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Climate-Induced Wildfires and Strengthening Resilience in Electricity Infrastructure

COLLECTION: MANAGING RESPONSIBILITIES FOR CLIMATE CHANGE RISKS

ARTICLE

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ABSTRACT

In recent times, climate-induced disasters have overwhelmed many parts of the world destroying human and non-human communities and ecosystems. In this article, we focus on a unique type of infrastructure – electricity grids. We collate the latest climate science, relate it to electricity infrastructure and shine a light on the ways in which electricity infrastructure has been impacted by climate-induced wildfires in Australia and California. The two jurisdictions are comparable in many respects but illustrate different approaches to grid governance. They also conceptualize risk management differently, with Australia focusing on resilience as a standalone concept and California viewing resilience as only one aspect of climate change adaptation. We investigate the resilience strategies of both jurisdictions and identify the strategies, including technological ones, that are needed to build resilience in the sector.

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1. INTRODUCTION

The electricity grid is central to modern civilization. The grid was designed for the energy technologies and climate of the last century, and it remains to be seen how successfully it will adapt to changing technologies and to the extreme weather events (EWEs) fuelled by climate change.[1] Wildfires are a case in point.[2] By driving higher temperatures and increasing the frequency and duration of droughts,[3] climate change is exacerbating underlying wildfire risks.[4] Those fires can damage transmission and distribution lines.[5] Extreme heat from wildfires in turn increases conduction and can lead power lines to arc to the ground,[6] where they are more likely to touch brush and spark further fires or damage.[7] Whatever their sources, fires may spread more widely and quickly due to dry, hot conditions linked to climate change. Thus, climate conditions can both increase the risk that the grid itself will start fires and that the grid will be damaged by fire. Both pose serious challenges for managing climate risks.

For that reason, climate resilience is an important challenge for the power sector. There are many different definitions of resilience,[8] but reducing the exposure of electricity infrastructure to hazards, threats and their vulnerabilities is the aim. Essentially, for a grid to be resilient, it must have 'four fundamental properties of resilience namely – anticipation, absorption, recovery and adaptability after the damaging events'.[9] 'Anticipation' means the grid's ability to avoid any possible damage caused by an EWE. 'Absorption' refers to the grid's ability to minimize the damage caused by an EWE. With 'recovery', the grid is able to rebuild its damaged functionalities caused by an EWE. Meanwhile, with 'adaptability' the grid will learn from past events, improve its capability and be ready to deal with the next event.[10]

Grid operators are used to thinking in terms of reliability, but resilience presents fundamentally different challenges.[11] Grid reliability focuses on common failures to determine the frequency and duration of outages. These are usually high probability events of shorter duration which affect smaller regions. Resilience, on the other hand, deals with low probability, high impact events that may cause the entire system to collapse.[12] Estimating the likelihood of such catastrophic grid failure is difficult due to the rare occurrence of such events and to the lack of historical data.[13]

In this article, we examine two jurisdictions (Australia and California) with many similarities but with governance structures that differ in important ways. Both jurisdictions are confronting the increasing risks of wildfires to their grids. The two jurisdictions have similar populations,

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1 On the threats of extreme weather events to electricity infrastructure, see Cleo Varianou Mikellidou, Louisa Marie Shakou, Georgios Boustras, Christos Dimopoulos, 'Energy critical infrastructures at risk from climate change: A state of the art review' (2018) 11 Safety Science 110.

2 'Bush fire' and 'wildfire' have identical meanings.

3 See 'The Effects of Climate Change' (*NASA*, 1 September 2021) <https://climate.nasa.gov/effects/> accessed 10 September 2021; Benjamin Cook, 'Guest Post: Climate Change is Already Making Droughts Worse' (*Carbon Brief*, 14 May 2018) <https://www.carbonbrief.org/guest-post-climate-change-is-already-making-droughts-worse> accessed 9 August 2021.

4 Julie McNamara, 'California Wildfires and Power Outages Signal Long Road Ahead, But Climate Ambition Sets the Right Course' (*Union of Concerned Scientists*, 1 November 2019) <https://blog.ucsusa.org/julie-mcnamara/california-wildfires-power-outages-and-climate-ambition> accessed 9 August 2021.

5 See Larry Dale and others, *Assessing the Impact of Wildfires on the California Electricity Grid* (2018) iii–iv <https://www.energy.ca.gov/sites/default/files/2019-11/Energy_CCCA4-CEC-2018-002_ADA.pdf> accessed 9 August 2021.

6 See Troy Whitman and Scott Brown, 'Safety Alert: Power Line Hazards on Wildland Fires' (*Southern California Edison*) <https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3838367.pdf> accessed 29 January 2020; Umair Irfan, 'A Major Los Angeles Fire was Sparked by A Tree Branch Hitting A Power Line' (*Vox Media*, 30 October 2019) <https://www.vox.com/2019/10/30/20939808/getty-fire-california-wildfire-kincade> accessed 9 August 2021.

7 Irfan (n 6).

8 Varianou Mikellidou (n 1) 115.

9 Fauzan Hanif Jufri, Victor Widiputra and Jaesung Jung, 'State-of -The-Art Review on Power Grid Resilience to Extreme Weather Events: Definitions, Frameworks, Quantitative Assessment Methodologies and Enhancement Strategies' (2019) 239 Applied Energy 1049, 1050.

10 ibid 1051.

11 ibid 1049–1065.

12 ibid 1050.

13 ibid 1052.

GDPs, and climates. An important difference concerns governance. One is a nation state with a federalist system; the other is a state government within a federal system. In that regard, California is more comparable to an Australian state, but it differs dramatically in scale from its Australian counterparts. The jurisdictions differ in other important dimensions as well: their climate policies, with California far more advanced; in how jurisdiction over the power system is divided between different entities, with Californian regulators having more comprehensive authority than the Australian national electricity authority; and in their regulatory philosophies, with markets playing a larger role in Australia. They have also approached the concept of resilience from different angles.

This article utilizes these two sufficiently similar but usefully different cases to expose issues of grid governance and management, and to illustrate the different strategies adopted in places with similar climate challenges. We recognize, however, that each case is different, and therefore recognize the value of further comparative research on grid resilience with a broader set of cases. It would also be useful to expand the study to include hazards other than wildfires, since threats such as flooding may pose their own unique challenges.[14]

The causes contributing to climate induced impacts and poor grid reliability are complex and decades in the making and there is no 'silver bullet' solution to electricity infrastructure resilience challenges. A host of potential strategies is needed to reduce the risk of wildfires from grid equipment, mitigate the impacts of wildfires on the power system and ensure communities have more reliable access to energy. The potential solutions presented fall largely into the categories of (1) technological innovations; (2) better management of grid infrastructure and surrounding vegetation; and (3) land use policy and electricity infrastructure siting away from hazardous areas. Implementing these solutions will challenge existing governance systems and require making resilience a high priority for the electricity sector.

2. CLIMATE CHANGE, WILDFIRES, AND GRID VULNERABILITY

The Intergovernmental Panel on Climate Change has published a plethora of reports presenting the collective body of climate science research existing at a given point in time. Of particular relevance to this article are the IPCC Working Group II's 2012 Special Report 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation' (SREX)[15] and the IPCC Working Group I's Sixth Assessment Report 'Climate Change 2021: The Physical Science Basis' (AR6)[16] released in August 2021. The impacts of climate change are already being felt in dramatic ways. Since the 1950s, hot extremes (including heatwaves) have become more frequent and more intense across most land regions while cold extremes (including cold waves) have become less frequent and less severe (*virtually certain*). Human-induced climate change is the main driver of these changes (*high confidence*).[17] Some recent hot extremes which occurred over the past decade would have been extremely unlikely to occur without this human influence.[18] Moreover, it is likely that human influence has increased the chance of compound extreme events since the 1950s.[19] This includes increases in the frequency of concurrent heatwaves and droughts on the global scale (*high confidence*), and of fire weather events in some regions of all inhabited continents (*medium confidence*).[20] As warming progresses, we can expect increases in the frequency and intensity of hot extremes, heavy precipitation, and agricultural droughts in some regions.[21]

Drought and heat waves are associated with fire weather events because of the compound events of high temperatures, low soil moisture, low humidity, wind and a vapour pressure deficit. Compound hot and dry conditions will become more probable in nearly all land

14 See Robert M Verchick and Rosemary Lyster, 'Building a Climate-Resilient Power Grid: Lessons from Texas-Size Storms and the Queensland Floods' (2021) 3 Frontiers in Climate 1–8.

15 Christopher B Field and others (eds), *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation – Special Report of the Intergovernmental Panel on Climate Change* (CUP 2012).

16 Valérie Masson-Delmotte and others (eds), *Climate Change 2021: The Physical Science Basis* (CUP 2022).

17 ibid 10.

18 ibid.

19 ibid 11.

20 ibid.

21 ibid 28.

regions as global mean temperature increases and will be more frequent in some regions (*high confidence*). The extent of area burnt in western US forests, especially in California, has been linked to human-induced climate change resulting from a significant increase in vapour pressure deficit, which is a primary driver of wildfires. Observations in many regions of Australia show a long-term trend towards more dangerous weather conditions for bushfires, attributable at least in part to human-induced climate change. Given the projected increase in compound hot and dry conditions (*high confidence*), fire weather conditions will become more frequent with higher temperature increases in some regions (*high confidence*). Fire weather has become more probable in southern Europe, northern Eurasia, the US and Australia over the last century (*medium confidence*).[22]

As one of us has shown elsewhere,[23] the threats of extreme weather and slow onset events to electricity infrastructure have been well documented.[24] Clearly, given the IPCC's AR6 findings, a climate change risk assessment of threats to the grid is the starting point for developing resilience responses.

Although our focus is on wildfires, the IPCC's 2012 SREX[25] provides a comprehensive assessment of the many ways that climate change impacts electricity infrastructure. With regard to EWEs, electricity infrastructure is vulnerable to: extreme storm events, particularly wind and lightning; extreme rainfall events and floods; drought; and in some cases heatwaves.[26] One should also consider impacts on fuel production, storage and transportation. Traditional fuels like natural gas, coal, biomass and oil still provide most of the world's energy, and extracting and transporting those fuels will also be more difficult because of climate change. For example, Cyclone Yasi in 2011, and the 2017 Cyclone Debbie, flooded coal mines and rail lines in Queensland, Australia, stopping production and export for months.[27] Because of the variety of direct and indirect threats to the grid from climate change, a blinkered approach to considering individual threats may miss more systemic issues.

Responses to climate risks are necessarily dependent on the economics of the grid sector and the regulatory apparatus used in a given jurisdiction. We turn next to considering those issues in the Australian and Californian context.

3. THE STRUCTURE OF THE AUSTRALIAN AND CALIFORNIAN ELECTRICITY MARKETS

3.1 AUSTRALIA'S NATIONAL ELECTRICITY MARKET

The National Electricity Market (NEM) operates along the eastern seaboard of Australia, whereas California's electricity system is only partially vertically integrated and primarily state based. The NEM is a wholesale electricity market that operates across Queensland, New South Wales, Victoria, the Australian Capital Territory, South Australia and Tasmania. Tasmania joined the NEM when the construction of an undersea cable (the Basslink) between Victoria

22 ibid 130.

23 Rosemary Lyster and Robert RM Verchick, 'Protecting the Power Grid from Climate Disasters' in Rosemary Lyster and Robert Verchick (eds), *Research Handbook on Climate Disaster Law: Barriers and Opportunities* (Edward Elgar 2018); Rosemary Lyster and Rebekah Byrne, 'Climate Change Adaptation and Electricity Infrastructure' in Jonathan Verschuuren (ed), *Research Handbook On Climate Change Adaptation Law* (Edward Elgar 2013).

24 Len Stevens, *Assessment of the Impacts of Climate Change on Australia's Physical Infrastructure* (ATSE 2008); Parsons Brinckerhoff Australia, Energy Network Infrastructure and the Climate Change Challenge Report (2009) <http://trove.nla.gov.au/work/37303664?selectedversion=NBD45572997> accessed 9 August 2021; Ross Garnaut, *The Garnaut Climate Change Review-Final Report* (2008) ch 19 <https://library.bsl.org.au/jspui/bitstream/1/1002/1/Garnaut%20Climate%20Change%20Review%20-%20Final%20Report2008.pdf> accessed 9 August 2021; Cleo Paskal, *The Vulnerability of Energy Infrastructure to Environmental Change* (2009) <http://indico.ictp.it/event/a08182/session/50/contribution/32/material/0/1.pdf> accessed 9 August 2021; Mladen Kazunovic, Ian Dobson and Yimai Dong, *Impact of Extreme Weather on Power System Blackouts and Forced Outages: New Challenges* (2008) <https://www.researchgate.net/publication/228379681_Impact_of_Extreme_Weather_on_Power_System_Blackouts_and_Forced_Outages_New_Challenges> accessed 9 August 2021; Maunsell Australia Pty Ltd, *Impact of Climate Change on Infrastructure in Australia and CGE Model Inputs* (2008) <http://www.garnautreview.org.au/CA25734E0016A131/WebObj/02-AInfrastructure/$File/02-A%20Infrastructure.pdf> accessed 9 August 2021.

25 Field and others (n 15).

26 ibid 42, 235.

27 Clyde Russell, 'Steel Makers Brace for Surging Coking Coal Prices after Cyclone Debbie' (*Business Day*, 5 April 2017) <https://www.businesslive.co.za/bd/markets/2017-04-05-steel-makers-brace-for-surging-coking-coal-prices-after-cyclone-debbie/> accessed 9 August 2021.

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and Tasmania was completed in 2005. Inter-state trade is facilitated by interconnectors which transmit power between regions and across state borders to meet energy demands which local generators cannot meet, or when the price of electricity in another region is sufficiently low that it displaces local supply.

Prior to the establishment of the NEM in 1998, each State and Territory operated and owned its own electricity infrastructure assets and retail services. The NEM's origins lie in the competition and deregulation fervour which swept Australia following the 1993 Hilmer Inquiry into National Competition Policy.[28] Among the consequences of the Inquiry were: the review and reform of all laws which restricted competition; the restructuring of public sector monopoly businesses such as electricity; the introduction of competitive neutrality so that public businesses would not enjoy unfair advantages; and the extension of price surveillance to government business enterprises which retained a market monopoly. Consistently with these principles the States and Territories have variously privatised or leased their electricity businesses.

The actual market is regulated under the National Electricity Law (NEL) as set out in the Schedule to the National Electricity (South Australia) Act 1996. The NEM is essentially a continuous-time auction market that allows generators and users of electricity to enter half-ourly bids, indicating willingness to supply or demand electricity. Together, the bids form aggregate demand and supply schedules. Market clearing occurs every five minutes in recognition of the fact that available capacity and consumption can fluctuate. The dispatch price is determined at the intersection of the aggregate demand and supply schedules. Generator bids equal to or less than the dispatch price are accepted. The spot price of electricity is determined when the dispatch prices are averaged over a five-minute period, and this is the price actually paid to generators by purchasers. Not all purchases occur in this way, however, as participants can enter into bilateral arrangements or trade electricity in a forward market. Based on the vagaries of supply and demand, the spot price for electricity can vary. However, $14,500 is the regulatory limit for the spot price of 1 MWh of electricity.

Two bodies regulate the NEM – the Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER). The NEM is operated by the Australian Energy Market Operator (AEMO). The 'objective' of the NEM, set out in section 7 of the NEL, is

> to promote efficient investment in, and efficient operation and use of, electricity services for the long term interests of consumers of electricity with respect to (a) price, quality, safety, reliability and security of supply of electricity; and (b) the reliability, safety and security of the national electricity system.[29]

Noticeably absent is any reference to renewable energy sources, a reduction in greenhouse gas emissions, or the need for grid resilience.

Clearly, when disaster strikes the NEM anywhere in any state, the disruptions pulse through the entire network with the consequent risk of becoming separated from the grid and state-wide blackouts at any time. Consistently with the objectives, retailers are required to meet a reliability standard which seeks to ensure that 'the electricity system has sufficient capacity (including generation, demand response and inter-state transmission assets) to produce and transport electricity to meet consumer demand'.[30] The reliability standard requires at least 99.998% of forecast customer demand to be met each year.[31] Security of supply gauges the power system's capacity to continue operating within defined technical limits, even in the event of the disconnection of a major power system element such as an interconnector or large generator.[32] However, between 2009–2018 only 4.1% of power blackouts were caused by security of supply issues and 0.3% by reliability issues. 95.6% were caused by damage to infrastructure caused by storms or bushfires,[33] hence the salience of this discussion.

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28 See http://ncp.ncc.gov.au/docs/National%20Competition%20Policy%20Review%20report,%20The%20Hilmer%20Report,%20August%201993.pdf accessed 21 July 2022.

29 National Electricity Law, s 7.

30 See The Reliability Standard (*AEMC Reliability Panel*, February 2020) 1 available at https://www.aemc.gov.au/sites/default/files/2020-03/Reliability%20Standard%20Factsheet.pdf (accessed 9 January 2022).

31 ibid 3.

32 See Power System Operation available at https://aemo.com.au/en/energy-systems/electricity/national-electricity-market-nem/system-operations/power-system-operation (accessed 9 January 2021).

33 AEMC (n 30) 2.

3.2 CALIFORNIA

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California's regulatory electricity system[34] comprises three state institutions,[35] including the California Energy Commission (CEC), the California Public Utilities Commission (CPUC) and the California Independent System Operator (CAISO).[36] The CEC focuses on reductions in both energy costs and the environmental impacts of energy use.[37] It is California's lead energy policy and planning agency and has seven main responsibilities concerned with ensuring adequate supplies of electricity and natural gas, promoting energy efficiency, conservation and innovation, investigating renewable and alternative energy resources and technologies, certifying certain thermal power plants and energy emergency planning and management.[38] The CPUC formulates policies and rules for electricity and natural gas rates and services provided by private utilities,[39] with two main aims of protecting consumers and promoting the use of clean energy resources.[40] CAISO is regulated by the Federal Energy Regulatory Commission (FERC).[41] It independently operates and monitors the 'high-voltage, long-distance electric transmission lines' that constitute the majority of California's and a small part of Nevada's electricity network.[42] It ensures equality of transmission system access for diverse electricity generation resources, the flow of electricity in accordance with federal standards and, through various means (including facilitation of daily market transactions), that electricity supply meets demand.[43] CAISO also facilitates California's wholesale electric power markets, although it has no financial interest in them.[44]

California's electricity sector was deregulated between 1996 and 2002.[45] Wholesale markets remain deregulated under federal law, but retail deregulation was a dramatic failure. Electricity shortages were common and severe, wholesale power became more expensive, utilities almost became insolvent and the market institutions began to fail and were dismantled.[46] The reasons for these failures continue to be debated, although several factors are relevant, including '[a] shortage of generating capacity, [b]ottlenecks in related markets, [w]holesale generator market power, [r]egulatory missteps, and [f]aulty market design'.[47]

In 2020, California's electricity grid, energy customers and communities faced multiple threats related to safety and energy reliability. Two of the most prominent threats included deadly wildfires and decreased grid reliability through power outages,[48] both those arising from fire-related damage to the grid and public safety power shutoffs (PSPS).[49]

In the next Section, we consider how wildfires have impacted the Australian and Californian power systems.

34 See 'California's Energy Governing Institutions' (*California Energy Commission*, June 2015) <https://www.energy.ca.gov/sites/default/files/2019-06/Fact_Sheet_California_Energy_Governing_Institutions.pdf> accessed 2 September 2021.

35 ibid 1.

36 ibid.

37 ibid.

38 ibid.

39 ibid.

40 ibid 2.

41 ibid.

42 ibid.

43 ibid.

44 ibid.

45 Christopher Weare, *The California Electricity Crisis: Causes and Policy Options* (2003) v and 1 <https://www.ppic.org/wp-content/uploads/rs_archive/pubs/report/R_103CWR.pdf> accessed 2 September 2021.

46 ibid v.

47 ibid v.

48 McNamara (n 4).

49 See 'Public Safety Power Shutoff' (*Pacific Gas and Electric Company*, 2021) <https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/public-safety-power-shutoff-faq.page> accessed 9 August 2021.

4. CATASTROPHIC WILDFIRES AND ELECTRICITY INFRASTRUCTURE IN AUSTRALIA AND CALIFORNIA

4.1 THE AUSTRALIAN 'BLACK SUMMER FIRES 2019–2020'

Before describing the impacts of Australia's 'Black Summer Fires 2019–2020' (the Summer Fires) on electricity infrastructure, their toll needs to be acknowledged. The Australasian Fire and Emergency Service Authorities Council (AFAC) National Resources Sharing Centre calculated[50] the area burnt to be 17 million hectares across the states of New South Wales, Victoria, the Australian Capital Territory, Queensland, South Australia and Western Australia. 34 people died in the fires, while 445 people subsequently died as a result of the smoke haze. 3,094 homes were lost. Scientists estimate[51] that up to three billion animals were killed or displaced by the fires including an estimated 143 million mammals, 180 million birds, 51 million frogs and a staggering 2.5 billion reptiles.[52]

4.2 THE CALIFORNIA WILDFIRES

Wildfires in California in recent years have been particularly deadly, with three 'consecutive year[s] of catastrophic blazes'.[53] The 2017 fire season, which brought 6,000 wildfires killing at least 46 people, destroying more than 10,000 structures, resulting in more than $10 billion in damage and burning over one million acres, resulted in 'historic levels of death and destruction'.[54] That is, 'historic' until the following year, when the 2017 fire season was eclipsed. The 2018 Camp Fire alone killed 85 people, burned close to 19,000 structures, caused $16.5 billion in damage and destroyed the town of Paradise.[55] The smoke caused by these massive wildfires also created significant air quality concerns for many communities across the state. The 2019 wildfire season was less deadly and destructive than in previous years, but still caused significant hardship, including through widespread evacuations and the use of preventative blackouts.[56]

4.3 IMPACTS OF THE FIRES ON ELECTRICITY INFRASTRUCTURE

4.3.1 Impacts on Victoria's electricity infrastructure

Fires broke out in Victoria on 21 November 2019 catalysed by lightning strikes.[57] In total, 3,500 fires burned across Victoria over 98 days.[58] Emergency Management Victoria reported 1,510,937 hectares had been burned and 405 residential and 653 non-residential structures had been damaged.[59] The fires in Victoria were attributed almost entirely to dry lightning

50 See 'Cumulative Season Summary' (*AFAC*, 28 February 2020) <https://twitter.com/AFACnews/status/1233262259612213248> accessed 30 November 2020.

51 Chris Dickman and others, *After the Catastrophe: A Blueprint for a Conservation Response to Large-Scale Ecological Disaster* (2020) <https://www.nespthreatenedspecies.edu.au/media/0akfale0/after-the-catastrophe-report_v5.pdf> accessed 30 November 2020. See also Graham Redfearn and Adam Morton, 'Almost 3 Billion Animals Affected by Australian Bushfires, Report Shows' (*The Guardian*, 28 July 2020) <https://www.theguardian.com/environment/2020/jul/28/almost-3-billion-animals-affected-by-australian-megafires-report-shows-aoe> accessed 30 November 2020.

52 Dickman ibid.

53 McNamara (n 4).

54 Lauren Tierney, 'The Grim Scope of 2017's California Wildfire Season is Now Clear. The Danger's Not Over' (*The Washington Post*, 4 January 2018) <https://www.washingtonpost.com/graphics/2017/national/california-wildfires-comparison/> accessed August 2021. See also Holly Yan, 'The Wildfires in California Just Keep Shattering Records This Year' (*CNN News*, 26 December 2017) <https://www.cnn.com/2017/12/26/us/2017-california-wildfire-records-trnd/index.html> accessed 11 August 2021.

55 Peter Eavis and Ivan Penn, 'California Says PG&E Power Lines Caused Camp Fire That Killed 85' (*The New York Times*, 15 May 2019) <https://www.nytimes.com/2019/05/15/business/pge-fire.html> accessed 11 August 2021; McNamara (n 4).

56 Susie Cagle, 'California's Fire Season Has Been Bad. But it Could Have Been Much Worse' (*The Guardian*, 1 November 2019) <https://www.theguardian.com/us-news/2019/nov/01/california-wildfire-season-2019> accessed 12 August 2021.

57 Ben Huf and Holly McLean, *2019–20 Bushfires* (Research Note No 1, Department of Parliamentary Services, Parliament of Victoria, February 2020) 1.

58 CFA Media, 'Final Significant Fire Contained in Victoria' (*Country Fire Association*, 28 February 2020) <https://news.cfa.vic.gov.au/news/final-significant-fire-contained-in-victoria> accessed August 2021.

59 'Victoria's Fire Season Ends' (*Emergency Management Victoria*, 1 May 2020) <https://www.emv.vic.gov.au/news/victorias-fire-season-ends> accessed August 2021.

storms. Suspicion of arson surrounded only one fire, which represented 0.003% of the entire damage.[60]

Transmission and distribution services in the affected areas are provided by AusNet Services, which operates Victoria's entire transmission network, with some interconnections with New South Wales and South Australia. The network comprises approximately 6,560 km of lines and 13,300 towers.[61] The distribution network consists of approximately 38,200 km of overhead lines, 6,900 km of underground cables and 334,400 poles, with 93% of the distribution network located in rural areas.[62]

On 14 January, AusNet reported that approximately 1,000 km of powerlines were not operational due to the ongoing bushfires.[63] At that time it was projected that 100 km of powerlines and a large portion of the 1,518 adjacent wooden poles in the burnt areas would need full replacement.[64] In its Full Year 2020 Results Release and Investor Presentation, AusNet reported that the Black Summer fires had mostly damaged poles and wires and added $15.4 million to response and recovery costs for the year.[65]

4.3.2 Impacts on New South Wales' electricity infrastructure

In NSW, Transgrid is a monopoly Transmission Network Service Provider (TNSP) and Essential Energy is the largest Distribution Network Service Provider (DNSP) and so we focus on these to understand the vulnerability of electricity infrastructure to fire and identify lessons learned.[66] Under hot and dry weather conditions, and with 95% of New South Wales affected by drought, the Bushfire Danger Period was declared by nine local government areas starting 1 August 2019, and by another twelve on 17 August 2019.[67] Approximately 5.37 million hectares totalling 7% of land in New South Wales was burned.[68] The fires were attributed almost entirely to lightning strikes, with only a small percentage of the fires potentially started by arson (about 1%).[69] It is worth noting that while NSW's electricity infrastructure was dealing with catastrophic bushfires, it was also seriously impacted by violent storms and mini-tornadoes, as discussed below.

TransGrid connects three NSW DNSPs as well as the DNSP Evoenergy across the border in the Australian Capital Territory. On 4 January 2020, bushfires, extreme heat and strong winds disrupted TransGrid's infrastructure at two of its substations. Several lines were damaged and not operational although one substation remained fully operational relying on battery support and diesel generation.[70] This continued until 16 January.[71] On 7 January 2020, transmission lines were again impacted due to airborne dust, bushfire debris and light rain. Two transmission lines tripped and were promptly restored; however, the New South Wales system was separated from Queensland for just under an hour.[72]

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60 Kevin Nguyen and others, 'The Truth About Australia's Fires — Arsonists Aren't Responsible For Many This Season' (*ABC News*, 11 January 2020) <https://www.abc.net.au/news/2020-01-11/australias-fires-reveal-arson-not-a-major-cause/11855022> accessed 13 August 2021.

61 Energy Safe Victoria, *Safety Performance Report On Victorian Electricity Networks* (Report, Parliament of Victoria, October 2019) 49.

62 ibid.

63 'AusNet Services Update on the Impact of the Victorian Bushfires on Electricity Supply' (*AusNet*, 14 January 2020) <https://www.ausnetservices.com.au/-/media/Files/AusNet/Media-Releases/Final-2019/Vic-bushfires---media-statement-140120.ashx> accessed 12 August 2021.

64 ibid.

65 AusNet, *Full Year 2020 Results Release and Investor Presentation* (Report, 12 May 2020) 2, 18.

66 For information on the impacts of the fires on all electricity infrastructure see Rory McFadden, *Research Report: Black Summer and Resilience in the NEM* (December 2020) 93.

67 NSW Rural Fire Service, 'Winter Fires Ravage Northern New South Wales' (2019) 41 Bushfire Bulletin 2.

68 New South Wales Department of Planning, Industry and Environment, *NSW Fire and the Environment 2019–20 Summary* (Report, March 2020) 9.

69 Nguyen (n 60).

70 'Network Update' (*TransGrid*, 8 January 2020) <https://transgrid.com.au/news-views/blog/Lists/Posts/Post.aspx?ID=223> accessed 13 August 2021.

71 'Network Update' (*TransGrid*, 16 January 2020) <https://transgrid.com.au/news-views/blog/Lists/Posts/Post.aspx?ID=231> accessed 14 August 2021.

72 'Network Update' (n 70).

Essential Energy, the DNSP serving 95% of New South Wales including mostly regional areas, reported fire damage to poles, pole-mounted substation sites and 'hundreds of kilometres' of overhead high voltage powerlines, with crews replacing more than 2,165 power poles and 2,272 crossarms.[73] Via Facebook, it reported on 31 December 2019 that 35,000 customers were offline due to fire damage to 132 kV transmission lines.[74] The next day, this remained at 33,000[75] and fires on 5 January 2020 caused further outages, with 35,600 offline.[76] By 10 January, this number had decreased to 3,800,[77] and 2,800 by 15 January.[78] Essential Energy noted that, following the 2018–19 bushfire season, it had started developing standard options for customers to use standalone power systems (SAPS).[79] Essential Energy appears to be continuing its work implementing SAPS in remote areas.[80]

Endeavour Energy, which services Sydney's Greater West and South Coast, reported damage to poles, crossarms and transmission lines after bushfires had burned more than 45% of its network area since early December 2019.[81] It also reported fire damage to a substation.[82] In response, Endeavour Energy used a standalone power system for the first time to restore power to remote areas affected during the bushfire season, using solar panels, batteries and a back-up diesel generator that are localised and operate independently to the rest of the network.[83]

Lack of reserve (LOR)[84] conditions were declared by the market operator, AEMO, in New South Wales on four occasions over the summer.[85] The first occurred on 4 January 2020 and reconnection took approximately 6 hours[86] but there were no widespread outages or load shedding.[87] Another occurred on 31 January 2020 when the Victorian and South Australian grids separated, as discussed above, and the interconnector between New South Wales and Victoria was affected. This demonstrates how the interconnected NEM can impact and undermine the resilience of an individual state's electricity infrastructure. It is important to note that, although the focus of this case study is the traditional grid, generation of electricity from renewable energy sources was also affected. As AEMO noted, the smoke and dust from the fires affected solar output by 6–13% and extreme ambient temperatures caused the derating of wind turbines.[88]

73 'Latest Updates' (*Essential Energy*) <https://www.essentialenergy.com.au/our-network/bushfires/bushfire-updates> accessed 15 August 2021.

74 @EssentialEnergyAU (Essential Energy), (*Facebook*, 31 December 2019) <https://www.facebook.com/EssentialEnergyAU/posts/2566819466729088> accessed 15 August 2021.

75 @EssentialEnergyAU (Essential Energy), (*Facebook*, 1 January 2020) <https://www.facebook.com/EssentialEnergyAU/posts/2569544616456573> accessed 12 August 2021.

76 @EssentialEnergyAU (Essential Energy), (*Facebook*, 5 January 2020) <https://www.facebook.com/EssentialEnergyAU/posts/2577667038977664> accessed 12 August 2021.

77 @EssentialEnergyAU (Essential Energy), (*Facebook*, 10 January 2020) <https://www.facebook.com/EssentialEnergyAU/posts/2588776147866753> accessed 12 August 2021.

78 'Latest Updates' (n 73).

79 Essential Energy, 'Network Innovation' <https://www.essentialenergy.com.au/our-network/network-projects/network-innovation> accessed 12 August 2021.

80 Essential Energy, 'Matt, Essential Energy SAPS Specialist, Bulahdelah' (*YouTube*, 23 November 2020) <https://www.youtube.com/watch?v=trgK5xt3RTY> accessed 12 August 2021.

81 @endeavourenergy (Endeavour Energy), (*Twitter*, 3 January 2020) <https://twitter.com/endeavourenergy/status/1212922385956913152> accessed 13 August 2021.

82 @endeavourenergy (Endeavour Energy), (*Twitter*, 12 August 2019) <https://twitter.com/endeavourenergy/status/1160908577776664576> accessed August 2021.

83 'Off Grid System Provides New Way to Power Bushfire Properties' (*Energy Source & Distribution*, 7 May 2020) <https://esdnews.com.au/off-grid-system-provides-new-way-to-power-bushfire-properties/> accessed 15 August 2021.

84 The declaration of lack of reserve is a notification by AEMO to the market of the short-term risk of involuntary load shedding. Generators can then offer more supply, or consumers can reduce their demand, both of which provide more reserve and minimise the risk of load shedding.

85 See 'Declaration of Lack of Reserve Conditions' (*AEMC*, 19 December 2017) <https://www.aemc.gov.au/sites/default/files/content/afe038ed-6d18-44f8-8855-338a35779489/ERC0226-Information-sheet-Final-determination.pdf> (accessed 3 December 2020).

86 AEMO, *Preliminary Report – New South Wales and Victoria Separation Event on 4 January 2020* (Report, 3 March 2020) 12–3.

87 Allen O'Neill, 'Operating Under Siege' (*Watt Clarity*, 9 January 2020) <http://www.wattclarity.com.au/articles/2020/01/operating-under-siege/> accessed 15 August 2021.

88 AEMO, *2019–20 NEM Summer Operations Review Report* (2020) 28, 31 <https://www.aemo.com.au/-/media/files/electricity/nem/system-operations/summer-operations/2019-20/summer-2019-20-nem-operations-review.pdf> accessed 1 September 2021.

4.4 DID ELECTRICITY INFRASTRUCTURE CAUSE ANY BUSHFIRES?

There is no evidence that the Black Summer Fires were caused by infrastructure failures such as falling transmission lines.[89] However, the 2009 Victorian Bushfires Royal Commission into the catastrophic 2009 Victorian bushfires found that 5 of the 11 fires were caused by failed electricity assets, as a result of which 119 people died. We discuss later the actions taken by the Victorian government to remedy this through improved native vegetation management.

In California, however, one of the most frequently discussed causes of high wildfire risk and resulting grid unreliability is ineffective management of grid infrastructure by the state's largest utility, namely Pacific Gas and Electric (PG&E). The utility manages 100,000 miles of the state's 250,000 miles of distribution lines, in addition to 18,500 miles of transmission lines.[90] Many commentators blame the utility's 'mismanagement of, chronic underinvestment in, and poor planning around its electricity system' for contributing to the prevalence of wildfires and associated risks to the grid.[91] In fact, the state's forestry department (Cal Fire) and the CPUC have determined that PG&E's transmission lines caused the deadly Camp Fire of 2018.[92] PG&E faces at least $30 billion in wildfire liability[93] and recently reached a $13.5 billion settlement with some victims of the Camp Fire, the 2015 Butte Fire and several 2017 wildfires.[94]

PG&E appears to have underinvested in maintaining and modernizing grid infrastructure. These under-financed investments include trimming vegetation around transmission and distribution lines[95] to avoid brush falling on lines and sparking fires in windy and warm conditions,[96] as well as inspecting power lines and repairing ageing grid equipment.[97] Others include replacing wooden utility poles with more fire-resistant materials such as steel,[98] insulating power lines[99] or burying them underground,[100] upgrading transformers and installing technologies to help better detect and isolate grid problems.[101] While PG&E has announced plans to invest in several of these techniques,[102] many fault the utility for creating the context for much of California's wildfire risk due to its historic under-investment.[103] In contrast, San Diego Gas & Electric (SDG&E) has invested in many such techniques to minimize wildfire risks.[104]

89 See Lisa Richards, Nigel Brew and Lizzie Smith, '2019–20 Australian Bushfires—Frequently Asked Questions: A Quick Guide' (*Parliament of Australia*, 12 March 2020) <https://www.aph.gov.au/About_Parliament/Parliamentary_Departments/Parliamentary_Library/pubs/rp/rp1920/Quick_Guides/AustralianBushfires> accessed 2 September 2021.

90 See McNamara (n 4); David Roberts, '3 Key Solutions to California's Wildfire Safety Blackout Mess' (*Vox Media*, 22 October 2019) <https://www.vox.com/energy-and-environment/2019/10/22/20916820/california-wildfire-climate-change-blackout-insurance-pge> accessed 16 August 2021.

91 See, e.g., McNamara (n 4).

92 Eavis and Penn (n 55); Peter Eavis and Ivan Penn, 'Report Detailing PG&E's Failures Raises New Hurdles for Utility' (*The New York Times*, 3 December 2019) <https://www.nytimes.com/2019/12/03/business/energy-environment/pge-camp-fire-report.html> accessed August 2021 (citing Electricity Safety & Reliability Branch, *SED Incident Investigation Report for 2018 Camp Fire with Attachments* (2019)).

93 Cagle (n 56); Eavis and Penn (n 55).

94 Ivan Penn and others, 'PG&E Reaches $13.5 Billion Deal With Wildfire Victims' (*The New York Times*, 6 December 2019) <https://www.nytimes.com/2019/12/06/business/energy-environment/pge-wildfire-victims-deal.html> accessed 16 August 2021.

95 See Roberts (n 90).

96 See Cagle (n 56)

97 See Michael Colvin, 'California Fires, Electricity Outages Need Not Be "The New Normal"' (*Environmental Defense Fund*, 14 November 2019) <http://blogs.edf.org/energyexchange/2019/11/14/california-fires-electricity-outages-need-not-be-the-new-normal/> accessed 16 August 2021.

98 Roberts (n 90); Anne C Mulkern, 'Are Blackouts Here to Stay? A Look Into the Future' (*E&E News*, 14 November 2019) <https://www.eenews.net/climatewire/stories/1061544621> accessed 17 August 2021.

99 See Mulkern (n 98).

100 See Roberts (n 90).

101 See Mulkern (n 98); Brian Murray, 'Learn from the Burn: What the California Fires Illuminate About the Energy Transition' (*Forbes*, 21 November 2019) <https://www.forbes.com/sites/brianmurray1/2019/11/21/learn-from-the-burn-what-the-california-fire-crisis-illuminates-about-the-energy-transition/#51b2b3cd3044> accessed 18 August 2021.

102 See 'Pacific Gas and Electric Company Amended 2019 Wildfire Safety Plan' (*Pacific Gas and Electric Company*, 6 February 2019) <https://www.pge.com/pge_global/common/pdfs/safety/emergency-preparedness/natural-disaster/wildfires/Wildfire-Safety-Plan.pdf> accessed18 August 2021.

103 See, e.g., McNamara (n 4); Roberts (n 90).

104 See Roberts (n 90); Mulkern (n 98).

Some of the money PG&E could have invested in grid infrastructure appears to have been directed to more profit-oriented motives instead. In the last 5 years alone, the utility returned $4.5 billion in shareholder profits and has spent 'millions' on state lobbying and paying bonuses to its executives.[105] PG&E was convicted in 2016 of safety violations related to a deadly gas pipeline explosion in San Bruno, California in 2010.[106] Judge Alsup, who is overseeing PG&E's criminal probation from this explosion,[107] stated at a 2019 hearing that '[a] lot of money went to dividends that should've gone to [trimming] trees' around the utility's power lines.[108]

Judge Alsup recently ordered PG&E to 'overhaul' its approach to inspecting transmission lines, hire more inspectors to oversee tree trimming and improve its record-keeping.[109] He noted that the current situation arose:

> because for years, in order to enlarge dividends, bonuses, and political contributions, PG&E cheated on maintenance of its grid — to the point that the grid became unsafe to operate during our annual high winds, so unsafe that the grid itself failed and ignited many catastrophic wildfires.[110]

Despite PG&E's historic approach, financial markets appear responsive to utilities' actions to respond to and plan for climate change impacts.[111] Utilities implementing resilience measures such as system hardening and efforts to mitigate greenhouse gas emissions 'attract investors' and enjoy benefits in stock valuation, while utilities that 'rely on business as usual discourage investors and increase stock price volatility'.[112]

The threat of liability for fires undoubtedly has helped to focus Californian utilities on the urgency of reducing fire risks. It makes the issue a priority for top management in a way that regulatory requirements alone might not do, but there are also substantial downsides to reliance on the liability system. Even a highly capable federal judge lacks the expertise regarding the power system possessed by regulators, and a judge is not well situated to consider how spending in this one area might impact other important priorities for the power system. A judge is also not in a position to establish a coordinated set of long-term policies. Yet, the liability system does ensure compensation for lost lives and massive economic loss caused by shortchanging risk prevention. The trade-offs, in other words, are complex. Closer coordination between the CPUC and judicial remedies could be highly productive, but there is no established pathway for a state agency and the federal judiciary to collaborate on solutions.

4.5 DID POOR HAZARD REDUCTION CONTRIBUTE TO THE FIRES?

4.5.1 Australia

On 11 November 2019, as the fires were raging, *The Australian* newspaper ran a banner headline on its front page 'Bushfire Threat Created by Greens'. It reported that the former Deputy Prime Minister, Barnaby Joyce, stated that the fires were caused by a lack of hazard reduction burning instigated by 'Greens-backed regulation'. The NSW Bushfire Inquiry reported that it had heard significant concern amongst the community that this was the case. However, the Inquiry concluded that although fuel loads were generally high across most of the fire affected areas of NSW, they were on average no higher than over the previous 30 years.

105 Cagle (n 56).

106 Joel Rosenblatt and others, 'PG&E Tries to Assure Strict Judge It's Safer on Wildfires' (*Bloomberg*, 15 January 2020) <https://www.bloomberg.com/news/articles/2020-01-15/pg-e-tells-judge-it-can-t-certify-full-probation-compliance> accessed 19 August 2021.

107 Because PG&E's criminal probation prohibits it from violating any laws, Judge Alsup is also closely observing the utility's role in causing subsequent wildfires; Rosenblatt and others (n 106).

108 Raquel Maria Dillon, 'Judge: PG&E Paid Out Stock Dividends Instead of Trimming Trees' (*KQED News*, 2 April 2019) <https://www.kqed.org/news/11737336/judge-pge-paid-out-stock-dividends-instead-of-trimming-trees> accessed August 2021.

109 Order Modifying Conditions of Probation, *United States v Pacific Gas and Electric Company*, No. 3:14-cr-00175-WHA (Northern District of California, 29 April 2020).

110 ibid 1.

111 See Herman K Trabish, 'BlackRock, Morgan Stanley to Utilities: Tackle Climate-Related Risks or Lose Market Value' (*Utility Dive*, 6 April 2020) <https://www.utilitydive.com/news/blackrock-morgan-stanley-to-utilities-tackle-climate-related-risks-or-los/575073/> accessed 20 August 2021.

112 ibid.

The dominant contributing factor was the dryness of the fuel. In some circumstances, hazard reduction briefly contained the fires, while in others it had no influence over the spread or intensity of the bush fire.[113]

4.5.2 California

Some also suggest that forest mismanagement by state authorities has worsened the dangers posed by rising temperatures and outdated infrastructure. California's electrical grid 'is a sprawling network of aging power lines that overlaps with a landscape that is drier and more vulnerable to wildfires than ever before'.[114] Many blame state authorities for insufficient forest management over the past several decades, including fire suppression efforts.[115] As a result, there are an estimated 147 million dead trees spread across the state.[116] These dried trees provide readily available fuel to any wildfires sparked by electrical grid infrastructure or human activity.

4.6 IS ELECTRICITY INFRASTRUCTURE PLACED IN BUSHFIRE PRONE AREAS?

Many settlements in Victoria and New South Wales are in fire prone areas which contain a mix of medium to low density housing and are typically close to heavy vegetation, often combined with steep slopes. This is true also of California, where another systemic contributor to wildfire risk is the extensive residential development in many areas of the state that are particularly prone to fires. About half of California's housing development is taking place in the wildland-urban interface (WUI),[117] increasing both the risks and ramifications of wildfires.[118] The California Department of Insurance estimates that 3.6 million homes exist in the state's WUI.[119] Two million homes in the state face high or extreme wildfire risks.[120] Wildfires are more likely to spread and cause damage in the WUI, as communities often lack fire preparedness and evacuation plans and many houses are built with materials that are not fire-resistant and are surrounded by flammable vegetation.[121]

Among its millions of customers, PG&E supplies electricity to many residents who live in such 'mountainous, forested areas growing hotter and dryer every year' as climate change progresses.[122] The physical reality of these environments makes it highly likely for utilities to either spark some wildfires in trying to deliver electricity, or to deliver electricity less reliably.

The forces driving development in the WUI are complex, including rising costs and decreasing availability of housing[123] and state incentives.[124] One challenge is that insurance premiums in such areas do not fully reflect actual risks of wildfire, so subsidized premiums enable development that does not fully account for such risks. Yet, wildfires appear to be reducing the availability and affordability of insurance in the WUI without properly accounting for wildfire mitigation measures, which may lead an increasing number of homeowners to 'decide to go uninsured, risking their life savings and ultimately seeking relief from the state and federal governments'.[125]

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113 ibid 47.

114 Colvin (n 97).

115 See, e.g., McNamara (n 4); Roberts (n 90).

116 Colvin (n 97).

117 Between 1990 and 2010, approximately half of the new housing units built in California were in the WUI; Annie Lowrey, 'California Is Becoming Unlivable' (*The Atlantic*, 30 October 2019) <https://www.theatlantic.com/ideas/archive/2019/10/can-california-save-itself/601135/> accessed 20 August 2021.

118 See McNamara (n 4).

119 California Department of Insurance's Availability and Affordability of Residential Property Insurance Task Force, *The Availability and Affordability of Coverage for Wildfire Loss in Residential Property Insurance in the Wildland-Urban Interface and Other High-Risk Areas of California: CDI Summary and Proposed Solutions* (2017) 1 <http://www.insurance.ca.gov/0400-news/0100-press-releases/2018/upload/nr002-2018AvailabilityandAffordabilityofWildfireCoverage.pdf> accessed 21 August 2021.

120 Dimitris Karapiperis, *The Increasing Risk of Wildfire and Insurance Implications* (2018) 17 <https://www.naic.org/cipr_newsletter_archive/vol24_wildfire.pdf> accessed 21 August 2021.

121 See Roberts (n 90).

122 ibid.

123 Lowrey (n 117).

124 See Roberts (n 90).

125 CDI Summary and Proposed Solutions (n 119).

5. REGULATORS' APPROACHES TO CLIMATE RESILIENCE

5.1. AUSTRALIA

The AEMC is understandably heavily invested in resilience, which it describes as the ability of the power system to 'avoid, survive, recover and learn' from an event and describes resilience measures as aimed at making the system stronger, more interconnected or smarter.[126] In the AEMC's view, existing frameworks within the NEM are designed to maintain satisfactory operation only in response to the finite set of credible contingency events and insufficiently manage the risk of indistinct and high impact low probability events which may co-occur.[127]

Following the Black Summer Fires, the AEMO released its *2019–2020 NEM Summer Operations Review Report*.[128] Consequently, its findings are a good indicator of what innovations are likely to be introduced to build resilience in the electricity sector. The report starts by noting that the need to harden assets against increasingly frequent and extreme climate events is acknowledged, specifically in relation to bushfires and extreme heat.[129] From a climate risk assessment perspective, a very important project is the Electricity Sector Climate Information (ESCI) Project, which aims to improve climate and extreme weather information for the electricity sector. The project has delivered a package of new national climate datasets of relevance to the electricity sector, including: maximum and minimum temperatures; wind speeds; bushfire conditions; solar radiation; rainfall; and dam inflows. The data is produced on a scale of 1.5–12 km across the NEM, at sub-daily intervals, to the year 2100. This information is presented in a variety of formats including maps, summary tables and time series plots, supported by guidance material.[130]

The AEMO's 2020 Integrated System Plan[131] also includes a list of criteria that the AEMO considers to be identifiable characteristics of a resilient power system.[132] This includes:

- asset design and construction that is able to physically withstand hazards;
- flexibility in system operation to respond to events;
- control systems and protection schemes/settings that are fit-for-purpose and work well together despite increasing complexity;
- ability for the system to withstand separation or islanding events in a stable manner;
- diversity in geographic location of assets and generation sources to mitigate impact of hazards that affect a specific location or generation type;
- sufficient redundancy in fuel to withstand sudden 'shocks'; and,
- functional weather and output prediction for renewable resources.[133]

There is currently no legal requirement for utilities to adopt these resilience measures. Given the highly privatised nature of the electricity infrastructure, regulating for resilience may prove difficult as resilience is not a National Electricity Objective, as discussed in the Introduction. Although the Federal and State governments have developed Critical Infrastructure Resilience Strategies these are directed largely at cybersecurity concerns.

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126 AEMC, *South Australian black system review* (Final Report, 12 December 2019) 5.

127 ibid 14; see also National Electricity Rules, cl 4.2–4.3.

128 *2019–2020 NEM Summer Operations Review Report* (AEMO: June 2020) available at <https://www.aemo.com.au/-/media/files/electricity/nem/system-operations/summer-operations/2019-20/summer-2019-20-nem-operations-review.pdf> accessed 9 January 2022.

129 ibid 3–4.

130 See 'Electricity Sector Climate Information (ESCI) Project' <https://www.energy.gov.au/government-priorities/energy-security/electricity-sector-climate-information-esci-project> accessed 1 September 2021.

131 See '2020 Integrated System Plan (ISP)' <https://aemo.com.au/en/energy-systems/major-publications/integrated-system-plan-isp/2020-integrated-system-plan-isp> especially Appendix 8, accessed 16 December 2020.

132 ibid Appendix 8. Resilience and Climate Change Plan, 10–1.

133 ibid.

5.2. CALIFORNIA

In 2015, California embarked on an assessment of climate change vulnerability across economic sectors. State agencies established a working group to help utilities assess their vulnerabilities and develop resilience plans. California situates resilience as an aspect of climate adaptation.[134] In a 2019 decision, the California Public Utilities Commission (CPUC) defined resilience as the 'achieved outcome of an adaptation strategy, and states that '"resilient" means able to withstand extreme and incremental events and the ability of utility systems to recover when a disruption occurs.[135] The CPUC's primary emphasis, however, was on the broader concept of climate change adaptation, and it adopted a formal definition of adaptation as applied to utilities:

> Climate change adaptation is adjustment in natural and human systems to a new or changing environment. Adaptation to climate change for energy utilities regulated by the Commission refers to adjustment in utility systems using strategic and data-driven consideration of actual or expected climatic impacts and stimuli or their effects on utility planning, facilities maintenance and construction, and communications, to maintain safe, reliable, affordable and resilient operations.[136]

The relative emphasis on adaptation rather than resilience in California may be due to the generally robust role of climate policy under Californian law, whereas Australia has currently taken only modest, halting steps to address climate change. The AEMO's greater emphasis on resilience as a separate concept only allows it to make climate change a technical basis for considering one aspect of risk, whereas the CPUC can view adaptation as a broader issue.

In 2016, the CPUC directed utilities to establish processes for resilience planning and incorporate discussion of climate risks into the risk assessments accompanying requests for rate increases. The state's three major utilities included climate risks within those assessments, with one utility going so far as to examine possible climate impacts on its operations in 2050.[137]

A 2020 order provides detailed procedures to ensure that climate adaptation receives serious consideration. It requires utilities to create cross-department 'climate change teams', makes all members of corporate boards responsible for overseeing climate adaptation planning, and mandates the appointment of an executive at or above the senior vice president level to supervise the teams.[138] In addition, utilities must obtain climate risk information about a contracting partner when entering into long-term power purchasing agreements and if possible obtain a 'facility safety plan considering climate risks' for a supplier when submitting the agreement for CPUC approval.[139]

It is also worth noting that these adaptation assessment and planning mandates are integrated into the CPUC's control over utility rates. Such an approach would not be feasible in the Australian context of fully deregulated power markets.

6. WILDFIRE REDUCTION STRATEGIES AND SYNERGIES WITH CLIMATE MITIGATION MEASURES

Our focus in this section is primarily on measures adopted within the electricity sector to combat fire risks. We recognize, however, the interrelationship between climate change adaptation (such as fire-risk reduction) and mitigation measures (such as use of distributed energy to reduce risk from transmission lines).

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134 For more extensive discussion of adaptation in the electricity sector, see Andrea K Gerlak, Jaron Weston, Ben McMahan, Rachel L Murray, Megan Mills-Novoa, 'Climate risk management and the electricity sector' (2018) 19 Climate Risk Management 12–22.

135 CPUC, Order Instituting Rulemaking to Consider Strategies and Guidance for Climate Change Adaptation: Decision on Phase 1 Topics 1 and 2, Rulemaking 18-04-019, (Oct. 14, 2019), at 54 https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M319/K075/319075453.PDF.

136 ibid 56.

137 Romany M Webb, Michael Panfil, and Sarah Ladin, 'Climate Risk in the Electricity Sector: Legal Obligations to Advance Climate Resilience Planning by Electric Utilities' (Sabin Center on Climate Change, December 2020) 12.

138 CPUC, Decision on Energy Utility Climate Change Vulnerability Assessments and Climate Adaptation in Disadvantaged Communities (Phase 1, Topics 4 and 5), Decision 20-08-046 (27 August 2020) 5.

139 ibid 72.

DOI: 10.36633/ulr.812

Moreover, important aspects of risk reduction require action outside the electricity sector, such as improved vegetation management on public and privately owned lands. This may be particularly true in the US context, where decades of fire suppression in forests have left a legacy of combustible fuel. Another example relates to building codes, which are outside the domain of electricity regulators but help determine vulnerability to fire risks. That being said, electricity regulators have key responsibility to ensure that the power system does not itself become a source of fire risk and that fires do not imperil the reliability of the power supply. Fragmentation of authority over related issues may make coordination more difficult but could also create opportunities for policy innovation.

6.1 AUSTRALIA

6.1.1 Technology responses for resilient electricity infrastructure

The first principle of grid resilience from a climate change perspective is to transition away from fossil fuels and CO_2 emissions. As Australia's Renewable Energy Agency notes in its Future Grid for Distributed Energy position paper, there is already a global energy transition towards a low-emissions future. One feature of this transition is the rise of the 'prosumer', a customer that both produces and consumes electricity using distributed energy resources (DER) such as rooftop solar photovoltaic (PV) systems, behind-the-meter batteries and electric vehicles (EVs). They feed the electricity which they do not consume back into the grid. Australians are already global leaders, having installed over 2.3 million rooftop PV systems, equating to around 23% of households. It is forecast that on-site DER will be used by over 40% of Australian customers by 2027. This includes 29 gigawatts of PV and 34 gigawatt hours of behind-the-meter batteries.[140]

Meanwhile, according to AEMO, the NEM is evolving to a highly diverse portfolio dominated by DER, but supported by enough resources that can be easily switched on or off. This allows the power system to reliably meet demand at all times. In the transition to 2040 away from fossil fuels, coal-fired generation is expected to fall from 23 GW to 9 GW and small-scale DER is expected to double, if not triple, holding grid demand relatively constant.[141]

From the perspective of resilience to wildfires, SAPS or microgrids may prove more reliable than grid-connected power for customers which are on the 'edge' or 'fringe' of the grid and therefore susceptible to any fault that occurs along the extensive connection to their property. Endeavour Energy plans to reduce costs associated with energy delivery by installing SAPS instead of rebuilding poles and wires in remote locations which are difficult to access.[142] The installation of SAPS has been labelled a 'game changer' for providing reliable power to rural communities.[143]

To respond to the problem of electricity assets causing bushfires, the Victorian government installed rapid earth fault current limiters (REFCLs) after the 2009 bushfires. Energy Safe Victoria (ESV) has had oversight of their implementation, providing assurance to Victorians through a dedicated expert advisory committee that they were operating to the expected standard to prevent bushfires starting. In total, 22 substations on the network have benefited from REFCL protection across Victoria, including some installations which were in operation ahead of schedule. A CPUC decision in 2020 required utilities to provide climate risk assessments every four years as part of their pricing and budgeting processes.[144] Notably, the decision placed special emphasis on requiring utilities to consider the needs of vulnerable disadvantaged communities.[145]

140 'Future Grid for Distributed Energy' (*Australian Renewable Energy Agency*, June 2020) <https://arena.gov.au/assets/2020/06/future-grid-for-distributed-energy.pdf> accessed 3 September 2021.

141 ISP (n 131) 39.

142 'Stand Alone Power Systems (SAPS)' (*Endeavour Energy*) <http://www.endeavourenergy.com.au/> accessed August 2021.

143 Kim Ho, 'Endeavour Offers SAPS For Customers in Remote Properties' (*Utility Magazine*, 14 May 2020) <https://utilitymagazine.com.au/endeavour-offers-saps-for-customers-in-remote-properties/> accessed 21 August 2021.

144 California Public Utilities Commission, Rulemaking 18-04-019: Decision on Energy Utility Climate Change Vulnerability Assessments and Climate Adaptation in Disadvantaged Communities (Phase 1, Topics 4 and 5) (27 August 2020), https://perma.cc/2GKK-VCNP.

145 ibid 108.

6.2 CALIFORNIA

In 2018, California mandated that all new homes have solar energy and enacted a mandate for carbon-free electricity by 2045. California has mandated that utilities obtain 50 % target of their power from renewable sources by 2030.[146] There are significant variations in these standards from state to state in terms of the targets, deadlines and types of generation classified as renewable. Utilities also must participate in California's emissions trading system, which was established by a 2006 law known as AB 32.[147]

Among the strategies adopted by California are expanded use of microgrids, battery storage and the use of distributed energy resources. For example, in February 2021, the CPUC approved a new $200 million incentive programme to support microgrid development in vulnerable communities.[148] Californian utilities have surpassed their goal of expanding energy storage capacity by 1.3 gigawatts in 2020. In May 2020, PG&E committed to five battery storage projects, totalling 420 megawatts of storage capacity, from power sources including solar and geothermal energy.[149] Southern California Edison Co. (SCE) similarly signed contracts for seven projects that will create 770 megawatts of storage capacity.[150] The CPUC has opened a proceeding to provide a comprehensive framework for distributed resources. According to experts, 'regulatory forecasts have suggested behind-the-meter solar generation, behind-the-meter storage capacity and electric vehicle demand will increase by 260%, 770% and 370% respectively from 2019 to 2030'.[151]

6.3 MANAGING THE ELECTRICITY INFRASTRUCTURE/VEGETATION INTERFACE

As discussed in 4.4 above, compared with the Californian wildfire case study, electricity infrastructure was not responsible for igniting any of the fires in the Summer Fires. Nevertheless, for comparative purposes, the advanced regulatory framework in Victoria and New South Wales may point the way forward for California.

Following devastating bushfires in 2009, the 2009 Victorian Bushfires Royal Commission Final Report found that electricity infrastructure failure caused five out of the eleven fires. It consequently made eight specific recommendations, most of which have been, or are being, implemented.[152] Interestingly, the Commission recommended extensive undergrounding of transmission lines. However, following public discussion of the costs versus the risks and other priorities, this recommendation was not adopted.

In Victoria, the Electricity Safety Act 1998 (Vic) assigns responsibility for the safety, reliability, security and efficiency of electricity transmission and distribution networks to major electricity companies and 'other responsible persons' (such as councils or 'specified operators' who are not major electricity companies), subject to regulation by ESV.[153]

According to the Electricity Safety Act 1998 (Vic), the duties of major electricity companies include submitting bushfire mitigation plans[154] and submitting electricity safety mitigation schemes (ESMSs) in accordance with Electricity Safety (Management) Regulations 2019 (Vic).[155] The Act also lays out duties for specified operators and establishes ESV's compliance audit

146 See <https://www.arb.ca.gov/html/fact_sheets/2030_renewables.pdf> accessed 6 September 2021.

147 See <https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program> accessed 6 September 2021.

148 See <https://theclimatecenter.org/cpuc-approves-200m-investment-in-microgrids-for-vulnerable-communities/> accessed 6 September 2021.

149 See <https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20200519_pge_poised_to_expand_battery_energy_storage_capacity_by_more_than_420_megawatts> accessed 6 September 2021.

150 See <https://dailyenergyinsider.com/news/25363-southern-california-edison-to-bring-770-mw-of-energy-storage-capacity-to-region/> accessed 6 September 2021.

151 See <https://www.utilitydive.com/news/california-begins-brainstorming-approaches-to-a-high-der-grid-of-the-future/605309/> accessed 6 September 2021.

152 Bernard Teague, Ronald Mcleod and Susan Pascoe, *2009 Victorian Bushfires Royal Commission-Final Report Summary* (2010) 12, 29–30 <http://royalcommission.vic.gov.au/finaldocuments/summary/PF/VBRC_Summary_PF.pdf> accessed 22 August 2021.

153 Electricity Safety Act 1998 (Vic), s 6.

154 ibid s 113A.

155 ibid s 99.

powers. Generally, the Electricity Safety Act 1998 (Vic) concerns controlling the risk of electrical infrastructure starting bushfires.[156]

The Electricity Safety (General) Regulations 2019 (Vic) lay out requirements for the installation of infrastructure, such as technical specifications on voltage and positioning from the ground.[157] The Electricity Safety (Bushfire Mitigation) Regulations 2013 (Vic) prescribe the particulars of bushfire mitigation plans for major electricity companies and specified operators.[158] The Electricity Safety (Bushfire Mitigation Duties) Regulations 2017 (Vic) prescribe additional bushfire mitigation requirements applying to major electricity companies under part 10A of the Electricity Safety Act 1998 (Vic), for example covering or replacing underground electric lines or providing annual compliance reports.[159] The Electricity Safety (Electric Line Clearance) Regulations 2015 (Vic) set out a code of practice for electrical line clearance and establish a duty to submit a compliance management plan to ESV.[160]

ESV has a significant role in overseeing Network Service Provider (NSP) compliance in relation to the bushfire season. ESV publishes an annual End of Fire Season report[161] in which it assesses pre-season preparedness, fire events and operational actions by Victorian NSPs.[162] ESV also receives annual bushfire mitigation compliance reports from each NSP in relation to works performed under the Electricity Safety Act 1998 (Vic) and audits each NSP against its individual annual bushfire mitigation plans and policies.[163]

In 2016, the Victorian Government introduced a new 'f-factor scheme' which provides a financial incentive plan for energy distributors aimed at reducing fire ignition resulting from network infrastructure.[164] This is based on the number of network ignition events within the financial year or annual fire season, referred to as 'ignition risk units' (IRUs), compared to a benchmark number set with reference to previous fire seasons.[165] DNSPs report their IRUs to the AER, which are then verified by ESV before a revenue adjustment (currently at $15,000) is made per IRU.[166] Revenue adjustments fell significantly in the 2017–18 and 2018–19 periods compared to the previous 2016–17 period due to a higher number of fires.[167] The results of the 2019–20 period have not yet been released.

6.4 LAND USE PLANNING FOR RESILIENT INFRASTRUCTURE

In recognition of the important role which land use planning plays in preventing disasters, the Australian Institute for Disaster Resilience released the 2020 Land Use Planning for Disaster Resilient Communities Handbook (LUPDRC Handbook). It notes that land use planning with the risk of natural disasters in mind is the 'single most important mitigation measure in minimising the increase in future disaster losses' for new development and infrastructure projects by decreasing or avoiding exposure to known or projected environmental risks.[168] It outlines good practice for effective land use planning to reduce disaster risk for new developments and its

156 ibid s 98.

157 Electricity Safety (General) Regulations 2019 (Vic), reg 230.

158 Electricity Safety (Bushfire Mitigation) Regulations 2013 (Vic), regs 6–7.

159 Electricity Safety Act 1998 (Vic), ss 120N, 120P. For AusNet's *2020 Compliance Report-Legislated Bushfire Mitigation Programs* (2020), see <https://esv.vic.gov.au/wp-content/uploads/2020/08/AustNet_2020_BFM_Compliance_Report.pdf> accessed 16 December 2020.

160 Electricity Safety (Electric Line Clearance) Regulations 2015 (Vic), sch 1, reg 9.

161 For Energy Safe Victoria's *2019–2020 Annual Report*, see <https://esv.vic.gov.au/wp-content/uploads/2020/12/ESV_AnnualReport_2019-20.pdf> accessed 2 September 2021.

162 See, e.g., Energy Safe Victoria, *End of Fire Season Summary* (2019).

163 See, e.g., AusNet (n 159) and Energy Safe Victoria, *AusNet Services 2017–18 Bushfire Mitigation System Audit-Final Report* (2018).

164 AER, *Final Determinations and Explanatory Statement Electricity F-Factor Scheme 2016–2020 for Victorian Electricity Distribution Network Service Providers* (2017) 5.

165 ibid.

166 'Victoria F-Factor Scheme Results for the 2016–2020 Period' (*Australian Energy Regulator*, 30 June 2020) <https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/victoria-f-factor-scheme-results-for-the-2016-2020-period/update#main-content> accessed 21 August 2021.

167 ibid.

168 Australian Institute for Disaster Resilience, *Land Use Planning for Disaster Resilient Communities* (AIDR 2020) vii.

intended audience is emergency management professionals, land use planners and developers, leaders and individuals in communities.[169] It finds that vulnerability is created where assets are placed in hazardous areas and the standards used are inadequate or outdated in relation to the location of the asset.[170] It includes summaries of each natural disaster type that threatens Australia and immediate and wider risk drivers and consequences.[171]

First, a 'resilience vision' should be developed at the appropriate planning scale.[172] Although the Australian Constitution leaves land use planning and development to the states and territories, planning occurs mostly at the local level (with the exception of overarching state-wide policy) in variable environmental contexts.[173] Second, trends should be identified and analysed, again at the appropriate scale; for example, regional hazard maps may provide insufficient detail to make local decisions.[174] Third, 'treatment options' such as risk avoidance, risk transfer or risk acceptance should be considered in light of hazards and the safest option selected.[175] The fourth step is implementation and the fifth step is ongoing monitoring and review.[176]

The LUPDRC Handbook includes a chapter on legislative and regulatory planning instruments, outlining what each entails and the role they play in disaster resilience.[177] It also includes a chapter on spatial planning instruments, which identifies that regional plans usually guide the provision and coordination of infrastructure.[178]

6.4.1 New South Wales

In New South Wales, the NSW Rural Fire Service provides a framework for land use planning and development assessment entitled *Planning for Bushfire Protection 2019* (PBP), although most of the infrastructure affected by the Summer Fires would have been developed many decades before this came into effect. Under section 4.14 of the Environmental Planning and Assessment Act 1979 (NSW), development consent can only be granted on bushfire prone land if the relevant consent authority is satisfied that it complies with the specifications under the PBP. Bushfire prone land is determined with reference to local fire hazard maps, which the Rural Fire Service collects and certifies every five years and to which it may make direct amendments at any time.[179] Local councils, being responsible for planning schemes, should consult with the Rural Fire Service about bushfire hazards in strategic planning in relation to bushfire prone land and may be directed to consider the PBP by the Minister for Planning.[180]

Although relevant, this standard is not related to the bushfire attack level (BAL), which is partially based on the type of vegetation (forest, woodland, etc.) and its distance from the building (usually between approximately 5 and 100 metres).[181] This involves identifying all the vegetation formations for each aspect of a development within 140 metres of the development site or asset both within and external to the site boundaries, which informs the likelihood of radiant heat and flame contact.[182]

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169 ibid 1.

170 ibid 14. See also National Resilience Taskforce, *Profiling Australia's Vulnerability: The Interconnected Causes and Cascading Effects of Systemic Disaster Risk* (2018) 18.

171 Australian Institute for Disaster Resilience (n 168) 15–8.

172 ibid 24–5.

173 ibid 24.

174 ibid 25.

175 ibid 26.

176 ibid 27.

177 ibid 30.

178 ibid 34.

179 Environmental Planning and Assessment Act 1979 (NSW), s 10.3.

180 ibid s 9.1.

181 Industry Safety Steering Committee, *ISSC3 – Guide for the Management of Vegetation in the Vicinity of Electricity Assets* (2016) 91–3.

182 New South Wales Rural Fire Service, *Planning for Bush Fire Protection: A Guide for Councils, Planners, Fire Authorities and Developers* (2019) 85 <https://www.rfs.nsw.gov.au/__data/assets/pdf_file/0005/130667/Planning-for-Bush-Fire-Protection-2019.pdf> accessed 20 August 2021.

6.4.2 California

Land use management is primarily a local responsibility in California. Nevertheless, the state has adopted a framework dealing specifically with the wildland-urban interface.[183] Municipal governments containing fire hazard areas must meet state planning requirements. The general land use plans for these municipalities are required to include measures to manage wildfire risk, including where feasible locating essential public facilities outside high risk areas and ensuring access and water supplies for emergency responders. California also imposes perimeter standards on the design and construction of structures and housing developments. Municipal governments may receive assistance from state staff with safety review and recommendations for policy updates. The Governor's office provides technical advisories on fire hazard planning and best practices. Recent legislation requires an ember-resistant zone within five feet of structures.

The biggest gap in Californian legislation relates to new housing in fire prone areas, which local governments can be reluctant to inhibit. Given California's notoriously expensive urban housing markets, cheaper housing more remote from urban centres is an attractive option for the less affluent.

7. CONCLUDING THOUGHTS

Regulatory authority is divided differently in Australia and California, with the AEMO serving as a dominant national authority while the CPUC must operate within a framework giving significant authority to a regional entity (CAISO) and national regulators (FERC). The formally less comprehensive role of the CPUC, however, has not seemingly hindered its responses to climate resilience. The CPUC's performance has been superior in highlighting climate as a key factor in responding to grid risks and in forcing electricity providers to internalize consideration of climate risks. The CPUC has been less successful than its Australian counterpart in preventing fire-induced grid faults from starting fires. Australia, in the meantime, seems to have made more progress in incorporating wildfire risks into land-use planning. Each system therefore can learn significant lessons from the other.

One theme that emerges from the case studies involves the effects of fragmentation on resilience strategies. In both the Australian and Californian cases, decision-making over resilience issues is divided among different levels of government, federal and state, and between the private and public sectors. If anything, decision-making in Australia is more fragmented due to Australia's more aggressive neoliberal programme of replacing regulation with market solutions, which have an inherent tendency to favour efficiency over other goals. California has concentrated more power in the hands of its Public Utilities Commission, though the Commission's control of the system is far from complete. Fragmented authority, however, could provide the opportunity for policy experimentation with resilience measures, in a way that a more unified system could sometimes discourage. The relationship between resilience, public versus private control, and fragmented regulatory authority deserves further investigation.

As the AR6 has warned, the wildfire problem will continue to escalate due to climate change, both in terms of the frequency of fires and their severity. Thus, making the grid resilient will be an ongoing challenge because climate change and EWEs are a shifting threat. In addition to the technology changes already occurring to help build resilience, this article has highlighted the reforms that are needed to deal with the WUI and the siting of electricity infrastructure away from wildfire prone areas. It is hoped that the experiences in Australia and California might provide some guidance and inspiration to other jurisdictions grappling with the threats of climate-induced wildfires to their electricity infrastructure.

183 Community Wildfire Planning Center, *Land Use Planning Approaches in the Wildland-Urban Interface: An analysis of four western states: California, Colorado, Montana, and Washington* (Feb. 2021) 10–14, <https://www.communitywildfire.org/wp-content/uploads/2021/02/CWPC_Land-Use-WUI-Report_Final_2021.pdf>.

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The authors have no competing interests to declare.

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