Chapter 3

Resilience from storage technologies and distributed generation

Introduction

3.1 This chapter begins by outlining the changing patterns of electricity supply and demand. It then considers the challenges involved in integrating renewable energy and decentralised forms of electricity generation into grid networks.

3.2 The chapter then considers a range of energy storage technologies and examines how storage technologies can contribute to the successful integration of renewables and decentralised forms of generation and at the same time, improve the resilience of Australia's electricity system.

3.3 Finally, the need for energy and storage system diversity is considered, particularly in relation to the provision of certain necessary ancillary services to grid networks.

Changing patterns of electricity supply and demand

3.4 One of the key challenges facing the electricity grid arises from the rapidly changing nature of electricity supply and demand.

3.5 Australia has historically generated its electricity from a relatively small number of centralised fossil-fuel power stations and delivered electricity to a large number of consumers. However, the supply side of the equation is undergoing rapid change. Dr Noel Simento, Managing Director for Australian National Low Emissions Coal Research and Development, commented:

> Our electricity supply has traditionally been delivered through the state grids to state based grids and large interconnectors between them. Our market systems were built on this basis, and it has served us well to date in achieving a competitive objective. We are, however, in a period of change and our commitment to reduce greenhouse gas emissions requires the deployment of low emissions energy technologies at an increasingly rapid rate. The inherent nature of these technologies is placing new demands on resilience and the operation of a network to grid.[1]

3.6 At the same time, the demand side of the equation is shifting too. Over the last several years, overall electricity demand in Australia has declined due to factors including increased energy efficiency. Simultaneously, peak electricity demand during extreme events (for example, prolonged heatwaves in the summer months) has placed increasing strain on the generation and distribution system during those periods. This trend has been quickened by the increasing uptake of rooftop solar by households in Australia, which means that demand from large-scale generators is lessened during the

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1 Dr Noel Simento, Managing Director, Australian National Low Emissions Coal Research and Development, *Committee Hansard*, 10 February 2017, p. 2.

middle of the day. Mr Robert Riebolge, Chief Network Analyst for 1414 Degrees, described these changes in electricity demand to the committee:

> The electricity demand profile in most Australian jurisdictions is becoming characterised by peaks and troughs that are increasingly widening and a baseload that is decreasing so that the ratio of the difference between the peak and the trough to the base is increasing. The generation mix and market rules in Australia have not been designed to meet this kind of demand profile, so the resilience of the electricity infrastructure will continue to deteriorate if measures are not put in place to address this problem quickly.[2]

3.7 In addition, there is the rise of what has been termed the 'prosumer', meaning an increasing number of households that also produce as well as consume electricity. The interactions between the changing nature of electricity supply and demand, the changing nature of generation technologies, the rise of the 'prosumer' and distributed electricity production, and the solutions offered by various energy storage technologies are covered in the following sections.

Integrating renewables into the electricity system

3.8 The integration of renewables into the electricity system was acknowledged by Energy Networks Australia as 'inevitable'.[3]

3.9 Despite this, it is clear that the pathway to ensuring this integration is accomplished successfully is still being developed. For example, the Australian Renewable Energy Agency (ARENA) outlined some of the challenges of guaranteeing security and reliability in the electricity system and the need for 'whole-of-system change across technology, markets and regulation' to ensure successful integration:

> As the mix of electricity generation changes to a higher level of renewables, Australia's electricity system will need to continue to provide secure, reliable power with more diverse, variable and distributed energy sources. This will involve a higher level of integration with flexible capacity, smart control systems, demand management, and improved technical standards to help withstand unexpected and extreme events.[4]

3.10 AEMO told the committee that it is currently a challenge to integrate intermittent renewables into the electricity market:

> AEMO sees the changing generation mix, with more asynchronous generation and intermittent generation as a challenge to the security of the system. Our ability to balance the security and reliability of energy supplied by these new technologies against the changing needs and preferences of the consumer is a primary focus for AEMO. The challenges arise in

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2 Mr Robert Riebolge, Chief Network Analyst, 1414 Degrees, *Committee Hansard*, 20 February 2017, p. 21.

3 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 34.

4 Australian Renewable Energy Agency, *Submission 32*, pp. 2 and 3.

> managing everyday 'credible contingencies', as we call them, as well as in extreme events.[5]

3.11 AEMO outlined the work it is currently doing to address these challenges:

> To help us deal with these issues, AEMO is conducting ongoing work in our Future Power System Security program, which aims to identify and quantify the challenges of main power system security in the NEM. We are also working in collaboration with the AEMC to change the market and regulatory frameworks to ensure these issues are managed into the future.[6]

3.12 Dr Evan Franklin, a fellow of the Energy Change Institute at the Australian National University (ANU), acknowledged the intermittent nature of renewable energy production from wind farms, solar farms and rooftop PV. He noted that one possible solution would be to have 'levels of ramp rate control' so that the power output from wind and solar PV does not fluctuate so rapidly. Another option would be to limit the speed with which intermittent generators could alter their output. However, Dr Franklin observed that requirements or incentives would be needed to bring about the widespread adoption of these changes by companies and individual homeowners.[7]

3.13 Mr John Bradley, Chief Executive Officer of Energy Networks Australia, was of the view that a new and more active role would be required from electricity distribution businesses to help integrate renewables into grid networks:

> The transition there to integrate renewables into the distribution system is to move towards much more active management—having good sensing, so you can see the power quality, the voltage rise, the fluctuations and power quality occurring in the network, and you can anticipate and respond to that.[8]

3.14 Meanwhile, the Australia Institute submitted that what were previously the two key obstacles to the widespread adoption of renewables, namely price and intermittency, are now capable of being resolved:

> Solar and wind costs have fallen so rapidly over the past decade that they are now competitive with fossil fuels, so the price argument is losing traction [while] battery and other forms of storage technology are rapidly overcoming the variability argument.[9]

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

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

7 Dr Evan Franklin, Senior Lecturer; Fellow, Energy Change Institute, Australian National University, *Committee Hansard*, 10 February 2017, p. 6.

8 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 34.

9 The Australia Institute, *Submission 54*, p. [iv].

3.15 However, Mr Oliver Yates, Chief Executive Officer of the Clean Energy Finance Corporation, pointed out that, in order to address the issue of intermittent generation, there needed to be far greater investment in large-scale storage technologies and electricity distribution infrastructure. However, he also noted that storage technologies faced 'regulatory challenges in entering the market'.[10]

3.16 The Clean Energy Finance Corporation set out what they saw as the key factors that needed to be planned for in order to achieve a balanced grid:

- diverse generation technologies within the system;
- geographically diverse generation technologies so that uncorrelated renewable resources can be drawn on from across Australia;
- strong transmission interconnections between regions to move power around Australia to balance supply and demand;
- large-scale storage, whether it be in batteries, solar-thermal, pump hydro or the coordination of small-scale batteries; and finally
- markets and a regulatory system that encourage all of these factors to occur at the same time.[11]

3.17 Similarly, Dr Matthew Stocks, a fellow of the College of Engineering and Computer Science at the ANU, also noted that the current transmission network is very weak. He argued that both storage and stronger inter-state connections would be crucial elements in strengthening the resilience of the electricity network because improved interconnections would strengthen the whole network and allow stored energy to be shared more easily between states.[12]

3.18 However, Dr Stocks also made the important point that even in the case of a grid supplied solely by renewable energy, the amount of storage required to balance the system and the additional costs was less than might be imagined:

> The work that we have done there demonstrates that, if you distribute this generation very widely and develop an appropriate transmission network, you need a surprisingly small amount of storage and a relatively small amount of support to ensure that you can have a reliable balancing of energy supply over that five-year period. We have shown that the additional premium is quite small. We are talking less than three cents a kilowatt hour to enable the entire system to behave in a balanced manner in order to

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10 Mr Oliver Yates, Chief Executive Officer, Clean Energy Finance Corporation, *Committee Hansard*, 11 February 2017, p. 39.

11 Mr Oliver Yates, Chief Executive Officer, Clean Energy Finance Corporations, *Committee Hansard*, 10 February 2017, p. 39.

12 Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017, p. 5.

> ensure that the energy is distributed across the country in such a way that you meet all of the vagaries of the supply and demand in the network.[13]

3.19 The role of storage technologies in helping to integrate diverse renewable energy generation technologies into the electricity system is discussed next. The issue of markets, policies and regulations is discussed later in chapter 4.

New opportunities arising from storage technologies

3.20 As noted at the beginning of the chapter, the supply and demand for electricity in Australia is undergoing rapid change. The so-called baseload generators such as coal-fired power stations that have dominated Australia's electricity production in the past are relatively inflexible: that is, they are unable 'to quickly increase or reduce supply on a minute-by-minute or hour-by-hour basis'.[14]

3.21 In addition, the ability of consumers to modify their electricity demand is relatively limited at present. The end result of the inflexibility inherent in the current approach to supply and demand is an excess of electricity generation capacity because there has to be sufficient supply to meet peaks in demand.[15]

3.22 Mr Oliver Yates, Chief Executive Officer of the Clean Energy Finance Corporation explained to the committee that the real-time matching of supply and demand is very rare in markets, and consequently requires some form of balancing:

> The concept of a market where [a good or service] is produced and sold immediately, absolutely perfectly matching demand, does not exist in many markets around the world. In many markets, there is always a period where demand does not equal supply, and it is important that it is balanced out. [16]

3.23 Furthermore, as noted in the previous section, the increasing amount of intermittent electricity generation in the network poses an additional challenge in balancing supply and demand. The committee received evidence from a range of witnesses that energy storage would have significant value in balancing periods of shortage and excess in electricity supply and demand and was the key component that would allow a high penetration of intermittent renewable energy into the grid. [17]

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13 Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017, pp. 1–2.

14 Mr Justin Flint, *Submission 34*, p. 1.

15 Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017, p. 5; Mr Justin Flint, *Submission 34*, p. 1.

16 Mr Oliver Yates, Chief Executive Officer, Clean Energy Finance Corporation, *Committee Hansard*, 11 February 2017, p. 45.

17 See, for example, Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017; Mr Oliver Yates, Chief Executive Officer, Clean Energy Finance Corporation, *Committee Hansard*, 11 February 2017; Mr Justin Flint, *Submission 34*.

3.24 For example, Dr Stocks made the point that Australia actually has excess energy capacity:

> We do not, in this country, have a shortage of energy; we have a vast oversupply of energy capacity. What we have is periods of deficit and periods of excess, and storage is very good at being able to come in and fill that gap.[18]

3.25 Similarly, Mr Justin Flint pointed out in his submission that the increasing availability of cost-effective storage technologies would allow a situation where supply exceeded demand to be managed because the energy could be stored. Conversely, where demand exceeded supply, the system could draw on the stored energy.[19]

3.26 In addition, storage technologies can respond far more rapidly to changes in demand than a large traditional power station. This supply response would be further enhanced by modern communications technologies and distributed generation.[20]

3.27 AES Energy Storage submitted that energy storage should be considered as a viable alternative to building new generation capacity:

> Power systems that need new capacity – whether it is to meet growing peak demand or to compensate for the retirement of aging thermal generation – should be evaluating energy storage as an economic alternative to building new generation.[21]

Types of storage technologies

3.28 The following sections consider three types of storage technologies:

- battery storage;
- pumped hydro technology; and
- thermal storage.

Battery storage

3.29 Dr Evan Franklin, a fellow at the Energy Change Institute at the ANU, told the committee that while battery storage is an old technology, recent advances in lithium batteries have brought the costs down.[22] Dr Franklin noted that battery storage

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18 Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017, p. 5.

19 Mr Justin Flint, *Submission 34*, pp. 2–3.

20 Mr Justin Flint, *Submission 34*, pp. 2–3.

21 AES Energy Storage, *Submission 56*, p. 3.

22 Dr Evan Franklin, Senior Lecturer; Fellow, Energy Change Institute, Australian National University, *Committee Hansard*, 10 February 2017, p. 6.

has already become a sizeable industry with the result that battery storage 'can be deployed now'.[23]

3.30 Similarly, Mr Ivor Frischknecht, Chief Executive Officer of ARENA, told the committee that while battery storage technology had historically been very expensive, costs had fallen and would continue to fall significantly.[24]

3.31 Mr Frischknecht noted that ARENA was currently 'in the process of demonstrating a whole variety of different ways of deploying storage and, very importantly, getting value from storage'. Mr Frischknecht emphasised the point that getting value from battery storage was critical to ensuring deployment on a commercial basis.[25] The issue of allowing batteries to capture appropriate value is a critical matter and one to which the committee returns in the following section.

3.32 At the household scale, Mr Osborne observed that a house with a smart battery system should be able to supply about 80 per cent of its own needs, and buy the remaining 20 per cent 'when it is cheapest and most abundant in the grid'.[26]

3.33 The next step beyond the generation of electricity on rooftops is the imminent deployment of substantial amounts of battery storage. Mr Osborne noted that Morgan Stanley has predicted that Australia could have five gigawatts of battery storage by around 2020. As Mr Osborne noted:

> …so we are going to move that five gigawatts from being out of control, going up and down with the sun, to being in control by 2020. So it will be the biggest controlled power station—about three or four times bigger than Tumut 3 pumped hydro dam—by 2020. So that is not very far away. It is very rapid.[27]

3.34 Dr Franklin told the committee that predictions about the future uptake of battery storage systems at the household level in Australia vary from a million in 2025 (Morgan Stanley) to 2.5 million in 2035 (Bloomberg New Energy Finance). Dr Franklin set out both the scale of the predicted contribution to the grid:

> Two-and-a-half million households with a battery storage system would end up being equivalent to something like 10 gigawatts of power generation capacity if it was arranged so that it could be deployed when required.[28]

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23 Dr Evan Franklin, Senior Lecturer; Fellow, Energy Change Institute, Australian National University, *Committee Hansard*, 10 February 2017, p. 6.

24 Mr Ivor Frischknecht, Chief Executive Officer, Australian Renewable Energy Agency, *Committee Hansard*, 10 February 2017, p. 40.

25 Mr Ivor Frischknecht, Chief Executive Officer, Australian Renewable Energy Agency, *Committee Hansard*, 10 February 2017, p. 40.

26 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 18.

27 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 19.

28 Dr Evan Franklin, Senior Lecturer; Fellow, Energy Change Institute, Australian National University, *Committee Hansard*, 10 February 2017, p. 8.

3.35 Dr Franklin also explained the mechanism by which battery systems could charge and discharge:

> Battery systems can discharge and charge very rapidly… You would normally charge batteries from solar during the day, of course, and have that available in the evening. If you depleted all of the batteries in the evening, then you would require other sources: wind or other generators to provide that recharging of batteries.[29]

3.36 The committee also received evidence about the development of utility scale battery storage from Australian companies including Lyon Group and Zen Energy.

3.37 Mr David Green, a partner in Lyon Group, told the committee that over the past two years, Lyon Group has brought together more than 1500 MW of solar PV utility-scale projects and more than 1000 MW of large-scale battery storage projects. Both the solar PV and battery storage projects are ready to be deployed and be operational within two years.[30]

3.38 Mr Green also noted that funding for the solar PV projects was underpinned by a major United States fund. The utility-scale battery storage would be developed in Australia in alliance with Mitsubishi Corporation and AES (headquartered in the United States).[31]

3.39 State and territory governments have embraced not only renewable energy generation, but are also focused on battery storage. For example, Mr Simon Corbell, a former Australian Capital Territory (ACT) Environment Minister, explained the ACT's Next Generation Renewables Program which started in early 2016:

> …the ACT government embarked on a significant program of supporting and subsidising the rollout of battery installations at 5000 individual household and small business sites across the territory. That program is ongoing and it highlights the importance of providing support to new technologies to bring forward their deployment at scale, to allow lessons to be learnt about how that deployment can take place in the most efficient way, and to build support for a growing industry.[32]

3.40 In his current role as the Victorian Renewable Energy Advocate, Mr Corbell told the committee that the Victorian state government had decided 'to invest significantly in large-scale battery storage to improve grid stability and provide for dispatchable load into the Victorian NEM region'. Mr Corbell noted that the Victorian

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29 Dr Evan Franklin, Senior Lecturer; Fellow, Energy Change Institute, Australian National University, *Committee Hansard*, 10 February 2017, p. 9.

30 Mr David Green, Partner, Lyon Group, *Committee Hansard*, 20 February 2017, p. 22.

31 Mr David Green, Partner, Lyon Group, *Committee Hansard*, 20 February 2017, p. 22.

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

government had committed to developing '20 megawatts of large-scale battery storage in grid-constrained parts of the state'.[33]

3.41 Nevertheless, the committee received evidence which suggested that even though battery prices are declining rapidly, other storage technologies are more cost-competitive at a utility-scale:

> Battery storage technology is rapidly advancing and costs are declining fast as production increases to meet growing demand from electric vehicles and stationary energy storage applications. However, the cost of batteries for bulk energy storage is still relatively high (compared to both wholesale costs of energy and compared to other forms of bulk energy storage – thermal and hydro in particular). This means that small, behind-the-meter battery systems, the market being driven by retail tariff margins, will dominate over utility-scale battery systems for some time to come.[34]

Committee view

3.42 The committee notes that the large-scale deployment of batteries at both household level and utility-scale is imminent and will occur rapidly from this point.

3.43 The committee considers that the rapid uptake of battery storage will help deliver important elements of system security relatively quickly compared to other generation and energy storage systems.

3.44 The committee is also of the view that the installation of batteries at the household level would provide citizens with greater control over their power and the committee returns to this theme later in the chapter in the section on distributed generation and storage.

3.45 The committee is also aware that there are certain regulatory barriers currently hindering the rapid deployment of storage technologies, and this matter and associated recommendations are presented in chapter 4.

Pumped hydro storage

3.46 This section outlines two distinctly different types of pumped hydro:

- large river-based pumped hydro storage; and
- small off-river pumped hydro storage.

Traditional large river-based pumped hydro

3.47 Pumped hydro has traditionally been based on large rivers. Large river-based pumped hydro storage is a well-established technology that has been in place in Australia and other countries for decades. Dr Stock informed the committee that:

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

34 ANU Energy Change Institute, *Submission 28*, p. 12.

> There are more than 150 gigawatts deployed around the world, including two gigawatts deployed within the Australian network in Tumut 3 in the Wivenhoe scheme and also in the Shoalhaven.[35]

3.48 The ANU Energy Change Institute informed the committee that owing to its relatively low cost, pumped hydro was the dominant form of energy storage world-wide:

> Pumped hydro energy storage is the dominant form of worldwide energy storage because it is an established technology, is cheap and provides a broad range of support services for the electrical grid. Water is pumped up a height difference when there is excess energy generating capacity available (i.e. when it is low cost) and the water is released to generate power when demand (and hence cost) is high. Owing to its comparatively low cost, over 96% of all energy storage installed in global electrical power systems to date have used pumped hydro technology.[36]

3.49 However, large river-based pumped hydro storage systems have significant environmental impacts and developments have been hotly disputed in the past. In some cases large river-based pumped hydro storage systems have been part of water management and diversion systems such as the Snowy river scheme. Such schemes have delivered water to farms, but have environmental costs, including the degradation of the diverted river.[37]

Off-river pumped hydro

3.50 Pumped hydro storage can also be operated off-river. The ANU Energy Change Institute submitted that the small size of off-river pumped hydro means that a wide range of sites could be developed across Australia:

> Recent research, meanwhile, has shown that there are numerous excellent sites in Australia for systems which are off-river, requiring relatively small reservoirs (oversize farm dams) at the top and bottom of hills with the water cycling between as supply and demand varies. Abandoned mines may also be used as reservoirs, as per the proposed Kidston mine being developed by Genex.[38]

3.51 The Alternative Technology Association informed the committee of research undertaken by the Melbourne Energy Institute:

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35 Dr Matthew Stocks, Fellow, College of Engineering and Computer Science, Australian National University, *Committee Hansard*, 10 February 2017, pp. 1–2.

36 ANU Energy Change Institute, *Submission 28*, p. 14.

37 Australian Government, The Snowy Mountains Scheme—Environmental impacts of the scheme, http://www.australia.gov.au/about-australia/australian-story/snowy-mountains-scheme (accessed 4 April 2017); Joshua Larsen, Badin Gibbes and John Quiggin, 'Dam hard: water storage is a historic headache for Australia', *The Conversation*, 27 October 2014, https://theconversation.com/dam-hard-water-storage-is-a-historic-headache-for-australia-33397 (accessed 4 April 2017).

38 ANU Energy Change Institute, *Submission 28*, p. 14.

According to the Melbourne Energy Institute (MEI), the best option is to build a dam on a tall hill or cliff. This height creates strong water pressure, enabling significant energy to be stored with a relatively small dam. Suitable sites are plentiful, and the theoretical cost is $200 per kWh of usable storage capacity. When added to a solar farm, a dam to store 5 hours of generation would increase the system cost by about 25%.[39]

3.52 The Melbourne Energy Institute has developed the following table which provides a comparison of conventional large river-based hydro, and off-river pumped hydro systems. One of the key findings arising from the comparison is that the much smaller size of off-river pumped hydro storage means there are thousands of potentially suitable sites in Australia.

Table 3.1: Comparison of conventional hydro power and off-river pumped hydro.

	Conventional large river hydro	**Off-river pumped hydro**
Purpose	Energy generation, irrigation, flood control, recreation	Short-term energy storage and use
Electricity output	High	High
Water requirement	Once-through, no recycling	Recycled. Make-up required for evaporation minus rainfall
Water storage period	Months or years	Hours
Reservoir size	Can be > 10,000 hectares	5 to 50 hectares
Location	Yes	Can be off-river using 'turkey-nest'
Number of possible sites in Australia	Limited	Thousands

Source: Melbourne Energy Institute, *Pumped Hydro Energy Storage.*[40]

3.53 Genex submitted that off-river pumped hydro systems have advantages relative to battery storage systems:

- large scale (e.g. able to provide storage for macro scale wind or solar PV farms);

39 Alternative Technology Association, *Submission 26*, p. 3.

40 Tim Forcey, *Pumped Hydro Energy Storage*, Melbourne Energy Institute, 8 May 2014, p. 21, http://energy.unimelb.edu.au/__data/assets/pdf_file/0003/1526592/Tim-Forcey-AESCE-2014.pdf, (accessed 22 March 2017).

- long lived asset—up to a century life-cycle;
- clean and environmentally sustainable form of energy storage that requires less mining of rare elements and less toxic materials to recycle or dispose of after use than chemical storage systems; and
- poses no fire risk.[41]

New off-river pumped hydro developments in Australia

3.54 The committee notes that the Clean Energy Finance Corporation and ARENA are assisting Genex Power to investigate the feasibility of developing an off-river pumped hydro scheme in an old mining site at Kidston in Northern Queensland.[42]

3.55 Genex Power (Genex), an Australian public company, is currently developing a large-scale hydroelectric pumped storage project in an old gold mining site at Kidston in Northern Queensland.[43]

3.56 The Clean Energy Finance Corporation and ARENA provided funding for Genex to conduct a technical feasibility study which is now complete.[44]

3.57 Genex notes that the Kidston pumped hydro storage project will be a closed loop system that will transfer water from an upper to a lower reservoir. The lower storage reservoir will be the existing Eldridge Pit. The upper storage reservoir will be a 'turkey's nest' type dam constructed on the waste rock dump to the north of Eldridge Pit. The project will also utilize the existing Wises Pit to act as a balancing storage to hold excess water and to mitigate flood risks.[45]

3.58 The completed Kidston pumped hydro project will have an installed generation capacity of 250MW, with a total energy storage capacity of 1500MWh based on a 6 hour full generation cycle.[46]

3.59 It is also possible to develop pumped hydroelectricity storage using seawater and a cliff-top dam such as the facility in Okinawa, Japan.[47]

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41 Genex, *Submission 3*, p. 5.

42 ANU Energy Change Institute, *Submission 28*, p. 14; The Prime Minister, the Hon Malcolm Turnbull MP, Media Release, *ARENA Finalising Grant to Energy Australia*, 21 February 2017, https://www.pm.gov.au/media/2017-02-21/arena-finalising-grant-energyaustralia, (accessed 22 March 2017); for further details see Kidstone solar and pumped hydro projects, http://www.genexpower.com.au/, (accessed 22 March 2017).

43 Genex, *Submission 3*, p. 1.

44 Genex, *Submission 3*, p. 1; see also The Prime Minister, the Hon Malcolm Turnbull MP, Media Release, *ARENA Finalising Grant to Energy Australia*, 21 February 2017, https://www.pm.gov.au/media/2017-02-21/arena-finalising-grant-energyaustralia, (accessed 22 March 2017).

45 Genex, The Kidston Pumped Storage Hydro Project (250MW), http://www.genexpower.com.au/the-kidston-pumped-storage-hydro-project-250mw.html (accessed 30 March 2017).

46 Genex, *Submission 3*, p. 1.

3.60 One such project has already been identified in Australia with ARENA providing EnergyAustralia with $450 000 to conduct a feasibility study for a 100MW to 200MW pumped hydro storage project close to Port Augusta and Whyalla in South Australia's Upper Spencer Gulf.[48]

3.61 The committee also notes that ARENA has funded an ANU study to identify potential off-river sites across Australia.[49]

Committee view

3.62 The committee draws attention to the significant difference between traditional hydroelectric generation that involves the damming of rivers as compared to off-river pumped hydro that can be installed on a much smaller scale with minimal negative environmental impacts.

3.63 The committee considers that off-river pumped hydro-electricity storage has the potential to provide a significant contribution to the effective operation and resilience of Australia's electricity systems.

3.64 The committee also notes the potential for coastal pumped hydro storage which only requires a single reservoir, is not susceptible to drought or evaporation, and has the potential to be co-located near wind and solar electricity generators.

3.65 Combining renewable generation systems with nearby off-river pumped hydro can provide an excellent way to balance the variable timing of renewable electricity supply with the fluctuations in electricity demand.

3.66 The committee also notes that a combination of pumped hydro, batteries, and thermal storage has the capacity to provide a full range of ancillary services required for electricity system stability and this matter is dealt with later in this chapter.

3.67 Finally, the committee received evidence about regulatory changes that could encourage the deployment of large scale pumped hydro (and thermal energy) storage systems. These matters are discussed in chapter 4.

Thermal energy storage

3.68 Thermal energy storage is a technology that stores thermal energy by heating or cooling a storage medium so that the stored energy can be used at a later time for

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47 Melbourne Energy Institute, *Pumped Hydro Energy Storage*, http://energy.unimelb.edu.au/mwg-internal/de5fs23hu73ds/progress?id=IoMdMs2VI9SLXou6B4MdHprxGwY-t-eqLQub2PHV7D0, (accessed 22 March 2017).

48 The Prime Minister, the Hon Malcolm Turnbull MP, Media Release, *ARENA Finalising Grant to Energy Australia*, 21 February 2017, https://www.pm.gov.au/media/2017-02-21/arena-finalising-grant-energyaustralia, (accessed 22 March 2017); Khama Reid, 'umped hydro power station ideal for SA Spencer Gulf site, EnergyAustralia says', *PM*, ABC, 22 February 2017, http://www.abc.net.au/news/2017-02-22/pumped-hydro-power-in-spencer-gulf-energy-australia/8292596 (accessed 30 March 2017).

49 The Prime Minister, the Hon Malcolm Turnbull MP, Media Release, *ARENA Finalising Grant to Energy Australia*, 21 February 2017.

heating and cooling applications and power generation. There are three kinds of thermal energy storage systems:

- sensible heat storage that is based on storing thermal energy by heating or cooling a liquid or solid storage medium (e.g. water, sand, molten salts, rocks);
- latent heat storage using phase change materials or PCMs (e.g. from a solid state into a liquid state); and
- thermo-chemical storage (TCS) using chemical reactions to store and release thermal energy.[50]

3.69 The International Renewal Energy Agency summarised the relative performance of the above systems as follows:

> A TES [thermal energy storage] system's economic performance depends substantially on its specific application and operational needs, including the number and frequency of storage cycles. In general, PCM and TCS systems are more expensive than sensible heat systems and are economically viable only for applications with a high number of cycles. In mature economies (e.g. OECD countries), a major constraint for TES deployment is the low construction rate of new buildings, while in emerging economies TES systems have a larger deployment potential.[51]
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> The storage of thermal energy (typically from renewable energy sources, waste heat or surplus energy production) can replace heat and cold production from fossil fuels, reduce CO_2 emissions and lower the need for costly peak power and heat production capacity. In Europe, it has been estimated that around 1.4 million GWh per year could be saved— and 400 million tonnes of CO_2 emissions avoided—in the building and industrial sectors by more extensive use of heat and cold storage. However, TES technologies face some barriers to market entry. In most cases, cost is a major issue. Storage systems based on TCS and PCM also need improvements in the stability of storage performance, which is associated with material properties.[52]

3.70 Many applications of thermal energy storage use and store heat directly, however the technology can also be effective for storing or creating electrical energy. The committee was informed about two types of thermal energy storage for electricity, one based on molten salt and the other based on molten silicon.

50 International Renewable Energy Agency, *Thermal Energy Storage Technology Brief,* January 2013, p. 1.

51 International Renewable Energy Agency, *Thermal Energy Storage Technology Brief,* January 2013, p. 1.

52 International Renewable Energy Agency, *Thermal Energy Storage Technology Brief,* January 2013, p. 1.

Molten salt with solar-thermal power

3.71 Molten salt and related thermal storage technologies are often used in conjunction with concentrating solar-thermal power (CSP) systems. CSP systems use a large array of mirrors to concentrate sunlight onto a 'receiver' where the energy is collected by heating a fluid. This fluid can be stored and used later to make steam and run a turbine to produce electricity.[53]

3.72 The ANU Solar Thermal Group explained that CSP with integrated storage was capable of delivering utility-scale round-the-clock solar energy:

> The particular benefit of CSP is that its configuration allows energy storage as an easily and cost effectively integrated part of the system. Systems with as much as 15 h of storage capacity have been installed (eg Gemasolar, Spain and Crescent Dunes, USA), achieving commercial supply of 24-h solar energy for the first time.[54]

3.73 The ANU Solar Thermal also noted the potential for CSP systems to be hybridised in order to manage the transition to a totally renewable electricity grid:

> CSP systems can also be hybridised with small amounts fossil or biomass fuels, for higher levels of reliability with minimal redundant equipment, a configuration which may [assist] in a reliable migration towards 100% renewables in coming years. CSP systems can also be beneficially hybridised with other renewables such as PV.[55]

3.74 The Australian Solar Thermal Energy Association told the committee that most new CSP systems and more than half of the existing CST systems incorporate intermediate storage use molten salt thermal energy storage to provide dispatchable energy:

> Concentrating Solar Thermal Power plants use steam turbines with synchronous generators for power generation and have thermal energy storage built in to the overall system for typically 6-15 hours of full load operation at any time that dispatch is desired. Their ideal size is in the range 50–250MW.[56]

3.75 Importantly, CSP also provides a range of ancillary benefits traditionally supplied by coal-fired generators and are capable of being configured to provide black-start capability.[57]

3.76 The ANU Solar Thermal Group argued that while CSP with storage is more expensive than wind and solar PV systems (that provide no storage or ancillary

53 ANU Solar Thermal Group, *Submission 40*, p. 1.

54 ANU Solar Thermal Group, *Submission 40*, p. 1.

55 ANU Solar Thermal Group, *Submission 40*, p. 1.

56 Australian Solar Thermal Energy Association Ltd, *Submission 43*, p. 1.

57 Australian Solar Thermal Energy Association Ltd, *Submission 43*, p. 1.

benefits), studies in the United States indicate that CSP with storage is cheaper than batteries (and likely to remain so for the foreseeable future) and pumped hydro.[58]

3.77 Further advantages of CSP with molten salt storage include:

- minimal carbon footprint;
- ability to withstand changing climatic conditions;
- a decrease in the annualised cost of electricity with integrated storage; and
- significant potential job creation from production of local content.[59]

Molten silicon

3.78 The committee was informed about another thermal energy storage technology based on molten silicon. Silicon has a high melting point, 1414 degrees Celsius, which allows for high efficiency energy recovery relative to lower temperature thermal technologies.[60]

3.79 1414 Degrees Limited is a South Australian company set up to commercialise a Thermal Energy Storage System (TESS) originally developed by the CSIRO. 1414 Degrees informed the committee that TESS possesses a significant competitive advantage over other storage technologies because of its scalability and high energy density:

> The heat store is constructed from readily available, low cost components and production units will be containerised and modular. A TESS module approximately the size of a 40ft shipping container could house $10MWh_{th}$ of energy storage and to scale up, modules may be added and to scale down, modules may be removed or smaller ones manufactured. For all sizes of the TESS, the heat store shares a common design principal.[61]

3.80 The committee was informed that the TESS was well suited to medium scale energy storage and had a number of advantages, including:

- the potential to be installed in any location;
- low environmental impact due to use of abundant, relatively non-toxic materials;
- an ability to supply both electricity and heat;
- simultaneous and rapid charging and discharging;
- the potential to be very cost effective; and

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58 ANU Solar Thermal Group, *Submission 40,* p. 1.

59 ANU Solar Thermal Group, *Submission 40,* p. 1.

60 1414^{o}, *Submission 51,* pp. 1–2.

61 1414^{o}, *Submission 51,* p. 2.

- the ability to provide ancillary services as the energy recovery system will be a rotating generator.[62]

3.81 Silicon based TESS is complimentary to other storage technologies as shown in the following table. It can operate as:

- smaller 'behind the meter' technology (TESS-EC (energy consumer)) for commercial energy consumers that require heat as well as electricity; or
- bulk grid storage technology (TESS-GRID).

Table 3.2: Comparison of energy storage technologies

Rating	Technology	Discharge time	Efficiency	Network benefits
<10MWh/h	**TESS-EC** Super capacitors Lithium Ion Advanced Lead Acid Flow Batteries Sodium sulphur	High hours Minutes Low hours High hours	Medium High High	Demand management Peak shaving Peak shifting Time of use tariffs PV self-sufficiency Network augmentation deferral
Between 10MWh/h and 100MWh/h	**TESS-Grid** Molten salt Compressed air energy storage	High hours	Medium Medium Low	Network augmentation deferral Congestion relief Utilisation of surplus renewables Frequency regulation Spinning reserve Voltage support
100MWh/h	Pumped hydro storage	High hours	Medium	Frequency regulation Spinning reserve Voltage support Arbitrage

Key: TESS-EC = 'behind the meter' Energy Consumer storage technology

TESS-Grid = bulk grid storage technology

Source: 1414°, *Submission 51*, p. 3.

Committee view

3.82 The committee considers that thermal storage technologies such as those discussed above have the potential to make significant contributions to the operation

62 1414°, *Submission 51*, p. 2.

and resilience of Australia's electricity networks. The committee views these technologies as being complementary to other storage technologies, including batteries and pumped hydro. In particular, it appears that thermal storage technologies may offer a number of advantages for medium or intermediate scale storage of electricity and other forms of energy.

3.83 From the evidence that the committee has received it appears that there is an abundance of complementary technology options for energy storage to facilitate the operation and resilience of Australia's electricity networks.

Ancillary services provided by a diversity of energy storage systems

3.84 A range of ancillary services such as system inertia, spinning reserve and synchronous capacity for frequency and voltage support are essential for the security of the electricity system.

3.85 One of the main arguments traditionally raised against the greater use of intermittent renewable energy is the inability of renewable technologies to provide the ancillary services that were typically rendered by fossil fuel-fired power generators.

3.86 Dr Noel Simento, Managing Director of the Australian National Low Emissions Coal Research and Development, explained that traditional synchronous generators such as coal-fired power stations have traditionally provided inertia and voltage support to the network at no additional cost.[63]

3.87 Mr Karl Rodrigues, Acting Director of Energy at the CSIRO, acknowledged that while storage technologies would be particularly useful as a means of sharing the increase in intermittent renewable electricity in the grid, he noted that some means of providing system inertia would still be needed for frequency control.[64]

3.88 However, the committee received evidence that a diversity of storage technologies, in addition to providing a readily available source of power, can support other aspects of electricity network operations and resilience, including black-start capabilities, an issue that has become particularly pertinent in the aftermath of the power black-out in South Australia in September 2016.

3.89 The Energy Change Institute explained that the characteristics offered by pumped hydro vary according to how it is configured:

> Pumped hydro plants can be configured in a number of different ways: most plants use a single turbine/pump set and a single electric machine (generator/motor), but some may use a separate turbine and pump with a single machine, or for greatest flexibility but highest cost a separate turbine-generator and pump-motor configuration. Configuration and electric

63 Dr Noel Simento, Managing Director, Australian National Low Emissions Coal Research and Development, Committee Hansard, 10 February 2017, pp. 2–3.

64 Mr Karl Rodrigues, Acting Director, Energy, CSIRO, *Committee Hansard*, 11 February 2017, p. 38.

> machine type together determine the ability of the plant to offer flexibility in terms of power system operation.[65]

3.90 The Energy Change Institute also explained how direct electro-mechanical synchronous pumped hydro can provide black-start capability

> Synchronous pumped hydro systems can provide black start capabilities without requiring additional power generation support. Such systems are thus well-suited to rapid recovery after region-wide black events (such as occurred in the South Australian system in September 2016) with conventional hydro plants typically considered be the generator of choice for initiating system black starts.[66]

3.91 Genex noted that pumped hydro 'has the potential to support grid stability through inertial spinning reserve and very fast ramp rates from zero to 100 per cent in minutes'.[67]

3.92 The Energy Change Institute set out the contributions that a diverse mix of storage technologies could contribute to the resilience of electricity infrastructure—including very fast primary frequency response, spinning reserve, inertia, voltage stability, energy balancing, and black-start capability—as Australia transitions to an electricity system based largely (or even solely) on intermittent renewable generation:

- Battery storage will provide:
  - very fast dynamic primary frequency response;
  - secondary response (or spinning reserve) services;
  - local demand smoothing; and can also
  - facilitate islanded or microgrid operation.
- Pumped hydro technology will be used for:
  - provision of inertia;
  - primary frequency response;
  - secondary spinning reserve;
  - medium term (in the order of days) energy balancing;
  - voltage stability; and
  - black-start capabilities.
- Concentrating solar power with thermal storage can provide:
  - inertia;
  - voltage stability;

65 ANU Energy Change Institute, *Submission 28*, p. 14.

66 ANU Energy Change Institute, *Submission 28*, p. 16.

67 Genex, *Submission 3*, p. 5.

- short to medium term (hours to overnight) energy balancing;
- some spinning reserve capability; and
- black-start capabilities.[68]

Benefits arising from decentralised electricity generation

3.93 Some of the challenges facing Australia's electricity system have arisen from a lack of diversity and the centralisation of electricity generation and storage which makes the system inflexible and unable to respond to challenging events. In the past the system has been characterised by a small number of large scale generation facilities and a very small number of large scale storage systems (large river pumped hydro such as the Snowy scheme). Mr Steve Blume, President of the Australian Solar Council, provided an example of the potential challenges facing centralised systems:

> Take, for example, the UK. If they build that nuclear power plant of 2,000 gigawatts, that will be eight per cent of their electricity system. If that goes out, even for maintenance, what do you use to get the eight per cent when that is not running? It is a big question. If you start relying on individual things that is what will happen.[69]

3.94 In contrast to the challenges facing a centralised system, several witnesses commented on the potential benefits of decentralising electricity generation in Australia through the further uptake of household solar PV and battery storage.

3.95 Innovative approaches are springing up without market intervention. The committee heard evidence from software providers, Reposit Power, about the 'community power station' concept:

> We add intelligence to home and business energy systems, so these are home and businesses that are investing in solar panels on their roofs and batteries, usually wall-mounted batteries. We do a couple of things. One is we make those systems achieve a lower bill for the consumer by adding intelligence behind the meter, making those systems interact better with appliances that they have in their home and business. We also allow those systems to band together when it makes sense and form what I will call for today a 'community power station'. That is a power station that can operate very much like a hydro dam or a pump storage dam: it can consume energy when it is cheap and produce energy when it is expensive. When it is not required, those systems all go back to helping the home or business have a low energy bill and a good interesting electricity experience.[70]

3.96 Mr Luke Osborne, Director and Chief Operating Officer of Reposit Power, expanded on the potential of the 'community power station' to provide resilience through distributed generation:

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68 ANU Energy Change Institute, *Submission 28*, p. 1.

69 Mr Steve Blume, President, Australian Solar Council, *Committee Hansard*, 10 February 2017, p. 27.

70 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 13.

> It is decentralised…this power station is everywhere. It is everywhere where there are homes and businesses, and already there are 1½ million homes and businesses that have solar panels on their roofs, and they are distributed everywhere there are populations. So decentralisation is inherently safer, if you like, than centralisation because you do not have a point of failure. If we think about what happened in South Australia: we lost transmission lines, which then led to the loss of the interconnector, which then lost the whole state. Those are problems of centralisation. You do not have that in a decentralised world. We can lose one or two houses or one or two businesses, but that is not important in the context of the whole community power station.[71]

3.97 Dr Andrew Mears, Director and Chief Executive Officer of SwitchDin, similarly argued that decentralised electricity generation would help future-proof electricity infrastructure by increasing system resilience:

> a decentralised energy service based around renewable energy technology and battery storage is a key factor for building a futureproof and resilient electricity infrastructure. What has happened in many countries, including Australia, is that we have seen a deconvolution of the energy sector. We have moved from a time when we had very centralised governance arrangements around a centralised infrastructure. We are moving to disaggregate those governance arrangements, so now we have separate retail, distribution, transmission and generation elements in our energy system… [W]e are getting much greater participation now for consumers in this energy market, which did not exist before, so there is a much more a dynamic marketplace. I think that inherently brings us a more resilient electricity sector.[72]

3.98 Mr Osbourne also informed the committee that a 'community power station' can potentially be implemented very quickly because the additional infrastructure (over and above panels and batteries that residents are already installing) is cheap and easy to implement and the approval processes are far simpler than for a larger industrial scale facility.[73]

3.99 In summary, Mr Osbourne contended that the key advantages of 'community power stations' were that they were:

- fast to respond;
- decentralised;
- cheap to build; and

71 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 13.

72 Dr Andrew Mears, Director and Chief Executive Officer, SwitchDin, *Committee Hansard*, 10 February 2017, p. 14.

73 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 1.

- quick to approve.[74]

3.100 Dr Mears was of the view that SwitchDin had resolved the issues of integration and control, thereby enabling small-scale, distributed systems to participate in the new energy sector of the future.[75]

3.101 Similarly, Mr Osborne stated that companies facilitating distributed generation were already operating successfully within the NEM:

> I do not think there are many barriers at all. We are up and operating. A customer can go right now and buy our gear. They can put it on their house. They can choose a plan from one of a number of retailers that are for battery participants and that allow them to do this interactive stuff. We can do it today, and that is because in the nineties we went through a great reform. We built the NEM… I think it is well designed. We can operate in it.[76]

3.102 Mr Blume was of the view that aggregators were the future of the electricity market:

> There will be aggregators who will look at individual businesses and homeowners and what their energy resources are and they will say: 'We'll give you a deal. Here's the deal. We will manage your system for you.'[77]

3.103 The committee heard numerous examples of community led-proposals that had grasped or were working towards this goal. For example, Mr Phil Browne submitted that:

> It makes great sense that the government should lead the way…by creating a network of many solar energy plants with battery storage distributed across the country. In addition to being cheaper in the long term, these solar plants would distribute power to local communities, and importantly, in the event of a storm disrupting power supply, it would not cause the massive loss of power to most of the state as occurred in South Australia when the current distribution grid was destroyed in a super storm.[78]

3.104 The Northern Alliance for Greenhouse Action noted that collaborative action to develop distributed energy networks might lead to some unlikely partnerships between the public and private sector:

> The design of local energy solutions requires collaboration between parties that have traditionally not worked in close partnership, such as local

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74 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 1.

75 Dr Andrew Mears, Director and Chief Executive Officer, SwitchDin, *Committee Hansard*, 10 February 2017, p. 14.

76 Mr Luke Osborne, Director and Chief Operating Officer, Reposit Power, *Committee Hansard*, 10 February 2017, p. 14.

77 Mr Steve Blume, President, Australian Solar Council, *Committee Hansard*, 10 February 2017, p. 27.

78 Mr Phil Browne, *Submission 18*, p. 1.

> governments and electricity networks. Distributed energy resources require participation and collaboration from diverse stakeholders in order to ensure that overall system security and reliability is maintained.[79]

3.105 Local energy trading was seen as a particularly important driver in reducing the costs of new energy storage technology through economies of scale:

> …local energy trading improves the return on investment of energy storage and related devices significantly which will serve to increase the frequency of uptake and accelerate the reduction in system costs in accordance with technology maturity curves.[80]

3.106 Concerns were raised that the shift to decentralised electricity generation by consumers created uncertainty that neither government nor industry can control. Mr Bradley warned that:

> Customers could drive 25 to 40 per cent of all system expenditure between now and 2050. The significance of that is it is going to be over $200 billion worth of expenditure that is actually determined by customers or their agents. In that environment, neither the industry nor governments can command and control the way in which the system develops.[81]

3.107 Mr Bradley stated, however, that the right incentives from both government and industry would lead to better market outcomes:

> All we can do is send incentives. So that is government sending incentives, which is around carbon abatement, through outcome based carbon policy. In the industry's case, it is sending incentives about the potential rewards for customers that could use their solar and batteries to help reduce the need for network expenditure and rewarding customers for those kinds of services.[82]

3.108 Dr Mears added that with such a system consumers may become 'prosumers' and there may need to be different mechanisms to reflect the value of their contributions to the electricity system:

> The Power of Choice review has led to transformations in the expectation of incumbents around what the consumer will mean in the future of this sector. The really big shifts that need to happen are about extending that more deeply. How do consumers who are now becoming what we call 'prosumers'—they are producing energy as well as consuming energy—fully participate? At the moment, for example, if your solar system generates excessive electricity, you can export it onto the network. You are remunerated with an amount, which perhaps does not reflect the potential value you could otherwise get if you were allowed to find a better buyer for

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79 Northern Alliance for Greenhouse Action, *Submission 17*, p. [2].

80 Nexergy, *Submission 25*, p. 5.

81 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 32.

82 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 32.

> that electricity, for example. So enabling the sorts of peer-to-peer trading opportunities, being able to quantity the costs that the networks would charge for allowing you to do that sort of activity and clarifying or making these process more transparent would enable a whole range of new business models for energy services.[83]

Electricity demand management

3.109 The committee also heard about other smart devices that can contribute to managing electricity demand. Mr Blume explained how what are termed 'demand response enabling devices' work:

> They are very simple little things. There are 750 000 households with them on their hot-water systems. And what do they do? When there is big demand, they either pump electricity into those hot-water systems or turn the hot-water systems off. There are about half a million of them on air conditioners, and they drive the air conditioners. It is not like all of a sudden your air conditioner turns off and you think, 'Bugger—I've got no air conditioning.' They turn it off in lumps all over the network—two minutes off here, two minutes off there. That is called demand response, and the demand response technology up until now has not been used very much.[84]

3.110 Energy Networks Australia noted developments in Australia that help incentivise fleets of millions of distributed energy resources to contribute towards lowering the cost of the centrally delivered infrastructure:

> The kinds of resources we are talking about are not only solar—or solar with smart inverters, particularly—or storage; they are also sophisticated demand response programs. There are aggregators of demand response that will offer customers a simple interface to allow them to control devices like hot water or pool pumps, so that they can respond on call and help beat the peak and manage the peak lopping...[85]

Committee view

3.111 The committee considers that a diversity of distributed generation and storage technologies have the potential to greatly enhance the operation and resilience of Australia's electricity networks. The committee further considers that in Australia we are collectively past the small scale proto-typing of such technologies and it is now time to move forward with a detailed scoping study for substantial deployments of distributed generation and storage technologies. The committee wishes to emphasise that the scoping study it is recommending should address academic research on the resilience of distributed systems.

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83 Dr Andrew Mears, Director and Chief Executive Officer, SwitchDin, *Committee Hansard*, 10 February 2017, p. 14.

84 Mr Steve Blume, President, Australian Solar Council, *Committee Hansard*, 10 February 2017, p. 26.

85 Mr John Bradley, Chief Executive Officer, Energy Networks Australia, *Committee Hansard*, 10 February 2017, p. 33.

3.112 The committee affirms that it is essential for the Commonwealth government to show leadership in the high level design of Australia's electricity system. While acknowledging that markets will play a necessary role in the implementation of the electricity system, left to their own devices, markets and corporations cannot and will not achieve an overall design for Australia's electricity system that is in the best interests of Australia and its people.

Recommendation 3

3.113 The committee recommends that the Commonwealth government conduct a detailed scoping study to evaluate options for distributed generation, new software services, and storage technologies to contribute to the resilience of Australia's electricity networks.