Electricity system resilience

A discussion paper

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Introduction

In Australia, current regulations do not require, incentivise or enable distribution networks to robustly plan for and respond to extreme weather events and other shocks. Without reform, electricity system resilience will only worsen as the climate changes.

This discussion paper contributes to a national conversation about electricity resilience. We draw on research that we conducted as part of the Southcoast Microgrid Reliability Feasibility (SμRF) project, which explored energy resilience in the Eurobodalla, NSW. The analysis in this paper is drawn from a review of academic and grey literature as well as from research interviews we conducted with 19 professionals and experts across the resilience and energy infrastructure fields.

Together, these help us to understand the different views and perspectives on electricity resilience and next steps for us in Australia.

We find there is an urgent need for:

1. an electricity system resilience governance framework that is lead by national government with participation from stakeholders at all levels
2. consultation to converge on a common understanding of the key dimensions of electricity resilience
3. trials and experimentation to better understand the institutional and socio-technical innovations that would make our electricity system more resilient.

This discussion paper is accompanied by a more extensive review of electricity resilience, which is which is available as Supplementary Information.

The case for action

Electricity supply is never more important than during an emergency. Outages affect the ability to send and receive emergency communication, operate evacuation centres, defend properties from fire, charge devices, provide water and sewerage, access and make purchases from essential businesses, and maintain a healthy temperature.

After an extreme event, ongoing outages stymy recovery activities.[1] The importance of electricity supply could increase with the 'electrification of everything' if this process is adopted in rural areas since, with electrification, comes an increase reliance on electricity, for cooking, heating, hot water and transport with electric vehicles.

Currently, major outages are excluded from electricity network performance metrics, which means that avoiding or minimising major outages is not properly incentivised by Australia's electricity regulations. As a result, there are limited incentives for providing a more resilient energy system on either a system level or a local community and household level.

For everyday outages, the regulations are based on finding the most economically efficient level of system reliability, beyond which grid operators can compensate customers in lieu of supplying power.

Recent studies have exposed how vulnerable our energy systems are:

- **The AEMC's review of the South Australian 2016 system black event** found that multiple distributed ('indistinct') events can create unexpected risks and identified the need to regularly review and identify risks from all sources so that the system can be responsive.[2]
- **The 2022 Victorian Electricity Distribution Network Resilience Review** highlighted the need to understand hazards and climate at the local scale so that investments can be targeted effectively.[3]
- **The 2020 Royal Commission into National Natural Disaster Arrangements** emphasised the importance of local knowledge as well the need for cooperation and effort at the level of whole-of-nation, government and society, with a long-term, strategic view.[4]
- **Energy Consumers Australia's study of community impacts of the 2019–20 East Gippsland fires** showed the need for an energy system with better community engagement, adaptive capacity to 'build back better' and enhance energy independence, and a future focus.[5]

Considered in sum, we can see that the energy system is struggling to manage resilience at different geographical and temporal scales, and across a wide range of stakeholders.

What is energy resilience?

Resilience is seen as an extension of reliability, but it's not.

Interviews revealed that regulators tend to see resilience as having the same meaning as reliability, only involving longer outages affecting more customers or larger areas. However, there are distinct differences between resilience and reliability.

Reliability is concerned with average network performance and focuses on low impact, high probability events affecting static systems, such as faults, overloads or maintenance.[6,7] Resilience, on the other hand, refers to the ability to restore functionalities that are important in meeting community needs following high impact, low probability events.[7] This does not necessarily mean restoration to the same system as before the disturbance, and in fact, requires the capacity to adapt to change if better alternatives are available.[8] Actions taken in the short term to decrease vulnerability need to be consistent with long-term actions to mitigate climate change, otherwise the system is adapting in the wrong direction.[9]

Better resilience should improve reliability, but the inverse is not necessarily true. In the Eurobodalla region of the NSW South Coast for example, where the SμRF project was focussed, the electricity network performs well on regulated reliability metric[10] but was highly vulnerable to the devastating Black Summer fires of 2019–2020.

One reason that definitions of resilience are always likely to remain contested is because they imply action and responsibility within them; a point to which we will return. Still, a robust dialogue and convergence around a broad definition – or at least an understanding of the key dimensions of resilience - is a precondition for advancing a policy agenda and should therefore be a top priority.

Resilience relies on many factors

Resilience requires attention on specific parts of a system – social and technical – as well as on the capacity of the broad system to cope with and adapt to uncertainty.[11] Resilience investments need to be balanced between both the specific and broad scales, since effort channelled into developing one could reduce resilience in the other if not considered systemically.[11] We must also pay attention to both technical and social/institutional infrastructures, as they are inextricably interlinked.[11,12]

The 2016 system black in South Australia provides a stark illustration of the issues of scale and the importance of considering social and institutional aspects. The event exposed the difference between the resilience of specific generation assets versus that of the overall system, and the subsequent Finkel review[13] highlighted the need for both technical and institutional changes to support power system reliability (the need for generation to meet demand).[14]

Importantly, resilience requires implementing systems of prioritisation of resources, triage and sequencing, as well as the ability to make supplementary investments as an extreme event is unfolding. For example, power restoration could be prioritised to certain properties – such as those serving as community shelters or the homes of the more vulnerable. These all require negotiation between Networks, local councils, state government, the communications sector, the regulator and communities. This is challenged by a lack of a shared understanding and language around value; the value of human life, comfort and the natural environment. A consistent theme from our interviews was an understanding that building resilience required trade-offs; but that there was a lack of clarity, capacity and authority to make those decisions.

Resilience requires looking inwards and outwards

As we have outlined, resilience is not a fixed, stationary point to be arrived at. Resilient systems require ongoing adaption to changing conditions and social goals and they require active engagement by multiple stakeholders to continuously learn and adapt. Rather than relying on models that predict the future, we need to improve our capacity to plan for, and respond to, different scenarios, with an understanding of processes and trends associated with demography, climate change, social practices and more.[8]

In practice, this requires institutions to promote cultures and frameworks of experimentation and second order learning – that is thinking, questioning and learning about how they are going about their work on resilience, including questioning their underlying assumptions and goals.[11,15] It also requires drawing on knowledge and practices from different disciplines – not just those related to technology change, but also social, cultural and economic trends that help us understand the changing uses and needs of electricity in our everyday lives. We have disconnected energy planning from wider issues like climate change or social inequality, and in so doing, have made it difficult to understand and plan for resilience.

Coordinating resilience through nested governance

Across our interviews, there was a common theme that responsibility for resilience is shared amongst many stakeholders, with no one actor having ultimate responsibility. However, for many participants, government was deemed ultimately accountable.

And yet, in recent decades, in energy, as in other areas, we have seen processes of outsourcing, privatisation, and disaggregation of responsibilities which have made questions of accountability and responsibility for resilience even more complicated.

An additional factor in assigning responsibilities for various facets of resilience is that resilience requires context-specific action. Something that works in one setting won't necessarily work in another. Some portion of resilience must stem from local actors, with appropriate guidance and support so that local action is aligned with the broader system context.

Responsibility cannot be left entirely with local organisations, as their resourcing and coordination (at a minimum) remain the responsibility of more centralised institutions. This resourcing and coordination carry with them a particular sense of responsibility – one that is all too often found to be lacking, together with the resources and coordination themselves.

Coordinating local action with higher scales of system is often referred to as 'nested governance'. It is a term relevant to other types of natural resource managed that have local scales but relate to a broader system like a river system inside a broader catchment. It requires competent, proactive and well-resourced institutions at all scales.

Governance for resilience

Our research participants emphasised the importance of local context and experimentation in developing resilience, as well as a need for a national resilience authority with a long view and better national/state-level coordination of agencies. Multiple levels of governance were seen as important that can combine the small-scale benefits of local knowledge, with the larger-scale benefits of investment and abilities to address potential poor governance.

Research has shown that governance for resilience within an organisation needs to occur at multiple scales, at the:

OPERATIONAL LEVEL

Focusing on ensuring the day-to-day ability to absorb disturbances

TACTICAL LEVEL

Focusing on continuous improvement, adaptive risk management and opportunistic adaptive capacity; and

STRATEGIC LEVEL

Working with other system players to ensure that the energy system is being transformed towards long-term sustainability in the context of inevitable change and disruption.

We lack a clear governance framework for Networks to prioritise network investments in line with the values of a sustainable and resilient energy system. In parallel, and in conversation, we also need to strengthen local energy resilience efforts in terms of planning and capacity for householders and communities. A lack of infrastructure to facilitate dialogue between communities and networks will hamper future resilience planning.

Roles and responsibilities

Energy system governance requires a cooperative approach with measures to improve resilience at different scales.[11] As the 2020 Royal Commission into National Natural Disaster Arrangements made clear, different responsibilities for critical infrastructure resilience are shared between spheres of government, market bodies, networks, communities, and individuals.

Here are some examples of how shared responsibility for energy resilience works in practice:[4]

- **The Federal government** regulates the energy system and manages national security risks.
- **State and territory governments** set rules in legislation and coordinate resilience measures and manage emergency response.
- **Local governments** identify critical infrastructures, work with others to manage risks and to make sure they can still operate their services in an emergency, and educate and notify communities about disruptions and risk management.
- **The Australian Energy Market Operator** coordinates the National Energy Market and manages risks to supply through planning, collaboration and continuous improvement.
- **Network operators** maintain supply, manage risks to their assets and keep others informed.
- **Individuals and communities** are expected to stay informed and prepare for disruptions.

While these roles appear to be clearly defined, our research has revealed that these roles and responsibilities are contested amongst professionals and that householders have a strong desire for more government leadership in ensuring energy resilience.

How do institutional frameworks of resilience reflect community expectations?

Communities, whose lived experience of extreme events is ultimately at the heart of resilience, are not currently given a voice in defining what resilience means to them, the futures that they desire, or how they would like to participate in the creation of such futures.

Instead, their participation is constrained as expected 'consumers' in markets, to at best be offered consumer protections and market information. Trust, social fabric, political economies, and vulnerabilities – i.e. the fundamental building blocks of how governance is arranged and goods and bads are distributed – are fundamental to resilience, but are considered out of scope in this framing.

In short, community expectations of resilience differ from the way that it is currently understood by decision makers in both government and market bodies, leaving a crucial gap between institutional frameworks and lived experiences.

Electricity reliability requirements prioritise resolution speed

The regulatory framework that informs DNSP actions incentivises the rapid return of electricity to customers and communities experiencing an outage. Additionally, major events, such as those caused by severe weather, are excluded from those incentives and rural, less dense networks, are less prioritised in the framework, so have worse routine reliability experiences generally.[16]

Rapid return to normal service is critical but doesn't allow for consideration of measures that may improve resilience. Culturally, the DNSP understands how to 'build back the same' quickly, rather than 'build back better' or 'build back differently'.

Critical infrastructure – Systems of National Significance

Electricity networks are 'Systems of National Significance' and fall under the *Critical Infrastructure Act* 2018.[17] A 2023 Critical Infrastructure Resilience Strategy[18] developed by the Department of Home Affairs raised the importance of resilience and consideration of multiple threats, including natural hazards; however, there is no link between the Act or the strategy and the electricity regulatory framework that would underpin DNSP investment in resilience. This has resulted in decisions by the Australian Energy Regulator to not fully support requested investment in resilience measures, even where customers request it.[19]

How could resilience be improved?

We have described how resilience requires attention on specific parts of a system – social and technical - together with awareness of the interconnections between these parts and institutional capacities to cope with and adapt to uncertainty.

Investments (financial and cultural) into bolstering resilience therefore need to be made within a comprehensive framework that balances the specific and broad scales, as effort channelled into developing one could reduce resilience in the other if not considered systemically.

Such a framework for electricity system governance (at all scales) should be complemented by engagement and education frameworks. These will:

- ensure that understandings of resilience align with lived experience in communities,
- manage community expectations, particularly around the inevitability of some blackouts and the impossibility of technology silver bullets to resilience,
- give voice, and support to, individuals and communities that may find it hard to respond and adapt,
- keep investments connected to public needs and values and provide public accountability into the process.

While requiring input from stakeholders at all levels, leadership in coordinating and funding the development of such frameworks rests, in our judgement and in the views of many research participants, inescapably with national government.

The way forward

Efforts to bolster electricity system resilience will be fraught without coordination in an overarching governance framework. Our research suggests that such a framework is currently missing, urgently required, and needs leadership from national government and participation from stakeholders at all levels.

Two actions are immediate priorities for informing the development of such a framework:

1. inclusive consultation is required to converge on a common understanding of the key dimensions of electricity resilience,
2. trials and experimentation are required to better understand the institutional and socio-technical innovations that would make our electricity system more resilient.

In developing an electricity system-specific resilience framework, that draws from the strength of nested governance approaches, we recommend referring to the resilience frameworks from climate adaptation, natural resource management, and business.

In addition to this high-level agenda, we note opportunities for constructive actions from many stakeholders in the Appendix.

References

1. NSW Government. 2022 *Flood Inquiry - Volume Two: Full Report*. (2022).
2. Australian Energy Market Commission. *Mechanisms to Enhance Resilience in the Power System: Review of the South Australian Black System Event*. https://www.aemc.gov.au/sites/default/files/documents/aemc_-_sa_black_system_review_-_final_report.pdf (2019).
3. State of Victoria. *Electricity Distribution Network Resilience Review*. https://www.energy.vic.gov.au/__data/assets/pdf_file/0039/578928/Network-Resilience-Review-Final-Recommendations-Report-FINAL.pdf (2022).
4. Commonwealth of Australia. *Royal Commission into National Natural Disaster Arrangements Report*. (2020).
5. The Insight Centre. *The Connections That Matter*. https://energyconsumersaustralia.com.au/wp-content/uploads/ECA-Connections-That-Matter-August-2021.pdf (2021).
6. Ausgrid *et al*. Network Resilience. 2022 Collaboration Paper on Network Resilience. (2022).
7. Mishra, D. K., Ghadi, M. J., Azizivahed, A., Li, L. & Zhang, J. A review on resilience studies in active distribution systems. *Renew. Sustain. Energy Rev.* **135**, 110201 (2021).
8. Nik, V. M., Perera, A. T. D. & Chen, D. Towards climate resilient urban energy systems: a review. *Natl. Sci. Rev.* **8**, nwaa134 (2021).
9. Kelly-Pitou, K. M. et al. Microgrids and resilience: Using a systems approach to achieve climate adaptation and mitigation goals. *Electr. J.* **30**, 23–31 (2017).
10. Ransan-Cooper, H., Russell, A. W. & Sturmberg, B. *Microgrids for Resilience? Findings from the SμRF Project*. (2024)
11. van der Merwe, S. E., Biggs, R. & Preiser, R. A framework for conceptualizing and assessing the resilience of essential services produced by socio-technical systems. *Ecol. Soc.* **23**, (2018).
12. Delina, L. L., Ocon, J. & Esparcia, E. What makes energy systems in climate-vulnerable islands resilient? Insights from the Philippines and Thailand. *Energy Res. Soc. Sci.* **69**, 101703 (2020).
13. Department of the Environment and Energy. *Independent Review into the Future Security of the National Electricity Market: Blueprint For the Future*. (Commonwealth of Australia, Canberra, 2017).
14. 1Australian Energy Market Commission, R. P. *The Reliability Standard*. https://www.aemc.gov.au/media/92652 (2020).
15. Hamborg, S., Meya, J. N., Eisenack, K. & Raabe, T. Rethinking resilience: A cross-epistemic resilience framework for interdisciplinary energy research. *Energy Res. Soc. Sci.* **59**, 101285 (2020).
16. Australian Energy Regulator. *Electricity Network Performance Report*. https://www.aer.gov.au/system/files/2023-Electricity-network-performance-report.pdf (2023).
17. Australian Department of Home Affairs. *Security of Critical Infrastructure*. C2023C00376 (C06) (2018).
18. Australian Department of Home Affairs & Cyber and Infrastructure Security Centre. *Critical Infrastructure Resilience Strategy*. https://www.cisc.gov.au/resources-subsite/Documents/critical-infrastructure-resilience-strategy-2023.pdf (2023).
19. Australian Energy Regulator. *Final Decision. Ausgrid Electricity Distribution Determination 2024 to 2029*. (2024).

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Appendix

The Federal government

- Provide proactive leadership, and funding support, for the development of the (cross-)institutional frameworks that facilitate coordination between critical infrastructure systems (for example electricity and telecommunications systems) and between all involved organisations (for example local governments and emergency services).
- Ensure that the Australian Energy Regulator is provided with a framework against which to assess resilience investment requests. This may be partially achieved by accommodating the Critical Infrastructure Act in the National Electricity Law, Rules and Frameworks.
- Ensure that there is a standard suite of accessible future climate projections for Australia, with clearly defined upper and lower bounds (Representative Concentration Pathways (RCPs), now replaced by Shared Socioeconomic Pathways (SSCs)[a]), that should be used for risk assessments of vulnerabilities and resilience for Systems of National Significance. This would support investment decisions based on a common understanding of the risk.

State and territory governments

- Provide leadership and coordination to local governments and to emergency services, which tend to be organised at a state level.
- Provide leadership in communication and expectation setting with communities that extreme weather events will continue to become more prevalent in a climate changed world and that this makes some disruption, and the need for local community preparedness, inevitable.
- Ensure that the national standard suite of accessible future climate projections are downscaled to the relevant state or territory.
- Require all relevant entities in the state or territory to use the downscaled projections in regional risk assessments of vulnerabilities and resilience
- Utilise the risk assessments from DNSPs to inform planning and projects for electricity resilience
- Undertake a state- or territory-wide risk assessment to identify vulnerable critical infrastructure and the interdependencies of critical infrastructures.
- Require local governments to undertake risk assessments of their own assets and dependencies on critical infrastructure, including electricity.
- Respect, value and invest in infrastructures of 'care'.[b]

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a https://environment.govt.nz/what-you-can-do/climate-scenarios-toolkit/climate-scenarios-list/ipccs-ssp-rcp-scenarios/

b https://static1.squarespace.com/static/5ae6de517c932736b15f2cc7/t/664331af1fb0a26dececb7e3/1715679679275/Care+through+disaster+in+practice+-+TOOLKIT.pdf

Local government

- Work with local communities to develop emergency response plans that consider electricity resilience, in ways that appreciate, respect, and draw strength from diverse circumstances, needs and capacities.
- Consider information from DNSPs on locations with vulnerable and at-risk electricity infrastructure, working to develop resilient solutions. These solutions may not be network investment, but support for community or household level options (not necessarily appropriate to be delivered by the DNSP).[c]
- Consider approaches that support communities that require extra support to respond to severe events where electricity affordability or access to technology may be an issue (e.g. severe heat events).

Local communities and individuals

- With support from local government, develop community and household emergency response plans.
- Invest in community connectedness[d] and infrastructure of 'care'.[e]

Electricity Networks

- Recognise that while DNSP have a critical role in identifying where their networks are vulnerable and the degree of risk, they may not be the best party to led or develop solutions, which communities often wish to prioritise communication and responsiveness over technical reinforcement.[f]
- DNSPs should assess the resilience of their network annually (a requirement as a SoNS owner), using a standard suite of common climate projections and an ISO 31000 compliant risk assessment framework, and be required to inform the relevant state government. Ideally, the risk assessment framework would be standardised across all DNSPs.
- DNSPs can propose solutions that reduce risk, but these network-focused approaches may not be the best option for impacted communities and customers.
- Recognise that following an event, time will be needed to craft the most appropriate resilience solution, which will be bespoke to each community, and that restoring electricity may need to undertaken in a way that can be easily and cost-effectively replaced with the resilience solution at a later date.

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c https://bsgip.com/wp-content/uploads/2024/05/Challenges-and-opportunities-for-grid-tied-microgrids-1.pdf

d https://www.thriving.org.au/files/Knowledge Hub/TCP/Disaster Planning and Recovery Collaborative Research Project Phase 2 Report.pdf

e https://static1.squarespace.com/static/5ae6de517c932736b15f2cc7/t/664331af1fb0a26dececb7e3/1715679679275/Care+through+disaster+in+practice+-+TOOLKIT.pdf

f https://engage.vic.gov.au/download/document/35884