alliance for Greenhouse Action, *Submission 17*, p. 1 referencing a quote from the 'Energy network infrastructure and the climate change challenge' report by Parsons Brinkerhoff to the Energy Networks Australia, http://pandora.nla.gov.au/pan/120149/20100517-1251/www.ena.asn.au/udocs/PB-Report-and-Note.pdf, March 2009, p. 1.

12 European Commission, *Climate Action: Paris Agreement*, https://ec.europa.eu/clima/policies/international/negotiations/paris_en (accessed 10 November 2016).

13 European Commission, *Climate Action: Paris Agreement*.

14 Joint Standing Committee on Treaties, *Report 163*, November 2016, p. xv.

> and will halve our per capita emissions making it one of the highest targets in the G20 on that basis.[15]

Emissions in Australia's electricity sector

2.20 Australia's obligations under the Paris Agreement have a direct impact on the electricity sector because Australia's fossil fuel electricity generators, coal in particular, are a major source of greenhouse gas emissions.

2.21 In its 2016 report on policy options for Australia's electricity supply sector, the Climate Change Authority noted that coal-fired power accounted for 88 per cent of the emissions from electricity generation:

> Of the generation sources that produce emissions, brown coal is the most emissions-intensive—that is, it produces the most greenhouse gas emissions per unit of generation—followed by black coal and gas…The total emissions from each fuel depend on the emissions intensity of the fuel itself and what share of total generation it makes up…Coal produces around 88 per cent of generation emissions, 35 per cent from brown coal and 53 per cent from black coal.[16]

2.22 Australia has an ageing fleet of high emissions coal-fired electricity generators. There are currently 24 coal-fired power stations operating in Australia. Nine coal-fired power stations were closed between 2010 and 2016 across the following states: New South Wales (three closures), Queensland (two closures), Victoria (two closures) and South Australia (two closures).[17] In addition, Australia's oldest and most polluting power station, Hazelwood in the La Trobe Valley in Victoria, closed its doors at the end of March 2017.[18]

Australia's Electricity Generation

2.23 The following sections outline the main sources of power generation currently used in Australia, and the issues that the various generation technologies face as Australia and the rest of the world shifts to a low-emissions future.

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15 Prime Minister the Hon Malcolm Turnbull MP, Ratification of the Paris Agreement on Climate Change and the Doha Amendment to the Kyoto Protocol, *Media Release*, 10 November 2016, https://www.pm.gov.au/media/2016-11-10/ratification-paris-agreement-climate-change-and-doha-amendment-kyoto-protocol (accessed 10 November 2016).

16 Australian Government, Climate Change Authority, *Policy Options for Australia's electricity supply sector: Special review research report*, August 2016, p. 15, http://www.climatechangeauthority.gov.au/sites/prod.climatechangeauthority.gov.au/files/files/SR%20Electricity%20research%20report/Electricity%20research%20report%20-%20for%20publication.pdf (accessed 3 November 2016).

17 Senate Environment and Communications References Committee, *Retirement of coal fired power stations: Interim report*, November 2016, p. 5.

18 ENGIE, Hazelwood to close in March 2017, *Media Release*, 3 November 2016, http://www.engie.com/en/journalists/press-releases/hazelwood-power-station-australia/ (accessed 21 March 2017).

Coal

2.24 Coal produced around 63 per cent of Australia's electricity in 2014–15, with black coal providing around 43 per cent and brown coal around 20 per cent.[19]

2.25 Within the NEM, coal accounts for 78 per cent of electricity generation and gas 9.9 per cent.[20]

Coal-fired power is in structural decline

2.26 The imperative to address climate change by reducing greenhouse gas emissions has meant that the generation of electricity from coal-fired power stations is in structural decline as the world moves rapidly towards an economic transformation underpinned by clean energy sources.

2.27 It is crucial to recognise that the shift away from coal is being driven by the major energy players in the market. The committee received a raft of evidence that coal-fired generation has no future. Indeed, Australia's largest energy companies were quite clear that they have no intention of investing in coal-fired generation.

2.28 For example, Mr Jim Kouts, Head of Corporate Affairs at ENGIE in Australia, told the committee that 'we are moving out of coal'.[21]

2.29 Similarly, AGL Energy Limited's (AGL) Greenhouse Gas Policy states that AGL will not build, finance or acquire new conventional coal-fired power stations in Australia, nor extend the operating life of any of its existing coal-fired power stations.[22]

2.30 When asked whether some gas-fired stations could be replaced with coal-fired stations as a way of dealing with the current domestic gas shortage, Mr Richard Wrightson, General Manager of Wholesale Markets at AGL, told the committee that AGL had no interest in developing further coal-fired power:

> The issue is: can you then build coal to replace them in any meaningful time frame? It is not an area AGL, from a policy perspective, is interested in developing. Obviously we will use our existing coal assets to their maximum so that we can cover off our risk and exposures, but it is not an area that we see longer term being the key. It is about how you can develop renewables into that space and how you can firm up renewables and make

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19 Australian Government, Department of Industry, Innovation and Science, Office of the Chief Economist, *Australian Energy Update*, October 2016, pp. 18–19, http://www.environment.gov.au/energy/publications/australian-energy-update-2016, (accessed, October 2016.

20 Senate Environment and Communications References Committee, *Retirement of coal fired power stations—Interim report*, November 2016, chapter 2, p. 3.

21 Mr Jim Kouts, Head of Corporate Affairs, ENGIE in Australia, *Committee Hansard*, 20 February 2017, p. 18.

22 AGL Energy Limited, *AGL Greenhouse Gas Policy*, 17 April 2015, p. 2, https://www.agl.com.au/about-agl/media-centre/article-list/2015/april/agl-policy-to-provide-pathway-to-decarbonisation-of-electricity-generation, (accessible from AGL, *Submission 56*, p. 7).

> them reliable for the system so that we can use those to support our customer base.[23]

2.31 AGL called for 'a market rule that suitably telegraphs the phase-out of legacy power plants' after 50 years.[24] They explained to the committee that:

> This will enable market participants to plan and invest in the necessary generation and associated infrastructure. It will also minimise the impacts of short-notice periods for closure on wholesale electricity supplies, such as those experienced with the impending closure of the Hazelwood power station and the recent closures of the Northern and Playford coal power stations in South Australia.[25]

2.32 AGL explained that a 50 year lifespan is being applied to their own facilities:

> …at 50 years of age we say the end of tactical life has been achieved and you should shut down the unit. That is the process that we have established as part of our greenhouse gas policy that in 2022 will shut down the Liddell facility, in 2035 our Bayswater facility and in 2048 our Loy Yang facility.[26]

Lack of investment prospects for coal fired power projects

2.33 Not only are the electricity generators getting out of coal, but investors have also deserted coal because it is simply uneconomic and the risks of investing in what will become stranded assets are too high.

2.34 For example, the Clean Energy Finance Corporation explained why it is highly unlikely to follow the Commonwealth government's suggestion to fund new coal-fired power stations, explaining that:

> …in a market of such volatility it would be very difficult to find a private sector or a commercial investor making a decision to invest in a coal-fired power station in the Australian market today. So we, like a commercial investor, are very unlikely to find circumstances in which that would be an appropriate investment to expose the taxpayers to. Remember, we are investing the taxpayers' money. They are expecting us to operate commercially and carefully with that money, and we have to assess all of the investments appropriately.[27]

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23 Mr Richard Wrightson, General Manager, Wholesale Markets, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 6.

24 Mr Douglas Jackson, Executive General Manager, Group Operations, AGL Energy Limited, *Committee Hansard*, 7 March 2017, pp. 2, 4.

25 Mr Douglas Jackson, Executive General Manager, Group Operations, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 2.

26 Mr Douglas Jackson, Executive General Manager, Group Operations, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 4.

27 Mr Oliver Yates, Chief Executive Officer, Clean Energy Finance Corporation, *Committee Hansard*, 10 February 2017, p. 40.

2.35 Mr John Grimes, Chief Executive Officer of the Australian Solar Council, expressed similar views, telling the committee that banks are almost universally pulling out of coal, and that many large proposed coal projects will not be financed.[28]

2.36 The corollary of the move away from coal by energy companies is an increase in the use of other energy technologies to generate electricity. However, gas-fired power generation faces significant obstacles as set out below. Renewable energy technologies are summarised in subsequent sections, and the solutions to issues of intermittency are covered in chapter 3.

Gas

2.37 Gas fired power stations accounted for approximately 21 per cent of Australia's total electricity generation in 2014–15.[29]

2.38 The role of gas in Australia's future energy mix is a matter of significant debate at the current time, due to its potential as a replacement for coal-fired baseload generation, and shortage and price issues in the Australian domestic gas market. The committee heard diverse evidence about the future role of gas in Australia's energy future.

2.39 Professor Garnaut noted that back in 2008 the *Garnaut Climate Change Review* saw a significant role for gas as a transition fuel that could be used to balance the intermittent sources of electricity provided by renewables. However, he explained that developments since then have reduced the potential for gas to fulfil that transition role:

> Since then the price of gas has increased several fold, incidentally at a time when there has been a dramatic reduction in the price of gas in the rest of the world—roughly a falling by half to two-thirds in the United States at time when there has been trebling or more of domestic gas prices in Australia. That is a challenge for keeping down the cost of the transition to renewables. It means that the economically efficient role of gas is smaller than it would have been.[30]

2.40 AGL told the committee that they 'see natural gas as being a necessary transition fuel over the next 10 to 20 years'. [31]

2.41 Similarly, ENGIE told the committee that gas-fired generation will continue to play a key role in the transition to a renewable energy economy:

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28 Mr John Grimes, Chief Executive Officer, Australian Solar Council, *Committee Hansard*, 10 February 2017, p. 25.

29 Australian Government, Department of Industry, Innovation and Science, Office of the Chief Economist, *Australian Energy Update*, October 2016, p. 19, https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aes/2016-australian-energy-statistics.pdf .

30 Professor Ross Garnaut, private capacity, *Committee Hansard*, 7 March 2017, p. 20.

31 Mr Douglas Jackson, Executive General Manager, Group Operations, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 6.

> Five to 10 years ago gas was often referred to as a transitional fuel. I think gas-fired generation is the transitional fuel. Looking at the technology that is before us, whether you are out at solar thermal, solar PV or wind, I think gas has a big part to play as we transition… Most experts agree that gas is the transitional fuel as we work our way through the technology.[32]

2.42 However, the committee heard that the move away from a carbon price signal has reduced the advantage that natural gas would have over coal as a lower-emissions fuel source:

> The challenge for gas has been exacerbated by the move away from carbon pricing. Carbon pricing recognises the advantage of gas over coal. It penalises coal more heavily than gas... I note that, as with the old Australian form of carbon pricing, a carbon intensity scheme would restore the differential treatment of gas and higher-emissions sources of fossil energy.[33]

Problems with the domestic east-coast gas market

2.43 Despite the views expressed above by the energy companies that gas has a role as a transition fuel, the committee heard a raft of evidence that the domestic east-coast gas market faces significant problems. These problems have been highlighted in South Australia. AGL argued that:

> South Australia is heavily reliant on gas now with the closure of Northern [coal-fired] power station, and I would claim there is a fair dysfunction in the gas market, which has created most of the systemic problems we are seeing in South Australia.[34]

2.44 AGL told the committee that there is limited access to flexible gas contracts in South Australia:

> So one of the major reasons the contract market has become so illiquid in South Australia, which is a sure sign that you have problems at a competition level, is the inability to source gas flexibly so that we can make decisions to come in and come out of that market and to contract or not. We would love to be able to contract more in that marketplace. One of the main restrictors on being able to do that is access to flexible gas contracts that we are able to trade in and out of.[35]

2.45 AGL told the committee that building new power stations in South Australia is not feasible because access to gas remains limited:

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32 Mr Jim Kouts, Head of Corporate Affairs, ENGIE in Australia, *Committee Hansard*, 20 February 2017, pp. 15–16.

33 Professor Ross Garnaut, private capacity, *Committee Hansard*, 7 March 2017, p. 20.

34 Mr Richard Wrightson, General Manager, Wholesale Markets, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 3.

35 Mr Richard Wrightson, General Manager, Wholesale Markets, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 3.

> AGL would love to build a new power station to replace TIPSA [Torrens Island Power Station near Adelaide]. We want to maintain our customer base in South Australia and we would like to build a new power station. But if you cannot access gas to run it, it is not a feasible opportunity, and that is basically why you have had no new power stations announced in South Australia. People are trying to resolve how they access fuel to run those power stations on a consistent basis. There will be a way, and we will work it through, but access to gas is critical to that.[36]

2.46 Beyond the supply problems in the east-coast gas market, AGL outlined a second dilemma facing energy companies, namely that battery prices may fall rapidly enough to render investment in new gas-fired generation redundant:

> Do you develop gas fast enough to beat battery technology in? I do not know the answer to that question, but that will be one of the key things. Can we develop enough gas to make building fast-start gas peakers, an answer to intermittency—or given the gas restrictions in Australia will battery costs beat that through? I do not know the answer.[37]

2.47 Finally, Mr Simon Corbell, the Victorian Renewable Energy Advocate, drew attention to a third issue relevant to any decision on developing new gas-fired generating capacity. He warned that any new investment in gas generation risks repeating the experience of coal with stranded assets:

> …any policy setting that provides for support for gas-fired generation should have regard to the fact that you do not want to create a situation where you have stranded assets in gas-fired generation in 20, 30 or 40 years time in the same way that we currently experience in relation to coal-fired generation. [38]

Solar

2.48 Australia has a high capacity for solar power generation. According to Geoscience Australia:

> The Australian continent has the highest solar radiation per square metre of any continent and consequently some of the best solar energy resource in the world.[39]

2.49 Solar power is generated when sunlight is converted into electricity or used to heat air, water or other materials and is usually generated using one (or both) of two major technologies:

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36 Mr Richard Wrightson, General Manager, Wholesale Markets, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 9.

37 Mr Richard Wrightson, General Manager, Wholesale Markets, AGL Energy Limited, *Committee Hansard*, 7 March 2017, p. 7.

38 Mr Simon Corbell, Victorian Renewable Energy Advocate, *Committee Hansard*, 7 March 2017, p. 15.

39 Australian Government, Geoscience Australia, *Solar energy*, http://www.ga.gov.au/scientific-topics/energy/resources/other-renewable-energy-resources/solar-energy (accessed 21 October 2016).

- solar thermal, which converts solar radiation into heat (thermal energy); and
- solar photovoltaic (PV), which converts sunlight into electricity directly by using photovoltaic cells.[40]

2.50 Solar thermal electricity is often used for space heating, to generate electricity using steam (as the water is heated with solar heat), and for hot water heaters.[41]

2.51 The vast majority of the electricity generated from solar PV comes from small-scale rooftop installation. As at 20 March 2017, there were over 1.6 million solar PV panel systems in Australia with a rated output of just over 5500 MW, and over 1 million solar hot water heaters.[42]

2.52 The Australian Bureau of Statistics (ABS) notes that the average size of roof top solar PV has increased as the price of panels has come down:

> The average size of an installed roof-top solar PV system in Australia is currently just under 4 kW in capacity. In recent years, driven largely by falling prices for solar PV panels, the average size of systems has increased and are often over 5 kW in capacity.[43]

2.53 However, solar PV can be scaled up to megawatt scale power plants. At the end of 2015, Australia had 17 solar PV farms larger than 1 MW in size with the two largest being the 102 MW facility in Nyngan, New South Wales (NSW) and the 53 MW facility in Broken Hill, NSW.[44]

Wind

2.54 According to the Australian Energy Resource Assessment, Australia has some of the best wind resources in the world, in the south-western, southern and south-eastern margins and extending inland, and including highland areas in south-eastern Australia.[45]

2.55 In contrast to solar PV, the vast majority of electricity generated by wind comes from large-scale wind farms. In 2015, there were 76 wind farms in Australia,

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40 Australian Government, Geoscience Australia, *Solar energy*.

41 Australian Government, Geoscience Australia, *Solar energy*.

42 Australian Government, Clean Energy Regulator, *Postcode data for small-scale installations* , 17 March 2017, http://www.cleanenergyregulator.gov.au/RET/Forms-and-resources/Postcode-data-for-small-scale-installations (accessed 20 October 2016).

43 Australian Bureau of Statistics, *4631.0 - Employment in Renewable Energy Activities, Australia 2014-15* , http://www.abs.gov.au/ausstats/abs@.nsf/0/0BC8668DB3C26EAECA257E23001108A5?Opendocument (accessed 19 October 2016).

44 Clean Energy Council, Large-scale solar PV, https://www.cleanenergycouncil.org.au/technologies/large-scale-solar-PV.html (accessed 28 March 2017).

45 Australian Government, Department of Industry, Geoscience Australia, Bureau of Resources and Energy Economics, *Australian Energy Resource Assessment*, Second Edition, 2014, p. 237, https://industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/GA21797.pdf (accessed 19 October 2016).

with a combined capacity of 4187 MW from more than 2000 turbines.[46] In addition to this large-scale infrastructure, as at 20 March 2017, more than 400 small-scale wind systems have been installed in Australia, with a rated output of approximately 1.4 MW.[47]

2.56 Wind resources are currently prioritised within the NEM because wind energy is automatically dispatched. This means that electricity generated from wind is used before other, more controllable, sources are dispatched.[48]

Hydroelectricity

2.57 As at 2014, Australia had 124 operating hydroelectricity plants, with a total installed capacity of 8500 MW. The main hydro resources in Australia are in NSW and Tasmania.[49]

2.58 Hydroelectricity provided around 40 per cent of renewable energy in 2014–15.[50] Although hydroelectricity currently accounts for the largest share of Australia's renewable electricity, the potential for future growth of hydroelectricity generation in Australia is limited by issues of water availability:

> Climate models suggest long-term drying over southern areas of Australia during autumn and winter, which will be superimposed on larger natural rainfall variability, resulting in Australia having variable surface water resources.[51]

2.59 The future growth of hydroelectricity is likely to be limited to 'the development of small-scale hydroelectricity plants and efficiency gains from the refurbishment of large-scale hydroelectricity plants'.[52]

2.60 Similarly, the Australian Renewable Energy Agency (ARENA) has stated that 'most major hydropower opportunities in Australia have already been realised' and:

> In the future there may be some growth in use of 'mini-hydro' schemes—which can be 'run-of-river', with no dam or water storage, or developed

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46 Clean Energy Council, *Wind energy*, https://www.cleanenergycouncil.org.au/technologies/wind-energy.html (accessed 12 January 2017).

47 Australian Government, Clean Energy Regulator, *Postcode data for small-scale installations*, (accessed 20 October 2016).

48 Australian Government, Department of Industry, Geoscience Australia, Bureau of Resources and Energy Economics, *Australian Energy Resource Assessment*, Second Edition, 2014, p. 240.

49 Australian Government, Department of Industry, Geoscience Australia, Bureau of Resources and Energy Economics, *Australian Energy Resource Assessment*, Second Edition, 2014, p. 223.

50 Australian Government, Department of Industry, Innovation and Science, Office of the Chief Economist, *Australian Energy Update*, October 2016, pp 19-20.

51 Australian Government, Department of Industry, Geoscience Australia, Bureau of Resources and Energy Economics, *Australian Energy Resource Assessment*, Second Edition, 2014, p. 223.

52 Australian Government, Department of Industry, Geoscience Australia, Bureau of Resources and Energy Economics, *Australian Energy Resource Assessment*, Second Edition, 2014, p. 223.

> using existing or new dams whose primary purpose is local water supply, river and lake water-level control, or irrigation.[53]

The National Electricity Market (NEM)

2.61 The NEM is the wholesale electricity market for the eastern and southern Australian states and includes Queensland, NSW (including the Australian Capital Territory(ACT)), South Australia, Victoria and Tasmania.[54]

2.62 Western Australia and the Northern Territory are the only Australian state and territory not connected to the NEM, largely due to the distances that would be involved in their connection to the network. These areas have their own electricity systems and regulatory arrangements. Power in WA is supplied by the Wholesale Electricity Market (WEM) which has been operated by the Australian Energy Market Operator (AEMO) since 2016.[55]

2.63 The NEM is described as follows:

> The NEM facilitates the exchange of electricity between generators and retailers. Retailers resell the electricity to business and households. Some large consumers also purchase electricity directly from the market. High voltage transmission lines transport electricity from generators to electricity distributors, who deliver it to homes and businesses on lower voltage 'poles and wires'.[56]

2.64 There are more than 100 registered participants in the NEM, including market generators, transmission network service providers, distribution network service providers, and market customers.[57]

2.65 One of the issues raised by witnesses was the vulnerability brought about by having a long, thin grid. The Australian Academy of Science, Technology and Engineering (ATSE) stated:

> Our view is that the Australian grid suffers particularly because it is a long, thin grid and South Australia and Queensland are particularly vulnerable to

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53 Australian Government, Australian Renewable Energy Agency (ARENA), *Hydropower*, https://arena.gov.au/about-renewable-energy/hydropower/ (accessed 3 November 2016).

54 Australian Energy Market Operator, National Electricity Market, https://www.aemo.com.au/Electricity/National-Electricity-Market-NEM (accessed 1 November 2016).

55 Australian Energy Market Operator, *Wholesale Electricity Market*.

56 Australian Energy Market Commission, *National Electricity Market*, http://www.aemc.gov.au/Australias-Energy-Market/Markets-Overview/National-electricity-market (accessed 13 October 2016).

57 Australian Energy Market Operator (AEMO), *National Electricity Market Fact Sheet*, p. 1, https://www.aemo.com.au/-/media/Files/PDF/National-Electricity-Market-Fact-Sheet.pdf . (accessed 20 October 2016).

> that because they are at the ends of a very long, thin line. In South Australia's case there are only a few interconnections into Victoria.[58]

2.66 The committee heard that ATSE has modelled improvements to the NEM based on further interconnections:

> …modelling that has been done by fellows of the academy that looks at increased interconnections, either through New South Wales or indeed through South Australia to Queensland, to create a loop of the NEM that would, potentially, relieve some of those issues and then you can spread out the weather variation across a larger area.[59]

Regulatory framework

2.67 The NEM is governed by a set of regulatory bodies—the Australian Energy Market Operator (AEMO), the Australian Energy Market Commission (AEMC), and the Australian Energy Regulator (AER)—established through the Australian Energy Market Agreement, an intergovernmental agreement developed through the COAG process and signed by the leaders of state, territory and Commonwealth governments in its initial form in 2004.[60]

Australian Energy Market Operator (AEMO)

2.68 AEMO is responsible for managing the power grid in the NEM and its secure operation.[61] Mr David Swift, Executive General Manager of Corporate Development at AEMO, outlined its operational role as follows:

> AEMO operates the National Electricity Market in eastern and south-eastern Australia and manages the power system underpinning it. AEMO is also the market and power system operator in Western Australia. In gas, we operate a range of wholesale and retail gas markets and trading hubs around Australia.[62]

2.69 The NEM works as a 'pool' or 'spot' market in which supply and demand of power is matched in real time through a centrally coordinated dispatch process. A generator of power offers to supply the market with a specified amount of electricity at a specified price for a set time period, although they can re-submit the

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58 Dr Matt Wenham, Executive Manager Policy & Projects, Australian Academy of Technology and Engineering, *Committee Hansard*, 7 March 2017, p. 28.

59 Dr Matt Wenham, Executive Manager Policy & Projects, Australian Academy of Technology and Engineering, *Committee Hansard*, 7 March 2017, p. 28.

60 Mr John Pierce, Chairman, Australian Energy Market Commission (AEMC), *Committee Hansard*, 7 March 2017, p. 50; COAG Energy Council, Australian Energy Market Agreement (as amended December 2013), http://www.coagenergycouncil.gov.au/publications/australian-energy-market-agreement-amended-december-2013 (accessed 20 March 2017).

61 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 60.

62 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 59.

offered amounts at any time. AEMO will decide from these bids which generator will supply the electricity to the grid, with the cheapest generator being used first.[63]

2.70 AEMO also has 'planning roles across both electricity and gas markets that aim to inform market participants, regulators and policymakers'.[64] Significantly, AEMO is responsible for the development of national forecasts of electricity and gas demand. Mr Swift stated:

> Electricity demand is forecast annually, down to the transmission connection point. We plan the Victorian transmission system and publish material on that. We undertake national planning and produce a National Transmission Network Development Plan. We also provide occasional papers from time to time, looking at specific issues.[65]

2.71 Mr Swift pointed out that while 'AEMO operates the systems and markets, it does not own any physical assets such as pipelines, transmission towers or wind farms'.[66]

Australian Energy Market Commission (AEMC)

2.72 Mr John Pierce, Chairman of the AEMC, explained the regulatory role of the AEMC as follows:

> We are the rule maker for the Australian energy markets, which includes the rules that govern…the NEM, the transmission and distribution networks, wholesale gas markets, natural gas pipelines and the retail sale of energy to consumers.[67]

2.73 Mr Pierce described the process for changing the market rules made by the AEMC as follows:

> Anyone except the Australian Energy Market Commission itself can propose to us a change in those rules, so those rules evolve over time in response to proposals for changes that are put to the commission. In that sense, the future development and evolution of the market framework is in the hands of the market participants, the other market institutions, governments, consumer groups, environment groups and various stakeholders within the sector.[68]

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63 Australian Energy Market Commission (AEMC), *National Electricity Market Fact Sheet*, (accessed 20 October 2016), p. 2.

64 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 59.

65 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 59.

66 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 59.

67 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

68 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

2.74 Mr Pierce advised that since the AEMC was established in 2005, there have been 'about 214 different changes in the rules'.[69]

2.75 The AEMC's review function was described by Mr Pierce as follows:

> [W]e also undertake reviews that are normally under terms of reference issued by the COAG Energy Council where they are seeking advice on how improvements to the regulatory and energy market arrangements may be made. A short way to understand how this process works is that, if somebody thinks that there is a problem and they think they also know what the solution is, they will put a rule change to us. If governments think that there is an issue and want potential solutions explored, that is when they tend to ask us to do a review. Recently, in addition to our statutory functions, the commission has been provided with terms of reference from the COAG Energy Council, requesting what is referred to as 'targeted strategic advice to inform the council's energy market strategy and priority setting process', so that will form part of our work program for this year.[70]

2.76 All of the AEMC's work is governed by three national energy policy objectives: the national electricity objective, the national gas objective and the national energy retailer objective. Mr Pierce explained in relation to these objectives:

> They are three different objectives, but they all sort of have a common theme, which is referred to as 'promoting the long-term interests of consumers' but with respect to a very specific set of variables: price, quality, reliability and security of those energy services as well as the system as a whole.[71]

2.77 The AEMC currently has four suggested priority areas in terms of market development, namely:

- systems security;
- the integration of the mechanisms used to achieve emission-reduction policy objectives and energy policy objectives so that they are aligned and work together;
- redesigning the way in which gas is bought and sold in gas markets; and
- the promotion of a competitive retail energy services sector.[72]

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69 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

70 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

71 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

72 Mr John Pierce, Chairman, Australian Energy Market Commission, *Committee Hansard*, 10 February 2017, p. 50.

Australian Energy Regulator (AER)

2.78 The AER regulates energy markets and networks under national energy market legislation and rules, with functions including:

- monitoring wholesale electricity and gas markets to ensure energy businesses comply with the legislation and rules, and taking enforcement action where necessary;
- setting the amount of revenue that network businesses can recover from customers for using networks (electricity poles and wires and gas pipelines) that transport energy;
- regulating retail energy markets in Queensland, NSW, South Australia, Tasmania (electricity only) and the ACT; and
- publishing information on energy markets, including the annual State of the energy market report, to assist participants and the wider community.[73]

2.79 Ms Michelle Groves, Chief Executive Officer of the AER, informed the committee that it has been undertaking work in recent times aimed at ensuring that the regulatory framework meets the challenges currently facing it. This work includes:

- developing new 'ringfencing' guidelines preventing networks from favouring their own affiliates over other businesses offering competitive energy services, such as rooftop solar, smart appliances and storage;
- working to implement more cost reflective network tariffs, to help consumers make informed decisions on how and when they should use electricity as new technologies evolve; and
- developing a new demand management incentive scheme and innovation allowance which will provide electricity distribution businesses with an incentive to undertake efficient expenditure on non-network options relating to demand management.[74]

Clarity around responsibilities of regulatory bodies

2.80 An issue of concern raised with the committee has been possible uncertainty about the responsibilities of the different regulatory bodies involved in the NEM, particularly during power outages. AEMO explained the particular responsibilities of each body in relation to the South Australian system failure event in 2016:

> In terms of the real-time event and the behaviour on the day, that is clearly our responsibility. In respect of the behaviours of parties and whether they complied with the rules, that would be the AER's responsibility. Then when

73 Australian Energy Regulator, 'About Us', https://www.aer.gov.au/about-us (accessed 20 March 2017).

74 Ms Michelle Groves, Chief Executive Officer, Australian Energy Regulator, *Committee Hansard*, 10 February 2017, p. 51.

we look at policies and rules that gets back to the COAG Energy Council and the AEMC.[75]

Issues facing the NEM

2.81 Stakeholders to the inquiry identified various issues that have seriously undermined the functioning of the NEM and that need to be resolved in order for Australia's electricity market to function effectively into the future. In addition to the physical impacts of a changing climate on electricity infrastructure (discussed in earlier sections), major issues cited by submitters and witnesses included:

- reduced and changing patterns of electricity demand from the grid;
- the integration of intermittent renewable energy into the grid;
- the uptake of energy storage solutions and decentralised forms of electricity generation without the necessary changes to the structure and rules of the electricity market to facilitate this; and
- a protracted period of policy uncertainty relating to carbon issues, creating an environment where industry is unable to make long term planning and investment decisions.
- an inefficient and change-resistant regulatory authority which is absurdly slow and has a strong bias towards incumbent players, and is technically ignorant of modern trends in overseas markets and technology.

2.82 The changing patterns of electricity demand and usage, the integration of intermittent renewable energy into the grid, and the uptake of energy storage solutions and decentralised forms of electricity generation are covered in chapter 3.

2.83 The issues arising from policy uncertainty and the need for a carbon price signal, certainty around renewable energy targets, and necessary changes to the structure and rules of the NEM to facilitate the uptake of storage technologies are covered in chapter 4.

Recommendation 2

2.84 The committee recommends that the Finkel Review incorporate the impacts of climate change on electricity security into its consideration and recommendations.

75 Mr David Swift, Executive General Manager, Corporate Development, Australian Energy Market Operator, *Committee Hansard*, 10 February 2017, p. 60.