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Response to Capacity Mechanism Project High-level Design Paper

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25 July 2022

Anna Collyer

Chair

Energy Security Board

Lodged electronically

Dear Ms Collyer,

Re: Capacity Mechanism Project High-level Design Paper

The Collaboration on Energy and Environmental Markets (CEEM) at UNSW Sydney welcomes the opportunity to make a submission in response to the Energy Security Board's (ESB) Capacity Mechanism Project High-level Design Paper.

About us

The UNSW Collaboration on Energy and Environmental Markets (CEEM) undertakes interdisciplinary research in the design, analysis and performance monitoring of energy and environmental markets and their associated policy frameworks. CEEM brings together UNSW researchers from a range of Faculties, working alongside a number of Australian and international partners. CEEM's research focuses on the challenges and opportunities of clean energy transition within market-oriented electricity industries. Effective and efficient renewable energy integration is key to achieving such energy transition and CEEM researchers have been exploring the opportunities and challenges of market design and policy frameworks for renewable generation investment, as well as investment in the necessary flexible resources to facilitate its integration, for the past two decades. More details of this work can be found on the Collaboration website. We welcome comments, suggestions, questions and corrections on this submission, and all our work in this area.

Please contact Abhijith (Abi) Prakash regarding this submission (abi.prakash@unsw.edu.au), and Professor Iain MacGill, Joint Director of the Collaboration (i.macgill@unsw.edu.au), and/or Associate Professor Anna Bruce, CEEM's Engineering Research Coordinator (a.bruce@unsw.edu.au), for other CEEM matters.

Our submission

We welcome the opportunity to comment on the ESB's Capacity Mechanism Project. We broadly agree with the ESB that there are currently significant barriers to a timely and effective transition to a low-carbon NEM. In particular, **we agree that deep and wide-ranging uncertainties** may**:**

- **Prevent the timely exit of ageing thermal generation**; and
- **Suppress the significant investment in clean energy infrastructure** required to compensate for the exits of large power stations and, more broadly, effectively and efficiently decarbonise electricity supply in southern and eastern Australia. Achieving the latter is critical in achieving our wider net-zero goals as electricity supply is also likely to underpin efforts to reduce carbon emissions in other sectors of the Australian economy.

We acknowledge that market reform and designing policy frameworks to address these uncertainties is a challenging task, and we sympathise with the ESB's remit given the scope and magnitude of the challenges that need to be addressed.

However, **our view is that the ESB's proposed capacity mechanism is inadequate and perhaps inappropriate to deliver an effective and efficient energy transition.** The mechanism proposed by the ESB would likely be a **second-best solution (or worse)** to the various barriers explored in the High-level Design paper's "Case for Change" and in this submission.

As such, we have taken an alternative approach to this submission that first **contests the nature and representation of the barriers to energy transition in the NEM** (as presented in the "Case for Change" in the High-level Design Paper) **and the benefits of capacity auctions, let alone the capacity mechanism proposed by the ESB** (Sections 1.1 and 1.2). We then proceed to **outline what we see as the key barriers to transition, as well as a suite of coordinated solutions to these barriers** (Section 1.3). Finally, we discuss the **underappreciated need for (physical) power system resilience,** and advocate for **the implementation of a supply-demand resilience mechanism** in Section 2. Such a mechanism would provide a robust set of "backstop" reserves should growing threats to electricity provision materialise, and is justified considering that the costs of mitigation measures are likely to be relatively small when compared to the direct and broader social costs of electricity sector failure, both in the short-term with regard to affordability and security, and in the longer-term with respect to decarbonisation.

We would of course be very happy and interested to discuss these comments further with the ESB if that is of interest to you and your colleagues. All the best for this challenging but extremely important work, and sincere regards,

Abhiijith Prakash, Ashleigh Nicholls, Declan Heim, Anna Bruce and Iain MacGill

Collaboration on Energy and Environmental Markets
UNSW Sydney

Executive summary

Section 1: Addressing the case for change

In our view, **two interrelated aspects of the energy transition are inappropriately represented** in the Case for Change section of the High-level Design Paper**, or inadequately addressed** by the proposed capacity mechanism:

1. The proposed capacity mechanism **is not designed to facilitate investment in new, transition-enabling resources**.
    - The proposed capacity auction delivery timeframe is relatively short (T-3 or T-4 years), and a longer contract length for new resources was only briefly mentioned in the High-level design paper. As proposed, we are of the view that the ESB's capacity mechanism may be inadequate to provide material improvements to long-term investment certainty for new resources in the NEM.
    - Further concerns are that the proposed capacity mechanism has relatively weak pay-for-performance features, and that there may be a reliance on participant self-reporting, given that the *ex-post* assessment metric has "some significant enforceability weaknesses".
    - Regulating coal-fired power plants closures is a preferable mechanism to reduce the likelihood of disorderly and disruptive exits and provide certainty for private investments. Counter to facilitating investment in resources required for transition, the proposed capacity mechanism may in fact delay exit of thermal generation and increase uncertainty for new investment.
    - Jurisdictional support schemes are likely to provide greater certainty to investors and are thus better placed to deliver a timely, effective and robust energy transition. Such schemes could include support for large-scale storage and be designed to coordinate

resource deployment with network (transmission system build-out and/or system security) needs.

2. The proposed capacity mechanism is **incomplete without a concrete mechanism for addressing emissions reductions**. Furthermore, it **does not assure transition to a low-carbon power system** as it **does not explicitly target a portfolio of resources that enables the deployment of VRE and facilitates the secure and reliable operation of a low-carbon NEM**.
    - We are of the view that resource flexibility and diversity (rather than capacity alone) is required for an effective, efficient and resilient low-carbon grid.
    - In particular, the capacity de-rating methodology favoured by the ESB may not deliver these outcomes. We discuss an alternative de-rating methodology that better recognises resource flexibility and diversity in our submission. However, this methodology may progressively de-rate each new round of variable renewable energy capacity, and thus need to balance against the need for large-scale VRE deployment to facilitate decarbonisation.

Section 2: A supply-demand resilience mechanism

In addition to the factors at play that are endogenous to the power system and the NEM (e.g. coal retirement, significant new entry), we use this opportunity to discuss *exogenous* factors and their implications on operation, planning and investment in the NEM during energy transition. Notably, we observe that:

- There is a growing societal dependence on a reliable electricity supply. As a result, **widespread and long-duration electricity outages or supply shortages are even more societally unacceptable.**
- There are **growing threats to reliable electricity supply**, including the changing nature of our power system and the increased frequency and severity of extreme weather events due to climate change.

Existing market and/or non-market mechanisms may not adequately insure the NEM against high impact, low probability (HILP) events that hamper system balancing over timeframes of a few minutes to a few weeks. Firstly, cost-benefit analysis, which underlies most market-driven decision making, and efficiency, a primary goal of market-based mechanisms, are arguably antithetical to "hardening" the NEM for resilience. Secondly, current regulatory frameworks aimed at delivering resilience are focused on expanding actions available to AEMO to enhance operational resilience. As such, they do not facilitate infrastructure investment that may be required to address resilience in planning timeframes. Lastly, there is some doubt as to whether the Reliability and Emergency Reserve Trader (RERT) in its existing form can address sustained supply shortfalls (that extend for days or weeks, for example) following HILP events.

Given these factors, **there is a clear need for a mechanism to provide "supply-demand resilience"** (resilience to HILP events that threaten supply-demand balance within resource adequacy timeframes). Such a mechanism may be justified on the grounds that **HILP events entail asymmetric costs**– that is, the additional cost of mitigation measures is likely to be small compared to total system costs, and likely to be dwarfed by the direct and broader social costs of market and/or power system failure.

To address this need, we propose a "**supply-demand resilience mechanism**", constituting of **Jurisdictional Strategic Reserves** (JSR) with an **emphasis on diversity in fuel type and network location** to address the increasingly prevalent risk of HILP events. We envision such a mechanism would enhance existing RERT arrangements. At a high-level, the supply-demand resilience mechanism might function as follows:

1. **AEMO prepares advice for each jurisdiction on the quantity and nature of JSR** that may be required, involving:
    - The identification of a suite of severe reliability/HILP events to consider.

    - A determination of candidate JSR resource mixes, with an emphasis on considering resource type and network location diversity.
    - Assessment of candidate JSR resources mixes through “stress-testing”.
2. Jurisdictions (i.e. state governments) receive publicly-available AEMO advice and **tender for resources as they see fit**
3. JSR would function as **out-of-market “standing reserves”** in operational timeframes and may only be deployed through current arrangements for RERT.

In Section 2.3.2, we “screen” a set of major HILP events that have affected system balancing both in the NEM and other jurisdictions. From our qualitative assessment of root causes and observed responses, we conclude that a **reliable, technologically diverse and geographically dispersed set of resources, which could be procured as a part of JSRs, is best able to mitigate against a variety of HILP events**.

We stress that our proposal would only be able to address supply-demand resilience, a subset of broader power system resilience. **A more holistic approach to resilience should consider how resilience can be incorporated into planning and investment processes in the NEM.**

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Key Abbreviations

AEMC: Australian Energy Market Commission

AEMO: Australian Energy Market Operator

AER: Australian Energy Regulator

ARENA: Australian Renewable Energy Agency

BESS: Battery energy storage system

CAISO: California Independent System Operator

CRM: Capacity remuneration mechanism

DSR: Demand side response

ELCC: Equivalent load carrying capacity

EFC: Equivalent firm capacity

ESB: Energy Security Board

FCAS: Frequency control ancillary services

HILP: High impact low probability

ISP: Integrated System Plan

JSR: Jurisdictional Strategic Reserve

LSE: Load serving entity

LTESA: Long Term Energy Service Agreement

MISO: Midcontinent Independent System Operator

NEM: National Electricity Market

PASA: Projected Assessment of System Adequacy

PJM: Pennsylvania-New Jersey-Maryland Interconnection

RERT: Reliability and Emergence Reserve Trader

SWIS: South West Interconnected System

VCR: Value of Customer Reliability

VRE: Variable renewable energy

WALDO: Widespread and long duration outage

1 Addressing the case for change

In our view, **two interrelated aspects of the energy transition are inappropriately represented** in the Case for Change section of the High-level Design Paper**, or inadequately addressed** by the proposed capacity mechanism: the **facilitation of investment in new, transition-enabling resources**, and the **delivery of extensive carbon emissions reductions in the electricity sector.**

Elements of these aspects are discussed in further detail in Sections 1.1 and 1.2. In these sections, we draw on experience from global electricity markets with some form of capacity remuneration mechanism (CRM). Numerous types of CRMs exist. National Grid (UK), Midcontinent ISO (MISO) and Pennsylvania-New Jersey-Maryland Interconnection (PJM) all have central buyer mechanisms comprising of volume-based and market-wide auctions for capacity[1]. Germany and Sweden (and at one stage, Belgium) have targeted, volume-based strategic reserves - contracted capacity, which in the case of Germany and Belgium, cannot be integrated into the energy market[2]. The Reserve Capacity Mechanism in the South West Interconnected System (SWIS) in WA and Resource Adequacy Mechanism in California ISO (CAISO) involve decentralised capacity obligations. In the SWIS, market customers have capacity requirements established through central forecasting and must secure bilateral contracts for capacity credits certified by AEMO, after which capacity auctions are held if insufficient capacity is procured. In CAISO, load serving entities (LSE) (retailers) are obliged to secure bilateral contracts for capacity to meet their forecast peak demand plus a reserve margin[3].

Many global CRMs have been reformed or established within the past 10 years. As such, CRM design is an evolving area with no globally prevailing design features[4].

1.1 Facilitating investment

While we agree that "*the uncertainties facing investors have never been greater*"[5], **we contest several assertions made in the ESB's High-level Design Paper**:

1.1.1 "A mechanism that is consistent NEM-wide is needed to drive private investment"

The High-level Design Paper suggests that private investment is at odds with state and federal government support schemes, as the latter poses risks and creates uncertainty for the former. Furthermore, there appears to be a preference for a NEM-wide mechanism to assist in driving private investment rather than a jurisdiction-by-jurisdiction approach.

We **question whether the NEM, in and of itself, has ever been truly 'fit for purpose' for private investment**, given that resources at the NEM's inception were built by state-owned enterprises, and given that government owned corporations and government support schemes – State and Federal - have

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[1] Andreas Bublitz et al., 'A survey on electricity market design: Insights from theory and real-world implementations of capacity remuneration mechanisms', Energy Economics 80 (February 2019): 1059-1078, https://doi.org/10.1016/j.eneco.2019.01.030.

[2] Andreas Bublitz et al.; Par Holmberg and Thomas Tangeras, 'Strategic Reserves versus Market-wide Capacity Mechanisms', University of Cambridge Energy Policy Research Group, EPRG Working Paper, April 2021.

[3] Greg Williams, 'Profiling the Capacity Market Debate' (Australian Energy Market Commission, n.d.), https://www.aemc.gov.au/news-centre/perspectives/economists-corner-profiling-capacity-market-debate.

[4] Andreas Bublitz, 'A Survey on Electricity Market Design: Insights from Theory and Real-World Implementations of Capacity Remuneration Mechanisms', *Energy Economics* 80 (February 2019): 1059–78.

[5] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', June 2022, i, https://www.energy.gov.au/sites/default/files/2022-06/Capacity%20mechanism%20high-level%20design%20consultation%20paper.pdf.

facilitated the entry of many dispatchable and VRE resources since the NEM's inception[6]. Moreover, it may well be **risky to solely rely on the private sector to deliver the significant investments required for energy transition to occur in a timely and effective, let alone robust manner**. As we discuss in greater detail in the next section (Section 1.1.3), we are of the view that government support schemes provide certainty for private investment – certainly more so than any existing mechanisms (which are in constant flux due to extensive and ongoing market restructuring) or the proposed capacity mechanism.

It seems **unlikely that a capacity mechanism would indeed provide an investment support mechanism that is consistent NEM-wide, as jurisdictions would retain the ability to opt in or out and would be able to select which technologies can participate in their auction**[7]. We note that these features themselves could be a source of significant uncertainty for the private sector. Given the multitude of state government support schemes in place and the high likelihood of further state and federal government support schemes (noting the Constitutional powers and responsibilities allocated to state governments vis-à-vis electricity supply), NEM-wide mechanisms may be **better off seeking to facilitate jurisdictional schemes rather than attempting to replace them**.

1.1.2 "Incentives are sufficient, and should be linked to the intention to supply"

The ESB proposes that capacity credits be designed to incentivise the *intention* to supply (i.e. offer their de-rated capacity as available). One component for payment would be linked to the *intention* to supply across the year, and the other would be linked to the *intention* to supply during periods of low reserves[8].

As such, the ESB's proposed mechanism is **not geared towards capacity that *actually performs if and as required*. Withdrawing only one component of payment for non-performance during periods of system stresses increases the divide between participants' financial risks, and physical power system and broader social risks**. Furthermore, it is highly problematic that the metric for assessment cannot be relied upon by the AER ("availability has some significant enforceability weaknesses"[9]). Whilst we support "fostering a culture of compliance", we are of the view that a reliance on "self-reporting" is inappropriate[10].

While proportionate and enforceable penalties would be preferable, significant reform would likely be required to ensure that participants are obliged to provide information that is appropriate and truthful for assessment by the AER (given that constraints may prevent resources from being dispatched at their (de-)rated capacity). **Without appropriate enforceability, the proposed capacity mechanism risks additional costs to consumers with no material benefits to reliability.**

We also note that **existing financial products function in a similar manner to pay-for-performance capacity mechanisms**. The sale of **cap contracts, in combination with a high market cap**, strongly incentivises participants with generating resources to have these resources dispatched during periods of high prices (which are typically associated with tight supply-demand balance) or risk a "penalty" in the form of losses that are proportional to the degree of system stress. In exchange for the sale of a cap, participants receive a premium which, if the cap is defended by a generating resource, could be considered as a "capacity payment".

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[6] Energy Security Board, ii, 10; Alan Rai and Oliver Nunn, 'Is There a Value for "Dispatchability" in the NEM? Yes', *Electricity Journal* 33, no. 3 (2020): 106712, https://doi.org/10/gnv8qq; Iain MacGill, 'Is the Australian National Electricity Market "Fit for Purpose" in Delivering Clean Energy Transition', https://www.ceem.unsw.edu.au/sites/default/files/documents/macgill%20-%20APSRC%20plennary%20NEM%20fit%20for%20purpose%20web.pdf.

[7] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 5.

[8] Energy Security Board, 54.

[9] Energy Security Board, 55.

[10] Energy Security Board, 55.

However, **we are uncertain whether leveraging such products in mechanisms that enforce contracting will deliver investment in new resources**. Exchange traded caps cover long periods (a quarter or a year), with a strike price that has not been changed since the NEM's inception ($300/MW/hr). Is this product suitable for an energy system in transition? Furthermore, ASX Energy derivatives also provide only relatively short-term risk management, and **derivative markets are illiquid or regulated in some NEM states**[11]. Finally, a key concern is that **cap contract risk can be managed financially** (i.e. there is no obligation for these contracts to be backed by resources in the power system).

A question remains as to why a more performance-oriented reward scheme cannot be adopted, given that (more) stringent pay-for-performance capacity frameworks have been implemented in PJM, the SWIS and the UK. Beginning in the 2020/21 delivery year, PJM requires 100% of capacity to be available whenever emergency conditions are identified. This is monitored by comparing actual metered output with expected performance[12]. Capacity credits are awarded for over performance and non-performance charges are imposed for underperformance. The SWIS distinguishes between conventional and intermittent generators for performance penalties. The former is required to be available in every interval, or otherwise must pay reserve capacity refunds, though the latter has no obligation to ensure the availability of capacity. Demand side response (DSR) must have the ability to reduce demand between 8am and 8pm[13]. The UK penalises plants that do not meet their capacity expectations at 1/24th of the auction clearing price.

1.1.3 "A capacity mechanism provides much-needed long term investment signals"

In an effort to balance the trade-offs between the provision of *"forward investment certainty (tending towards earlier procurement) and the accuracy of capacity forecasts (tending to later procurement)"*[14], the ESB have favoured annual capacity auctions with the preliminary suggestion that an initial auction could occur perhaps "T-3 or T-4, or longer" from the year of delivery. That is, certainty surrounding revenue streams from a capacity mechanism is limited to 3-4 years before the delivery year.

Given these factors, **it is unclear how, if at all, the proposed capacity mechanism's auction delivery timeframe provides more certainty than existing mechanisms.** We note that market exchanges, such as ASX energy, trade standardised electricity futures and options for delivery years approximately 3 years out.

While longer contract lengths were flagged for new resources, it was raised with the proviso that "*long term investment support represents a risk transfer from capacity providers to customers and that such longer-term capacity contracts could become 'out of the money' over time*"[15]. This may certainly be the case, but is should be noted that insufficient investment in transition-enabling resources due to significant uncertainty and the associated higher cost of capital is also a risk that must be considered. We also note that jurisdictional schemes are currently providing long-term investment support – e.g. NSW's long duration storage long-term energy service agreements (LTESA) provides a form of revenue guarantee for BESS for up to 14 years, and pumped hydro for up to 40 years[16].

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[11] Australian Energy Regulator, 'State of the Energy Market 2021', 2021.

[12] Conleigh Byers, Todd Levin, and Audun Botterud, 'Capacity Market Design and Renewable Energy: Performance Incentives, Qualifying Capacity, and Demand Curves', *The Electricity Journal* 31, no. 1 (February 2018): 65–74.

[13] Western Australian Government, 'Storage Participation in the Reserve Capacity Mechanism' (Energy Transformation Taskforce, 2020), https://www.wa.gov.au/system/files/2020-07/Information%20Paper%20-%20Storage%20participation%20in%20the%20Reserve%20Capacity%20Mechanism.pdf.

[14] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 42.

[15] Energy Security Board, 40.

[16] NSW Department of Planning, Industry and Environment, 'Long-Term Energy Service Agreement Design Consultation Paper', August 2021.

It is important to point out that **long-term investment support can be made more robust** by using least-regrets or least worst-regrets decision-making frameworks (as in AEMO's ISP). However, **robustness will likely come at the cost of the fungibility of resource characteristics** (e.g. considering resource type or network location as is further discussed in Section 1.2.2), **and thus the suitability of single commodity market-based mechanisms** (e.g. the proposed capacity mechanism) for allocating such support. In contrast, **multiple resource characteristics can be considered in reverse auction/tender schemes**.

Globally, the extent to which CRMs facilitate investments in new resources varies significantly between electricity markets and depends on CRM design, including the **auction delivery timeframe and contract length**. National Grid determines capacity payments four years (T-4) and one year (T-1) prior to delivery and grants 1 year, 3 year and up to 15-year 'Capacity Agreements' to existing plants, existing plants requiring refurbishment and new build capacity respectively[17]. Despite the long-term contracts for new generation, between 2014 and 2018, 83.4% of total capacity payments went to existing generation, which likely would have remained available regardless of the capacity mechanism, and only 3.5% went to new build generation[18]. Belgium initially implemented strategic reserves to phase out thermal power plants; however, the 1-year contracts were not suitable for supporting new investment and so has since transitioned to a capacity market with long-term contracts of up to 15 years. The first capacity auction, T-4 2024/25 secured 36% of contracts from new build generation[19].

Global experience certainly suggests T-3 or T-4 auctions do not provide sufficient investment certainty to deliver the required investment in new capacity. In contrast, long-term tenders/contracts can not only secure revenue certainty for private investment, but also be assessed across multiple criteria (e.g. various resource characteristics).

1.1.4 A capacity mechanism will ease pressure on existing assets, but will not "extend the lifespan of ageing coal generators"

The ESB appears to be relying on a capacity mechanism as a panacea that will co-ordinate the exit of ageing and emissions-intensive coal-fired power stations with investment in and the entry of new resources.

Given that we see uncertainty in the timing of coal-fired power station closures as a key contributor to investment uncertainty for new entry resources (Section 1.3), the **ESB's capacity mechanism appears to be a second-best option (or worse) for addressing the timeliness and certainty of closure dates**. While they might occur 1-2 years ahead of notice-of-closure obligations, initial capacity auction rounds conducted 3-4 years ahead of a delivery year only indicate that there is a *potential* that resources may retire (i.e. in the event that the resources does not participate). Furthermore, **awarding coal-fired power stations capacity credits does not seem sufficient to ensure that their exit is not disruptive to grid and market operations**. Participants will likely consider revenue awarded through a capacity auction as one of many commercial factors, including contracting (and the cost of trading-out of positions), spot market revenue, operational viability and costs, and retirement costs (site remediation, staff redundancies, etc.)[20].

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[17] National Grid, 'Capacity Market Auction User Guide: Guidance Document for Capacity Market Participants', March 2017, https://www.emrdeliverybody.com/Capacity%20Markets%20Document%20Library/Capacity%20Market%20Auction%20User%20Guide%20v3.pdf.

[18] Greg Williams, 'Profiling the Capacity Market Debate' (Australian Energy Market Commission, n.d.), https://www.aemc.gov.au/news-centre/perspectives/economists-corner-profiling-capacity-market-debate.

[19] FTI Consulting, 'Investment and Flexibility Market Design', February 2021, https://www.nationalgrideso.com/document/232681/download.

[20] Frontier Economics, 'Barriers to Exit for Electricity Generators in the NEM', June 2015.

1.2 Delivery of emissions reductions and resources for a low-carbon grid

1.2.1 Emissions reductions

While we acknowledge that the ESB must work within its remit and thus ask Energy Ministers for advice on sectoral emissions reductions targets[21], the **proposed capacity mechanism is incomplete and does not assure transition to a low-carbon future without a concrete mechanism for addressing emissions reductions** in the electricity sector**.**

1.2.2 Resources for a low-carbon grid

Beyond operationalising emissions reductions targets, the ESB's proposed capacity mechanism **does not explicitly target a portfolio of resources that enables the deployment of VRE and facilitates the operation of a resilient, low-carbon NEM**. Rather**,** the proposed capacity mechanism appears to be focused on a single resource quality/commodity: capacity.

Global CRMs have employed different mechanisms to meet decarbonisation objectives. On one hand, several jurisdictions have restricted the participation of emissions-intensive resources. In the UK, to support emissions reductions targets, diesel generation was disallowed from participating in capacity auctions[22]. Germany implemented a similar framework, such that lignite-fired coal plants are not able to provide capacity reserves. In 2016, Sweden introduced regulations requiring their strategic reserves to be entirely comprised of renewable energy capacity. Whilst this assists in meeting emission-reduction goals, it has come at the cost of reduced competition during capacity auctions. On the other hand, CRMs in some other jurisdictions have been blamed for supporting carbon-intensive generation. PJM's capacity mechanism has received criticism that the auction favours larger power plants, typically thermal generation, and therefore does not facilitate low carbon technology and promote flexibility[23].

a) Balancing flexibility

There is broad international consensus that resource flexibility, rather than capacity alone, will be required for both resource adequacy and the effective and efficient operation of low-carbon power systems[24]. Balancing flexibility not only encompasses capacity, but also ramping capabilities, energy capacity (i.e. duration of flexibility provision) and the response time of resources[25].

Without explicit flexibility requirements, there is limited global evidence a flexible resource mix will be achieved through a CRM. CAISO is one of the only electricity markets currently explicitly incorporating flexibility into their capacity mechanism. In 2015, CASIO expanded the existing resource adequacy requirement to introduce a ramping requirement. This mandated that suppliers must enter into bilateral contracts to secure sufficient flexible capacity to cover their needs. Notably, the cost of delivering capacity contracts did not significant change prior to and following the introduction of the flexibility [26].

[21] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 69.

[22] Greg Williams, 'Profiling the Capacity Market Debate'.

[23] Greg Williams.

[24] International Energy Agency, *Status of Power System Transformation 2018* (OECD, 2018), https://doi.org/10.1787/9789264302006-en; Redefining Resource Adequacy Task Force, 'Redefining Resource Adequacy for Modern Power Systems' (Reston, VA: Energy Systems Integration Group, 2021), https://www.esig.energy/wp-content/uploads/2021/08/ESIG-Redefining-Resource-Adequacy-2021.pdf; Hannele Holttinen et al., 'Design and Operation of Energy Systems with Large Amounts of Variable Generation: Final Summary Report, IEA Wind TCP Task 25' (VTT Technology, 2021).

[25] Baraa Mohandes et al., 'A Review of Power System Flexibility With High Penetration of Renewables', *IEEE Transactions on Power Systems* 34, no. 4 (July 2019): 3140–55, https://doi.org/10/gjtr5p.

[26] FTI Consulting, 'Investment and Flexibility Market Design'.

National Grid's CRM has no centrally determined flexibility requirement, although there are current reforms examining the benefit of introducing one. The UK Government expected the implementation of a CRM would facilitate investment in flexible gas-fired generation. However, this was not achieved as capacity payments were below the operating cost of combined cycle gas generation (CCGT). National Grid's 2016 T-4 auction was the first time new and existing storage capacity received contracts, yet they totalled only 6% of the contracted capacity in the auction[27]. The SWIS has no explicit flexibility requirement and the current mechanism for determining qualifying capacity from storage in the SWIS means long-term storage (durations beyond 4 hours) is not incentivised[28].

Additionally, short-term energy market price caps/ceilings in electricity markets with capacity markets are typically set lower than in those without capacity markets, given that the "missing money" problem is believed to be at least partially addressed by capacity payments. However, such **price cap reductions have the potential to undercompensate flexible generation** and therefore reduce the incentive to invest in flexible assets[29].

b) Resource diversity

Resource diversity (vis-à-vis network location, resource/technology type, energy/storage duration, etc.) has received less attention in power systems globally than in the NEM, as it is an implied outcome of cross-jurisdictional interconnection[30]. However, **because the NEM is an isolated power system, planning and investment processes should explicitly aim to deliver resource diversity**. This is important for two reasons. First, while the length and span of the NEM mean that diverse VRE resources can be exploited, access to this diversity may be limited by the NEM's stringy network, its mostly north-south topology and relatively weak interconnection between market regions. Second, severe and/or prolonged events may diminish the assistance that a network segment and/or a particular resource type can provide to system balancing (we explore this and its implications on power system resilience in Section 2, but note that similar concerns have been raised by AEMO in the 2022 ISP[31]).

A capacity mechanism would be **better placed to deliver resource diversity if an appropriate de-rating/capacity assessment methodology were selected**. One such class methodology identified by the ESB is **Effective Load Carrying Capability** (ELCC, which increases system load following the addition of a generator to the system to assess its contribution) **and the closely related Equivalent Firm Capacity** (EFC, which compares an additional generator to a "perfect" one)[32]**.** ELCC/EFC are more sophisticated de-rating methodologies as they assess resources as a part of a larger system; that is, they identify resource synergies/diminishing gains from additional capacity of a particular type (Figure 1). A consequence of this is that capacity assessment can be dynamic and thus reflect an evolving resource mix and power system.

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[27] Andreas Bublitz, 'A Survey on Electricity Market Design: Insights from Theory and Real-World Implementations of Capacity Remuneration Mechanisms'.

[28] Graham Pearson, 'Is It Time for a Full Review of WA's Reserve Capacity Mechanism?' (Australian Energy Council, October 2021), https://www.energycouncil.com.au/analysis/is-it-time-for-a-full-review-of-wa-s-reserve-capacity-mechanism/; Marsden Jacob, 'Revenue Adequacy for Generators in the WEM', April 2022, https://www.energycouncil.com.au/media/xlab4zma/mja-final-report-generator-revenue-adequacy.pdf.

[29] J. Mays, 'Missing incentives for flexibility in wholesale electricity markets', *Energy Policy* 149 (February 2021), https://doi.org/10.1016/j.enpol.2020.112010.

[30] Redefining Resource Adequacy Task Force, 'Redefining Resource Adequacy for Modern Power Systems'; Holttinen et al., 'Design and Operation of Energy Systems with Large Amounts of Variable Generation'.

[31] Australian Energy Market Operator, '2022 Integrated System Plan', June 2022, 25, https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/2022-integrated-system-plan-isp.pdf?la=en.

[32] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 32.

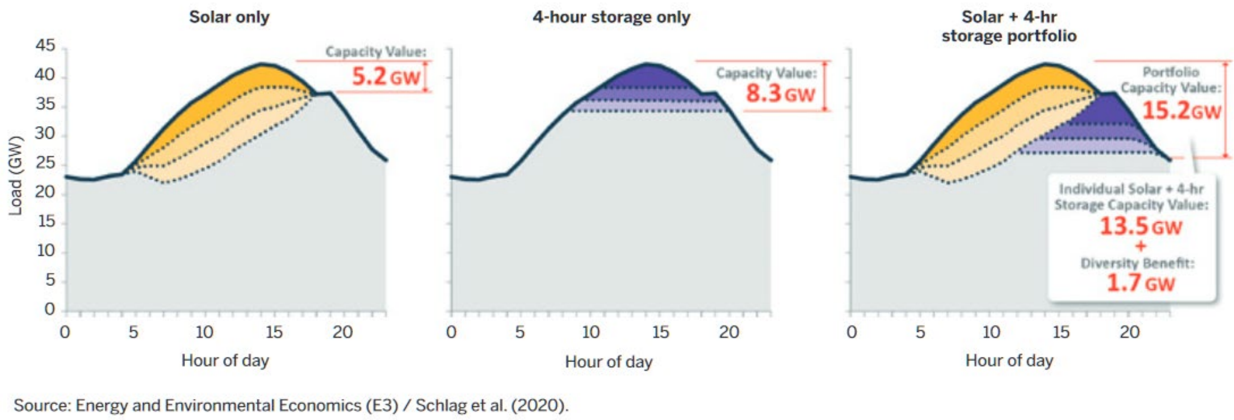

Figure 1: Effective Load Carrying Capability assessment of capacity value of (left) solar only, (middle) storage only and (right) solar and storage combined. Note that the portfolio capacity value exceeds the individual resource capacity values by the "diversity benefit"[33].

However, **integrating such methodologies into a market-based capacity mechanism can be challenging**. As identified by the ESB, ELCC/EFC are computationally intensive[34]. There are further issues beyond computational challenges that broadly apply to any methodology that attempts to "dynamically" assess the value of capacity[35]:

- Should capacity credits be allocated based on a resource's marginal contribution? Or should they be allocated based on some form of "averaging" which is more compatible with system planning metrics?
- "Chicken and the egg": how can you assess the ELCC of a resource when it depends on the outcome of the assessment? Put another way, if the ELCC of a resource depends on the resource mix, which resource mix do you use if a collection of resources is being assessed simultaneously in an auction round?
- How does this interact with transmission planning and access?

Given these challenges, we can see **why the ESB favours a "pre-defined" de-rating that is simple and predictable. However, this approach does not foster diversity, and may even hinder it:**

1. It is unclear if such an approach adequately values storage resources. This is already challenging, given that storage may be providing system services rather than capacity/energy. However, a pre-defined approach also obscures synergies offered by storage (e.g. Figure 1).
2. De-rating may favour certain resource types, such as gas-fired generation. A heavy reliance on one particular resource type may have significant implications for system resilience (explored further in Section 2) – e.g. loss of gas supply[36].

Some jurisdictions currently use ELCC/EFC but navigate the challenges listed above by assessing technology classes, rather than individual resources. In the UK, the amount of capacity from a plant that qualifies for the capacity market is determined by technology type, varying between 2% and 8% for VRE,

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[33] Redefining Resource Adequacy Task Force, 'Redefining Resource Adequacy for Modern Power Systems'.

[34] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 32.

[35] Nick Schlag, 'Considerations in Capacity Accreditation Using ELCC'.

[36] Jacob Mays et al., 'Private Risk and Social Resilience in Liberalized Electricity Markets', *Joule* 6, no. 2 (16 February 2022): 369–80, https://doi.org/10.1016/j.joule.2022.01.004.

90% for hydro and 80% for DSR. As discussed in the High-level Design Paper, the de-rating of VRE and short-duration storage is determined through an EFC assessment[37]. Despite the majority of contracts going to existing generators, there is some evidence of diversity in the mix that was delivered with the T-4 2024/25 auctions (44.8% of contracts from gas generation, 27.7% from DSR and 6.52% from BESS)[38]. Similarly, since 2021, PJM has begun to also use a class-based approach to ELCC/EFC capacity accreditation for VRE and BESS with unit-specific performance adjustment factors (PJM uses the term ELCC, but their assessment is more akin to EFC)[39], and MISO uses class-based ELCC to determine the qualifying capacity of wind[40].

Given these international precedents, if the proposed capacity mechanism proceeds to the detailed design phase, the **ESB should further explore capacity accreditation via ELCC to better promote "dynamic" capacity valuation and resource diversity** (at the very least, to a greater extent than would otherwise be accomplished via pre-defined de-ratings). However, the **diversity benefits of such de-rating methodologies will need to be balanced against the need for large-scale deployment of VRE to decarbonise the NEM**, as such methodologies are likely to progressively de-value each new round of VRE resources (though this may increase the value of enabling technologies such as storage).

1.3 Barriers and potential solutions

We see the following issues as particularly key **barriers to investment and energy transition in the NEM** that are not addressed by the introduction of a CRM as proposed by the ESB:

1. **Uncertainty around the exit of coal-fired power stations**, which not only affects the timing and adequacy of private investment, but also AEMO (and by extension, government) confidence that the power system can be securely and reliably operated upon generation exit without extended periods of market stress or the threat of significant load shedding.
2. **Transmission, or lack thereof**. Significant investment in infrastructure is needed to alleviate existing transmission system constraints, unlock good wind and solar resources, and enable inter-regional resource sharing. As AEMO has highlighted in its recent ISPs, it is critical that transmission-related workplans commence as soon as possible, given the potential for delays (e.g. due to supply chain issues, consultation with communities around access corridors) and "the asymmetry of risk"; that is "the risk of delaying investment is greater than that of investing early"[41].
3. **System security concerns, particularly those related to system strength**. Such concerns are impeding the deployment of VRE or constraining their dispatch.

We note that there is significant complexity in considering these barriers given that they are interrelated. That is, "siloed" solutions (such as the capacity mechanism, if implemented as proposed) increase the

[37] Western Australian Government, 'Storage Participation in the Reserve Capacity Mechanism'.

[38] FTI Consulting, 'Investment and Flexibility Market Design'.

[39] Andrew Levitt, 'Effective Load Carrying Capability at PJM', https://www.esig.energy/download/session-1b-effective-load-carrying-capability-at-pjm-andrew-levitt/?wpdmdl=8720&refresh=624328b04e2771648568496.

[40] Conleigh Byers, Todd Levin, and Audun Botterud, 'Capacity Market Design and Renewable Energy: Performance Incentives, Qualifying Capacity, and Demand Curves', *The Electricity Journal* 31, no. 1 (February 2018): 65–74.

[41] Australian Energy Market Operator, '2022 Integrated System Plan', 85.

risk of a "bumpy" transition (at the very least) and may impose additional direct costs on energy consumers and broader social costs on communities[42].

1.3.1 Potential solutions

Below, we outline a set of potential solutions, with a focus on addressing interrelated and/or interdependent factors between barriers and solution:

1. **Regulate the closure of coal-fired power stations**. This will create confidence for private investment (regardless of whether it is supported by jurisdictional schemes), and "fix the goalposts" for AEMO (with respect to system operation) and NEM jurisdictions (with respect to resource adequacy). A balance will need to be achieved between ensuring an orderly exit whilst enabling generation to be retired ahead of schedule if it is possible to do so, and between paying emissions-intensive and unreliable generation to remain in the system whilst also addressing "first-mover disadvantages" (i.e. the increased operational and financial viability of remaining coal-fired power stations following an initial retirement)[43]. Potential enhancements to existing notice-of-closure requirements and potential regulated closure mechanisms are discussed in detail by Edis and Bowyer[44].
2. **Jurisdictional (i.e. state and federal) investment support schemes should be strengthened and refocused not just to deploy VRE, but also to deploy transition-enabling resources.** As we highlighted in Section 1.2.2, resource diversity and flexibility (which incorporates energy limits/duration) are needed in addition to capacity.
    a. One way to achieve this would be to **support the large-scale deployment of energy storage**. An energy storage target has received support from the Clean Energy Council, the Institute for Energy Economics and Financial Analysis and the Victorian Energy Policy Centre[45], with the latter advocating for a Renewable Energy Storage Target scheme that would function in a similar manner to the Renewable Energy Target. However, we note that there are issues with certificate schemes that have led to numerous jurisdictions in Australia and overseas to move towards reverse auction/tender-based deployment policies. These issues include the risks and uncertainty associated with the certificate market itself, and the potential for larger retailers to exercise market power in certificate markets.
    b. Given these issues, we instead support **jurisdictional storage targets and investment support schemes** that provide revenue guarantees, such as the NSW Government's long-duration storage LTESAs. A jurisdictional approach could **enable solution co-ordination**

[42] Broadly, this is related to the "Theory of Second Best" in economics and the "Principle of Suboptimization" in engineering.

[43] Frontier Economics, 'Barriers to Exit for Electricity Generators in the NEM'.

[44] Tristan Edis and Johanna Bowyer, 'There's a Better Way To Manage Coal Closures Than Paying To Delay Them' (Institute for Energy Economics and Financial Analysis, September 2021), https://ieefa.org/wp-content/uploads/2021/09/Theres-a-Better-Way-to-Manage-Coal-Closures-Than-Paying-to-Delay-Them_September-2021.pdf.

[45] 'A Clean Fix for the Energy Crisis', Clean Energy Council, accessed 21 July 2022, https://www.cleanenergycouncil.org.au/advocacy-initiatives/energy-transformation/clean-fix-for-energy-crisis; 'IEEFA: Australia's Energy Crisis Can Be Solved with a Focus on Renewables, Not a Capacity Market That Locks in High Emissions Electricity', accessed 21 July 2022, https://ieefa.org/articles/ieefa-australias-energy-crisis-can-be-solved-focus-renewables-not-capacity-market-locks; Bruce Mountain et al., 'Electricity Storage: The Critical Electricity Policy Challenge for Our New Government. A Policy Proposal' (Victoria Energy Policy Centre, 2022), https://doi.org/10.26196/23JK-8F47.

(in consultation with AEMO and TNSPs), particularly given the diverse capabilities and services that storage (especially BESS) can provide:

i. **Equipping BESS with advanced inverter capabilities is "low-hanging fruit"**. While around 3 GW/ 7 GWh of battery energy storage systems have been shortlisted for ARENA grants to equip these projects with advanced inverter capabilities, this shortlist only represents approximately 10% of anticipated and proposed BESS projects in the NEM[46]. As highlighted by AEMO, advanced inverter capabilities can assist in managing system strength and frequency control issues (noting that resources do not have to be "grid-forming" to have "advanced inverter" capabilities; appropriately tuned "grid-supporting" active and reactive power control may be sufficient)[47].

ii. **Co-ordination with TNSPs and AEMO** could not only enable storage deployment to address system strength issues, but also **increase the potential for such resources to be considered as non-network options for transmission system augmentation**.

iii. A good example of such synergy is the Darlington Point Energy Storage, which has not only received ARENA funding to deploy advanced inverter capabilities but has also been contracted by TransGrid to temporarily provide network support services[48].

3. **Begin major investment in much-needed transmission.**
4. **Earnestly addressing "consumer-level" issues that reduce (but do not eliminate) the degree of investment required in large-scale resources**. While existing workstreams are attempting to address some of these issues (e.g. a more two-sided market, distribution-level services), more focus should be placed on addressing the **energy efficiency of consumption**[49]**.**

[46] Australian Energy Market Operator, 'Generation Information', February 2022, https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/nem-forecasting-and-planning/forecasting-and-planning-data/generation-information; '"Missing Piece of the Puzzle": 3 GW of Battery Projects Make It to ARENA's Grid Forming Shortlist', pv magazine Australia, accessed 21 July 2022, https://www.pv-magazine-australia.com/2022/07/06/missing-piece-of-the-puzzle-3-gw-of-battery-projects-make-it-to-arenas-grid-forming-shortlist/.

[47] Australian Energy Market Operator, 'Application of Advanced Grid-Scale Inverters in the NEM - White Paper', 2021.

[48] 'Edify Secures $13 Million for Darlington Point Big Battery Project', pv magazine Australia, accessed 21 July 2022, https://www.pv-magazine-australia.com/2022/07/11/edify-secures-13-million-for-darlington-point-big-battery-project/; Transgrid, 'Improving Stability in South-Western NSW', June 2022.

[49] Tristan Edis, 'What Is the Real Cause of Australia's Energy Crisis – and What Should We Do?', accessed 21 July 2022, https://ieefa.org/resources/what-real-cause-australias-energy-crisis-and-what-should-we-do.

2 A supply-demand resilience mechanism

2.1 The need for resilience

2.1.1 What is resilience?

CIGRE defines power system resilience as **"the ability to limit the extent, severity and duration of system degradation following an extreme event"**[50]. This "ability" consists of operational aspects, including the performance and response of the power system following an extreme event, as well as longer-term planning and investment aspects, including the degree to which system design and configuration is robust and the ability for post-event learnings to be assimilated by the industry (noting that a power system is a "system of systems")[51]. The **extreme events that are associated with resiliency are often high impact, low probability/frequency (HILP/F)** and include phenomena such as extreme weather, cyber-attacks and common-mode or cascading component failures. We note that **this definition and the solutions we discuss in this submission are focused on "physical" resilience, which we see as underappreciated in policy discussions when compared to "market" resilience** (which we discuss briefly in Section 2.3.3).

It should be stressed that **whilst reliability and resilience are related (i.e. both lead to unserved energy), they are distinct concepts**. In particular, there are large differences between how each is accounted for in informational and planning processes. Though certain power system component processes are stochastic in nature (e.g. VRE generation, forced unit outages), these processes can be characterised with some confidence (e.g. probability distributions or scenarios that describe a *distinct* event). Furthermore, a suite of modelling approaches exists to explore the resulting permutations of "reliability futures". An example is the Medium Term PASA process run by AEMO, which uses Monte Carlo simulations to test reliability outcomes across a range of VRE and demand scenarios and forced generator outage patterns[52]. **Whilst the impact of a reliability solution will vary across individual scenarios, it should ideally deliver a net benefit against potential costs** when considering the aggregate of the modelled "reliability futures".

In contrast, assessing resilience is challenging as **it can be difficult to characterise HILP events in such a way that that they can be modelled. Even if HILP events can be adequately characterised, a cost-benefit approach to decision-making (at present, the dominant approach to planning decisions in the NEM) is unlikely to lead to resilient planning** as such events (distinct or indistinct) often sit in the "long tail" of a probability distribution (i.e. low to very low likelihood). Taking the example of reliability modelling and now applying it to a resilience assessment, **a low likelihood of occurrence may mean that a distinct HILP event only materialises in 1-out-of-100 simulations (if any at all)**. Though the direct and broader social costs of such an event could be astronomical (though potentially difficult to quantify[53]), the low likelihood of occurrence is likely to lead to a cost-benefit analysis deeming the resilience measure to be "inefficient".

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[50] CIGRE Working Group C2 et al., 'Operating Strategies and Preparedness for System Operational Resilience', n.d.

[51] Mathaios Panteli and Pierluigi Mancarella, 'Modeling and Evaluating the Resilience of Critical Electrical Power Infrastructure to Extreme Weather Events', *IEEE Systems Journal* 11, no. 3 (September 2017): 1733–42, https://doi.org/10.1109/JSYST.2015.2389272.

[52] Australian Energy Market Operator, 'Medium Term PASA Process Description', 12 January 2021, https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/pasa/mt-pasa-process-description-v62.pdf?la=en.

[53] Australian Energy Regulator, 'Widespread and Long Duration Outages - Values of Customer Reliability: Final Conclusions', September 2020, https://www.aer.gov.au/system/files/AER%20-%20Values%20of%20Customer%20Reliability%20-%20Widespread%20and%20long%20duration%20outages%20-%20Final%20conclusions%20-%20September%202020.pdf.

We note that similar concerns have been raised by AEMO[54] and in outputs of the Electricity Sector Climate Information (ESCI) project[55].

2.1.2 A growing societal dependence on electricity supply

Electricity supply is as essential service which Australian society is becoming increasingly dependent upon:

1. Its direct end-uses in residences, businesses and public spaces (e.g. lighting, hot water) are essential to the health and ongoing well-being of people. The significance of electricity supply to Australians will only grow as end-uses are increasingly electrified on the path to decarbonisation. In particular, electricity will likely replace considerable energy demands that are currently being directly met by fossil fuels, such as those that service transportation and heating (space and water) needs;

2. Other essential services are dependent upon electricity supply. As AEMO outlined in its submission to the AER's Widespread and Long Duration Outage (WALDO) Value of Customer Reliability (VCR) Consultation Paper[56]:

   "…electricity systems have become substantially more critical to the effective operation of modern societies. While energy consumption has also risen, the ***interconnected nature of utilities and services means that extended outages are likely to impact social outcomes more substantially. For example, telecommunication services may discontinue beyond eight hours, and some sewerage services overload beyond two hours****. Therefore, further consideration must be given to the societal impacts during a long duration outage to the interconnected nature of utilities and services including water, telecommunications, transport and health."*

   Electricity supply may be particularly important during heatwaves and bushfires. During such events, access to cooling and water, which could be critical to the safety and well-being of affected communities, will be somewhat constrained if there is a loss of electricity supply;

3. As the Reliability Panel outlined in its submission to the AER's WALDO VCR Consultation Paper[57], services sectors constitute a large portion of the Australian economy. More so than other parts of the Australian economy, these sectors are somewhat reliant on grid-supplied electricity. As such, widespread loss of supply, or the risk thereof, may have substantial economic impacts.

For these reasons, **widespread outages or supply shortages are ever more societally unacceptable**. The Australian public's dissatisfaction with even a potential loss of supply is palpable following the recent threats of blackouts during the June 2022 energy crisis. Indeed, Australians are not confident in the resilience and reliability of our energy system. Energy Consumers Australia's June 2022 Pulse Survey

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[54] Australian Energy Market Operator, '2020 ISP - Appendix 8 . Resilience and Climate Change', 2020.

[55] Electricity Sector Climate Information Project, 'ESCI Project Final Report', July 2021, https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/799/ESCI%20Project%20final%20report_210721.pdf; Electricity Sector Climate Information Project, 'Extreme Weather: Exploring Power System Resilience to Coincident Extreme Heatwave and Bushfires', 9 September 2021, https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/734/ESCI%20Case%20Study%206_Impact%20of%20extreme%20events%20090721.pdf.

[56] Australian Energy Market Operator, 'Submission to AER WALDO VCR Consultation Paper', 5 June 2020, https://www.aer.gov.au/system/files/AEMO%20-%20Submission%20to%20AER%20WALDO%20VCR%20Consultation%20Paper%20-%20March%202020.pdf.

[57] Australian Energy Market Commission Reliability Panel, 'Submission to AER WALDO VCR Consultation Paper', 1 June 2020, https://www.aer.gov.au/system/files/Reliability%20Panel%20-%20Submission%20to%20AER%20WALDO%20VCR%20Consultation%20Paper%20-%20March%202020.pdf.

asked respondents to rate their concern (out of 10) in response to the following question: "*How concerned, if at all, are you that in the next 3 years that Australia's energy system will not be resilient to extreme weather events and there will be frequent electricity outages?*". **58% of respondents expressed high concern (7-10/10) and 32% of respondents expressed moderate concern (4-6/10) with respect to resilience of the energy system and the potential for outages**[58].

Considerable work must be undertaken not only to mitigate the likelihood and impacts of widespread outages or supply shortages, but also to restore confidence in the electricity industry. Such consumer confidence will be **vital if electricity supply is to meet growing energy demands and underpin economy-wide decarbonisation.**

2.1.3 Growing threats to electricity supply

In tandem to an increasing societal dependence on electricity supply, there are growing threats to reliable and secure electricity supply. As outlined by AEMO in an appendix to the 2020 ISP, these include[59]:

1. **Increasing frequency and impact of adverse and extreme weather events due to climate change**. Historically, the NEM has been stressed during extreme wind events (which contributed to the SA System Black in 2016 and the islanding of SA in 2020), heatwaves (several summers, including that of 2018/19 in which load shedding took place), bushfires (most notably in the Black Summer of 2019/2020) and cold snaps (which contributed to higher demand in the recent June 2022 energy crisis). Extremes in precipitation have also had profound effects on the NEM – the Millennial Drought affected hydro plant and coal-fired generation (due to cooling water availability)[60], and heavy rainfall associated with the recent La Nina event has disrupted some coal mines and thus fuel supplies for some coal-fired power stations. As outlined by the ESCI project, both the frequency and severity of many of these extreme weather events are expected to increase[61]:
    a. Very-high scientific consensus there will be increases in average and extreme temperature.
    b. Medium-high confidence there will be an increase in extreme fire weather.
    c. Medium confidence there will be an increase in extreme rainfall events and less rainfall in winter/spring
    d. Low confidence that compound (two or more) extreme events will increase in frequency and magnitude.
2. **Reconfiguration of the power system and market arrangements as energy transition progresses**. There are two aspects to this reconfiguration that are relevant to reliability and resilience:
    a. Reserve margins were relatively high at the inception of the NEM due to the investment strategies of the former State Government Electricity Commissions. These reserve

[58] Energy Consumers Australia, 'Pulse Survey', ecss.energyconsumersaustralia.com.au, accessed 12 July 2022, https://ecss.energyconsumersaustralia.com.au/sentiment-survey-june-2022/pulse-survey-june-22/.

[59] Australian Energy Market Operator, '2020 ISP - Appendix 8 . Resilience and Climate Change'.

[60] Paul Simshauser, 'Lessons from Australia's National Electricity Market 1998-2018: The Strengths and Weaknesses of the Reform Experience' (University of Cambridge Energy Policy Research Group, 2019).

[61] Electricity Sector Climate Information Project, 'ESCI Project Final Report'.

margins have declined (and may well continue to do so) with the retirement of large thermal generators that once contributed to the NEM's capacity overhang[62]. As discussed in Section 1.2.2, a "like-for-like" capacity replacement is inappropriate (as is a sole focus on capacity) given the need for flexible and diverse resources that enable energy transition.

b. Once dominated by large synchronous generation with a network that is designed around their location and responses, the NEM is increasingly accommodating asynchronous VRE, which:

    i. Is more weather-dependent, as well as more exposed to adverse weather. *Dunkelflaute* ("dark doldrums" - extended periods of low wind and solar potential[63]) and extreme weather events are of particular concern.

    ii. Must be specifically configured to ride-through disturbances or provide traditional network support services. Widespread tripping of legacy inverter-based resources following voltage disturbances can initiate or exacerbate system imbalances (e.g. following the trip of multiple generators on the 25th of May, 2021[64]);

    iii. May be located in "weak" and stringy parts of the network. This has implications for the availability of network support services, but also for alternative flow paths for energy from VRE should critical transmission corridors become constrained or unavailable (e.g. due to strong winds or bushfires).

3. **Increasingly interconnected systems**. This can lead to vulnerabilities that can trigger cascading failures. For example, the loss of electricity supply to natural gas compressors could result in low pipeline pressures, thus leaving gas generators unable to operate (which occurred during Winter Storm Uri or the "Texas Freeze" of 2021[65]).

2.1.4 Risk-averse operation and planning is clearly justified

Given the increasing societal dependence on and growing threats to electricity supply (Sections 2.1.2 and 2.1.3, respectively), the NEM's "stringy" network topology and lack of interconnection to other power systems, **there is clear justification for more *risk-averse* and robust power system operation and planning practices in the NEM**. Such practices should be able to improve system resilience by providing some degree of "hedging" against the threats posed by HILP events[66].

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[62] Simshauser, 'Lessons from Australia's National Electricity Market 1998-2018: The Strengths and Weaknesses of the Reform Experience'.

[63] Australian Energy Market Operator, 'Appendix 4. System Operability - Appendix to 2022 ISP for the National Electricity Market', June 2022, https://aemo.com.au/-/media/files/major-publications/isp/2022/2022-documents/a4-system-operability.pdf?la=en.

[64] Australian Energy Market Operator, 'Trip of Multiple Generators and Lines in Central Queensland and Associated Under-Frequency Load Shedding on 25 May 2021', October 2021, https://aemo.com.au/-/media/files/electricity/nem/market_notices_and_events/power_system_incident_reports/2021/final-report-trip-of-multiple-generators-and-lines-in-qld-and-under-frequency-load-shedding.pdf?la=en.

[65] Mays et al., 'Private Risk and Social Resilience in Liberalized Electricity Markets'.

[66] Rodrigo Moreno et al., 'From Reliability to Resilience: Planning the Grid Against the Extremes', *IEEE Power and Energy Magazine* 18, no. 4 (July 2020): 41–53, https://doi.org/10.1109/MPE.2020.2985439.

We emphasise that this does not mean that *all* outages should be prevented (this is somewhat impractical except at extraordinary cost and effort), but rather that the system be designed and configured in such a way that it is better placed to resist, respond and recover from a variety of potential HILP events. Even modest efforts to hedge the system may "go a long way" as, by their very nature, **HILP events entail asymmetric costs**[67] **– that is, the additional cost of mitigation measures is likely to be small compared to total system costs, and likely to be dwarfed by the direct and broader social costs of market and/or power system failure.**

A pertinent example of this is the cost associated with the NEM's current reliability "back-stop" – the Reliability and Emergency Reserve Trader (RERT). As highlighted by Iberdrola Australia, RERT costs from 2017-2021 were in the order of "$100m…, a small fraction of total NEM wholesale market turnover of ~$60bn over the same period" (i.e. approximately 0.2% of market turnover)[68]. During the recent energy crisis in June 2022, AEMO activated RERT in NSW and Queensland on 4 occasions, totalling $85.9 million (and a further $0.6 million in July 2022), costing on average $21,351/MWh[69]. However, the estimated payment for activation of the RERT on these occasions comprised approximately 0.3% of total market turnover for the 2021/22 financial year[70]. Total RERT payments for the 2021/22 financial year constituted 0.48% of market turnover. As such, the cost of procuring these "back-stop" reserves represents only a tiny proportion of the revenue accrued through the NEM by market participants.

2.2 Do current and proposed mechanisms deliver supply-demand resilience?

2.2.1 What is supply-demand resilience?

Supply-demand resilience is concerned with HILP events that threaten supply-demand balance within resource adequacy timeframes, which extend from a few minutes to even weeks and months. A supply-demand resilience solution will likely entail a diverse mix of resources (as was discussed in Section 1.2.2) that can respond not only to sudden HILP events (e.g. natural disasters that affect the availability of generation resources), but also to ones that have sustained consequences (e.g. fuel scarcity – a factor which contributed to the recent June 2022 energy crisis).

[67] Paul Nahmmacher et al., 'Strategies against Shocks in Power Systems – An Analysis for the Case of Europe', *Energy Economics* 59 (September 2016): 455–65, https://doi.org/10.1016/j.eneco.2016.09.002; Iain MacGill and Ryan Esplin, 'End-to-End Electricity Market Design - Some Lessons from the Australian National Electricity Market', *Electricity Journal* 33, no. 9 (2020): 106831, https://doi.org/10/gnv8qs; Niraj Lal et al., 'Essential System Services Reform: Australian Market Design for Renewable-Dominated Grids', *IEEE Power and Energy Magazine* 19, no. 5 (2021): 29–45, https://doi.org/10/gnv8rk.

[68] Iberdrola Australia, 'Iberdrola Australia Response to Capacity Mechanism Project Initiation Paper', 14 February 2022, https://www.energy.gov.au/sites/default/files/2022-02/Iberdrola%20Australia%20Response%20to%20Capacity%20Mechanism%20Project%20Initiation%20Paper.pdf.

[69] Australian Energy Market Operator, 'RERT Reporting', 2022, https://aemo.com.au/en/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert/rert-reporting.

[70] Market turnover data for 2021/22 financial year provided by Dr Dylan McConnell, Climate and Energy College, University of Melbourne. FY 21/22 market turnover was derived from market data published by AEMO - specifically the RRP and demand and nonscheduled generation volumes traded through regional reference node.

2.2.2 Can the market deliver supply-demand resilience?

Cost-benefit analysis lies at the heart of market-driven decision-making. This not only applies to investment and operational decisions made by market participants, but also more broadly to market design and reform that must align with the National Electricity Objective ("…efficient investment in, and efficient operation and use of,…"). In most cases, considering efficiency is important to ensuring that consumers have access to electricity supply that is both reliable and affordable.

However, as outlined in Section 2.1.1, it can be **challenging to justify resilience through a rigorous cost-benefit analysis**. In AEMO's Resilience and Climate Change Appendix to the 2020 ISP, AEMO partially attributes declining resilience in the NEM to the dominance of cost-benefit analysis in electricity industry decision-making[71]:

"the use of quantitative cost benefit analysis has become central to the justification of all regulated investments and market structures. Limitations in both climate and energy system modelling mean that full risk quantification of acute hazards is impractical. Limitations in economic and social cost modelling used to develop value of customer reliability estimates for widespread and long duration outages were also acknowledged by the AER. However, this does not diminish the importance of understanding and managing these risks."

Furthermore, conventional measures of efficiency and resilience are arguably antithetical as the latter inevitably involves some form of "hardening" or redundancy that often does not deliver material benefits over the vast majority of the solution's lifetime. An example of this is diversity (technological, geographical, etc.) in balancing resources. The benefits of resource mix diversity may only become apparent should shocks, stresses or HILP events restrict or prevent certain resources from contributing to balancing supply and demand in the NEM.

As such, **market-based mechanisms based on existing cost-benefit frameworks would seem ill-suited to ensuring that the NEM has supply-demand resilience.**

Below, we provide a brief assessment of why current and proposed market-based arrangements, including the proposed capacity mechanism, may not necessarily deliver supply-demand resilience solutions. We neither attempt to address resilience in frequency control arrangements (though this too is an important consideration in ensuring that the NEM has supply-demand resilience) nor do our assessments reflect other aspects of power system resilience, such as network resilience (we discuss this further in Section 2.3.3).

c) Market or scheme-driven investment

At a fundamental level, market participants must make investment and operational decisions that provide an appropriate expected return on investment proportionate to the risks involved (i.e. net benefits). Such **decisions are likely to be driven by the expected value of future spot prices (at its simplest, the probability-weighted average price)**. As such, investments by market participants should be able to deliver **benefits "in the aggregate", rather than addressing low-likelihood risks to the system.**

As future spot prices are likely to be reflected in any contracting arrangements, **one argument is that more complete contracting may better align participant (financial) risks with power system and social risks**. This is particularly the case when contracts sold by participants with generation portfolios resemble insurance products (e.g. existing cap contracts, which offer premiums to the seller in exchange for compensation for the buyer should spot prices exceed $300/MWh). In theory, more complete contracting should force participants to consider tail risks. In practice, **the decisions made by contracted market participants are likely to be partially, if not completely dependent on centralised informational processes**[72]**, including weather forecasts and AEMO's pre-dispatch and Projected Assessment of**

[71] Australian Energy Market Operator, '2020 ISP - Appendix 8 . Resilience and Climate Change'.

[72] Mays et al., 'Private Risk and Social Resilience in Liberalized Electricity Markets'.

System Adequacy (PASA) runs. As discussed in Section 2.1.1, such processes typically consider outcomes "in the aggregate" rather than considering tail risks or worst-case outcomes (thus leading to "expected value" rather than robust solutions), or altogether omit the consideration of difficult-to-characterise HILP events. For example, AEMO's informational processes typically consider a range of percentiles for certain system variables, but these are not chosen to assess forecasted tail risk (e.g. 10th, 50th and 90th percentiles for regional demand, as opposed to 1st or 99th percentiles).

d) Proposed capacity mechanism

The capacity mechanism design currently favoured by the ESB is one that appears to reward resources that have the *intention* to supply (i.e. offer their de-rated capacity as available). One component for payment would be linked to the *intention* to supply across the year, and the other would be linked to the *intention* to supply during periods of low reserves. Rewarding resources for the *intention* to supply, and that too for the *intention* across the year, means that the **proposed capacity mechanism does not strongly incentivise *actual* performance during periods of system stress**. The lack of any penalties and the partial application of pay-for-performance features in the ESB's proposed design is concerning as costs may be incurred in the absence of material reliability and/or resilience outcome. That is, the misalignment between participant financial risks, and direct risks to the power system and broader risks to society means that **gains may be privatised whilst risks are socialised.**

Furthermore, as discussed in Sections 1.2.2, a technology-agnostic approach to capacity procurement is not conducive to ensuring that the NEM and its sub-regions have an appropriate degree of resource flexibility and diversity that enables the transition to low carbon electricity supply.

e) RRO & the Physical Reserve Capacity Market (as proposed by Iberdrola Australia)

The Retailer Reliability Obligation (RRO) and the Physical Reserve Capacity Market (PRCM) proposed by Iberdrola Australia[73] are similar in the regard that both:

1. Are driven by AEMO forecasting a reliability gap 3-4 years ahead;
2. Include obligations that intend to drive investment should the market fail to respond:
    a. The RRO is decentralised and places an obligation on retailers to procure sufficient contracts to cover their expected share of a one-in-two-year peak demand event, and on certain generators to perform a market making function (Market Liquidity Obligation). Retailers manage financial risks (including their potential share of RERT costs and any AER civil penalties should they fail to comply); that is, contracts need not be associated with actual resources.
    b. The PRCM is centralized, with a central auction/tender for long-term capacity contracts (5+ years) being initiated. Resources that receive these contracts would then be able to offer reserves (either through the market, or out-of-the-market via RERT) prior to eventually transitioning to the energy market.

While the PRCM does provide more certainty that new resources will be deployed to respond to a reliability gap, we note that **both mechanisms rely on reliability assessments that may not capture HILP events** (Section 2.1.1). Furthermore, resources that obtain contracts under the PRCM will only be available once a gap is forecasted, the market is deemed to not have sufficiently responded and "strategic reserve" resources are built. An additional concern with resources procured under the PRCM is how and when such resources should be able to transition to market participation (if they should at all).

[73] Iberdrola Australia, 'Iberdrola Australia Response to Capacity Mechanism Project Initiation Paper'.

2.2.3 Are non-market mechanisms sufficient for supply-demand resilience?

In our view, current out-of-market mechanisms have some deficiencies in their ability to deal with supply-demand resilience events.

a) Protected and indistinct event frameworks

We commend the AEMC on the work it has undertaken to generalise the review of non-credible risks (via the General Power System Risk Review) and to implement protected and indistinct event frameworks. Such frameworks **enable AEMO to manage threats to operational resilience.**

However, these frameworks are limited in their application to planning timeframes which are more relevant to sustained supply-demand resilience. Specifically, as they predominantly apply to AEMO, there are **limited actions that can be undertaken within these frameworks to make the system "bigger" (e.g. additional balancing resources transmission) and "stronger" (e.g. line undergrounding, more weather-resilient infrastructure)**[74]. This may be compensated by relying on AEMO to make the system "smarter" via these frameworks (e.g. emergency control schemes such as System Integrity Protection Schemes). However, the **increasing use of these schemes "to defer investment in physical assets" introduces fragility of another nature** (e.g. susceptibility to cyber-attacks, unforeseen interactions)[75].

b) Reliability and Emergency Reserve Trader

RERT is an invaluable last-resort mechanism for addressing projected supply shortfalls. However, aspects of its current design limit the degree of supply-demand resilience it can provide. RERT appears to be predominantly provided by out-of-market demand response providers, many of which are tens of MWs (notably excluding some larger providers such as QGC, and Tomago and Portland aluminium smelters). While this should lead to resource dispersion and hence a degree of network diversity, **it is unclear whether**:

- **The potential short-notice RERT capacity in each state (market region) would be sufficient to mitigate supply-demand imbalances following a HILP event**. For example, a panel of providers representing 2,030 MW of short-notice RERT across the NEM was established in Q1 2022[76]. Would such a panel be able to address WALDOs in excess of 15 GWh (i.e. all panel members activated for over seven hours), particularly if cross-regional transfers are limited or unavailable? AEMO and the Reliability Panel consider that WALDOs of this magnitude are plausible[77].
- **Reserves procured via RERT would be able or willing to be activated for extended durations**. It may highly undesirable or even damaging for demand response providers to be activated for extended periods (e.g. greater risks of cell-level impacts, frozen cells or even potline shutdowns at aluminium smelters as outage durations increase[78]). Even if such costs were tolerable, it may not be possible to recoup them. RERT contracts are not considered by AEMO unless their costs

[74] Julian Eggleston, Christiaan Zuur, and Pierluigi Mancarella, 'From Security to Resilience: Technical and Regulatory Options to Manage Extreme Events in Low-Carbon Grids', *IEEE Power and Energy Magazine* 19, no. 5 (2021): 67–75, https://doi.org/10/gnv8sx.

[75] Australian Energy Market Operator, '2020 ISP - Appendix 8 . Resilience and Climate Change'.

[76] Australian Energy Market Operator, 'RERT Quarterly Report: Q1 2022', May 2022, https://aemo.com.au/-/media/files/electricity/nem/emergency_management/rert/2022/rert-quarterly-report-q1-may-2022.pdf?la=en.

[77] Australian Energy Market Operator, 'Submission to AER WALDO VCR Consultation Paper'; Australian Energy Market Commission Reliability Panel, 'Submission to AER WALDO VCR Consultation Paper'.

[78] David S. Wong et al., 'The Australian Energy Crisis, Its Impact on Domestic Aluminium Smelting and Potential Solutions', in *Minerals, Metals and Materials Series*, 2020, 791–802, https://doi.org/10.1007/978-3-030-36408-3_106.

on a $/MWh basis are below the average VCR for a region, which does not reflect the direct and the broader social costs of WALDOs.

- **Pre-activation and activation lead times might be too slow to effectively deal with HILP events**. AEMO's website suggests that at least three hours' notice would be required to activate short-notice RERT[79]. Activation may not be timely if HILP events are not captured by AEMO's reliability assessments or ahead processes.

2.3 A potential RERT enhancement: the supply-demand resilience mechanism

The challenging nature of quantifying WALDO VCRs[80] should not preclude resilience planning, especially given increasing societal dependence on and growing threats to electricity supply (Sections 2.1.2 and 2.1.3, respectively). Despite the barriers to an accurate cost-benefit analysis, there is likely to be an asymmetry between the costs of a resilience "hedge" and that of WALDOs or power system failure. As such, a prudent and practical approach would be to enhance existing non-market "back-stop" mechanisms such as RERT.

We propose that this be achieved by the ESB re-considering **Jurisdictional Strategic Reserves** (JSR, as proposed in the Finkel Review[81] and recommended to Energy Ministers following the ESB's Post 2025 Market Design project[82]) **with an emphasis on diversity in fuel type and network location.** Recent events have demonstrated the value of the former, whilst the NEM's (relatively) weakly interconnected regions and stringy network topology support a requirement for the latter. **We will hereon refer to this as a "supply-demand resilience mechanism".**

Our proposal is a supply-demand resilience mechanism that **seeks to address the risk of HILP events by enhancing RERT**. At a high-level, this would be achieved through the procurement of an out-of-market JSR portfolio, with the composition ideally being diverse with respect to resource/fuel type and network location, and informed by an AEMO-led consultation and modelling process. Below, we provide a high-level overview of how we envisage this mechanism functioning:

1. **AEMO prepares advice for each jurisdiction on the quantity and nature of JSR that may be required**, with explicit consideration of potential HILP events and the system's response to each of these. This may require:
    a. **The identification of a suite of severe reliability/HILP events to consider.** One potential avenue is to generate scenarios for assessment qualitatively through AEMO consulting with broad segments of government and society (e.g. meteorologists and climate scientists, strategic policy experts, electricity industry stakeholders). Given the potential difference in magnitudes of various events, weightings may need to be used to prevent one event from dominating the solution.

[79] Australian Energy Market Operator, 'Reliability and Emergency Reserve Trader (RERT)', accessed 15 July 2022, https://aemo.com.au/energy-systems/electricity/emergency-management/reliability-and-emergency-reserve-trader-rert.

[80] Australian Energy Regulator, 'Widespread and Long Duration Outages - Values of Customer Reliability: Final Conclusions'.

[81] Alan Finkel et al., 'Independent Review into the Future Security of the National Electricity Market', June 2017, https://www.energy.gov.au/sites/default/files/independent-review-future-nem-blueprint-for-the-future-2017.pdf.

[82] Energy Security Board, 'Post-2025 Market Design: Final Advice to Energy Ministers - Part A', 27 July 2021, https://esb-post2025-market-design.aemc.gov.au/32572/1629944958-post-2025-market-design-final-advice-to-energy-ministers-part-a.pdf.

b. **Determining candidate JSR resource mixes.**

   i. This could be achieved qualitatively by considering events from a), the potential for certain resource types and network locations in each region (e.g. comparing pumped hydro potential with suitable network connection points) and the need for resource type and connection point diversity.

   ii. A more quantitative method could involve approaches such as Modelling to Generate Alternatives, which considers resource mixes that are "near-optimal" to the least-cost resource mix that is generated by deterministic capacity expansion modelling exercises, such as AEMO's Integrated System Plan[83]. "Near-optimal" resource mixes may be similar in cost but perhaps markedly different in composition to the least-cost resource mix (though an emphasis on optimising on cost could lead to a particular resource type being favoured).

   Regardless**, such resources mixes should ideally consider existing RERT resources.** Final advice could even recommend that existing RERT resources contribute to a JSR if AEMO's assessment suggests that additional resources are unlikely to deliver material benefits.

c. **Assessing candidate JSR resources mixes by "stress-testing" them** via operational models with scenarios that capture some of the potential consequences of the events identified in a). Final advice could be provided by using a "least-regrets" decision-making framework that essentially selects the best performing resources mix across scenarios (similar to the assessment methodology used in Nahmmacher et al., which models shocks and stresses[84]). We note that this analysis framework is currently being used in the Integrated System Plan to improve the robustness of transmission planning[85]. There could be a formal feedback mechanism that then iterates through potential events and refines resource mixes.

2. **Jurisdictions (i.e. state governments) receive publicly-available AEMO advice and tender for resources as they see fit**. In doing so, state governments will ideally consider existing and emerging policy support schemes for in-market resources. State governments could:

   a. Entirely cover resource capital/establishment costs but stipulate conditions for a RERT offer (e.g. offer at average operating costs); or

   b. Partially cover resource capital/establishment costs and offer an ongoing revenue guarantee should RERT revenue be insufficient to cover amortised capital costs and ongoing operating costs. Conversely, if RERT revenue exceeds the revenue guarantee, a portion could be recovered by state governments. This approach may be preferable if approach a) would suppress existing RERT providers and may be more appropriate if JSR is deployed by AEMO to assist in other jurisdictions.

3. **Once available, JSR would function as out-of-market "standing reserves" in operational timeframes and may only be deployed through current arrangements for RERT**. Ideally, with

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[83] Joseph F. DeCarolis, 'Using Modeling to Generate Alternatives (MGA) to Expand Our Thinking on Energy Futures', *Energy Economics* 33, no. 2 (1 March 2011): 145–52, https://doi.org/10.1016/j.eneco.2010.05.002.

[84] Nahmmacher et al., 'Strategies against Shocks in Power Systems – An Analysis for the Case of Europe'.

[85] Australian Energy Market Operator, '2022 Integrated System Plan', 84.

JSR resources included, AEMO's RERT portfolio should be able to respond to events rapidly and sustain reserve provision for extended periods of time. Resources procured as a part of the JSR would remain out-of-market for the duration of the resource lifetime. **Deployment via existing arrangements for RERT means that JSR resources should not impact spot market prices nor any associated signals for investment.**

2.3.1 Suitability of the supply-demand resilience mechanism

There are numerous advantages associated with our suggested approach:

- Unlike the ESB's proposed capacity mechanism, **the supply-demand resilience mechanism does not treat resources as fungible** vis-à-vis capacity. Diverse reserves are likely better placed to respond to a broad range of HILP events.
- The **supply-demand resilience mechanism is geared towards resources that perform, rather than capacity that *intends* to perform.** In its High-level Design paper[86], the ESB suggested that a JSR is undesirable as:
    - "consumers and government may not support paying for new resources to sit idle instead of actively participating in the market"; and
    - "less efficient and higher emissions capacity providers may continue operating while new, more efficient and lower emissions capacity providers sit on the sidelines".

  However, based on how the ESB's proposed capacity mechanism might function, we suggest **that consumers and government may not support paying for older emissions-intensive generation that *intends* to perform, but may in fact be unreliable during periods of system stress. Rather, back-stop reserves should be provided by a highly reliable portfolio of resources** – something that the supply-demand resilience mechanism aims to achieve.
- As JSR resources would remain out-of-market for the duration of their lifetime and as intervention pricing (which applies during RERT activation) does not preclude a high market price cap and thus prevent scarcity pricing**, traditional market signals for investment can be retained.**
- As the mechanism is out-of-market, **there are minimal market changes required**[87]. This is particularly important **not only because significant market reform has contributed to investment uncertainty in the NEM, but also because parallel reform workstreams may have complex and even unforeseen interactions**. An example of such interactions is the extensive discussion in the high-level design paper on the impacts of inter and intra-regional transmission constraints on capacity procurement and participation.
- The supply-demand resilience mechanism **extends and formalises existing efforts made by state governments to procure standing reserves as a safeguard**. Put another way, standing reserves are already being implemented to a degree by some state governments. Notably, the South Australian government procured 276MW of diesel fast-start generators in 2017 to use as standing reserves, a measure taken in response to the 2016 South Australian blackout (although

[86] Energy Security Board, 'Capacity Mechanism - High-Level Design Paper', 18.

[87] CIGRE Working Group C5.17, 'Capacity Mechanisms: Needs, Solutions and State of Affairs' (Paris: CIGRÉ, February 2016).

these assets have since transitioned into the market on 25-year leases from the government)[88]. Additionally, the government contracted 70MW, 10MWh of Hornsdale Power Reserve as a 'back up reliability measure', for FCAS participation and the South Australian System Integrity Protection Scheme (SIPS)[89]. Similarly, the Victorian government procured 250MW, 125MWh of the Victorian Big Battery as reserves to provide SIPS in a similar fashion[90].

2.3.2 "Screening" of supply-demand resilience events

The need for a mechanism to address supply-demand resilience events spanning hours to days or potentially weeks is difficult to grasp given that major loss-of-load events in the NEM have predominantly been security related. Such events are often characterized by the coincidental trip of generation and/or the loss of transmission network, with the majority of lack of supply events related to the former being resolved within minutes (typically through the action of FCAS and/or under-frequency load shedding). However, it is possible that the impact of HILP events on the NEM may be sustained, thus limiting supply for prolonged durations. Many of the events subsequently explored in this section present a NEM that was on the precipice of a major HILP event, given the plausibility that any one of these events could have eventuated in more severe, prolonged supply-demand disruptions had another contingency event or supply impact coincided with such.

To qualitatively explore the effectiveness of proposed resource adequacy and resilience mechanisms, we "screen" major supply-demand resilience events, in Table 1, that have occurred within the NEM and globally. At a high level, **our screening suggests that existing mechanisms and the ESB's proposed capacity mechanism are unlikely to mitigate against the consequences or severity of each resilience event**. In most cases specific to the NEM, RERT functions as required, yet for durations extended up to a few hours and in relatively small quantities, i.e. tens to hundreds of MW, not GWs.

Again, reiterating Section 2.2.2, such a mechanism **(RERT) should be used as last-resort emergency relief, not as a means to avoid justified procurement of reserves**. While historically RERT has averted major supply-demand disruptions, this emergency relief mechanism is operating at its limits to provide a response for longer durations (as in the recent 2022 NEM Market Suspension event, which we discuss in Table 1). It is unclear how far a mechanism dominated by demand response will fare in more severe HILP events. Climate change is increasing the frequency and magnitude of extreme weather effects as well as the potential for multiple coincident stress factors and thus more severe consequences. Based on these factors, there is a **growing need for a reserve mechanism that extends beyond the last-resort or emergency relief provided by RERT as is**. Yet, the proposed market-based capacity mechanism neither plans for diversity to provide resilience nor penalises poor performance, and is thus unable to provide measures to better cope with resilience events.

The final remark of this screening is that in many of the screened events, there is somewhat of a **reliance on interregional provision of supply**. Although there are significant benefits through interconnection including being better able to mitigate against HILP events, there is a **magnified risk for managing these events should one or multiple interconnectors be limited or disconnected during an event**.

A **reliable, technologically diverse and geographically dispersed set of resources at a jurisdictional level is best able to mitigate against a variety of HILP events**. These factors consider the impacts to specific

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[88] Simon Evans, 'South Australian Government to Privatise Jay Weatherill's Diesel Generators', *Australian Financial Review*, 16 October 2018, https://www.afr.com/companies/energy/south-australian-government-to-privatise-jay-weatherills-diesel-generators-20181016-h16ph4.

[89] Aurecon, 'Hornsdale Power Reserve: Year 1 Technical and Market Impact Case Study', 2018, https://hornsdalepowerreserve.com.au/wp-content/uploads/2020/07/Aurecon-Hornsdale-Power-Reserve-Impact-Study-year-1.pdf.

[90] PricewaterhouseCoopers (PwC), 'SIPS 2020, Validation Business Case for a Victorian SIPS Service', 4 November 2020, https://www.energy.vic.gov.au/__data/assets/pdf_file/0028/495163/SIPS-2020_Executive-Summary-extract.pdf.

generation technology types such as gas and/or coal fuel shortages, impacts to hydro generation during droughts and *Dunkelflaute* periods impacting solar and wind availability. Similarly, a locational and jurisdictional consideration of reserves better manages against transmission line outages, which may occur due to storms, extreme winds or bushfires.

N.B.: An evaluation of warning period in Table 1, can be regarded as specific signs prior to the initiation of the event. This does not reflect potential reform following past resilience events that may have mitigated or reduced the severity of a subsequent event.

Table 1. Screening of Some Relevant NEM and International Resilience Events.

Event	Warning Period	Supply Impact + Severity	Assessment of Mechanisms
Texas Freeze February 2021 Severe cold weather event.	• 1-2 months prior: ERCOT Seasonal Assessment of Resource Adequacy (SARA) forecasts extreme load scenario level of reserves to be at risk of 'Energy Emergency Alert'. • 1 week prior: weather models raise alarm of a severe cold weather event yet with notable uncertainty in forecasts. • 2 days prior: Operating reserves deployed. • The commencement of the event outage is considered upon firm load shedding at 1:25am on February 15th [91].	• Demand peak exceeds SARA extreme load forecast by 9.5 GW. • Extreme cold temperatures limited supply across nuclear, wind, coal and gas generation, partially due to a lack of winterization of supply assets, however gas generation was most drastically affected. • A deficit of 21% of gas generation capacity and 28% of coal generation capacity against extreme load scenario in SARA. • A cyclical impact of gas compressors without electricity supply, exacerbating gas supply issues and limiting gas generation of electricity. • A prolonged duration of load shedding over 4 days totalling 10.5 GW[92]. • Over 200 lives lost attributed to the winter storm and combined electricity/gas failures[93].	• **A reserve mechanism which procures a diverse set of generation technology with uncorrelated effects to existing in-market generators may have reduced the severity of this event** or those of analogous nature that may be faced in the NEM (i.e. major gas fuel deficits). • Whilst a supply-demand resilience mechanism does not guarantee complete mitigation of load shedding, it is better placed to address such events given reliable standing reserves. • **It is unreasonable and unlikely that existing RERT providers could deliver demand response over periods spanning multiple days**.
NEM VIC-NSW Separation Event. January 4, 2020 Black Summer Bushfires + Heatwave.	• 4 days prior: AEMO issue market notice stating increased likelihood of a non-credible contingency event. • 3 days prior: AEMO issue market notice for extreme temperatures forecast for January 4, 2020. • Hours prior: AEMO issue market notice warning of possible impact of multiple transmission lines in NSW due to bushfires[94]. • Commencement of event is considered upon AEMO declaring an actual LOR2 at 4:00pm on January 4th with a 257MW shortfall in reserves[95].	• 137 bushfires were reported in NSW on January 4 with temperatures reaching 47°C in Sydney Basin. • Remaining transmission lines (not already affected by unplanned outages) tripped at 3:10pm islanding QLD and NSW from SA, VIC, TAS and south-western NSW[96]. • Estimated loss of 3GW of supply availability in NSW[97]. • AEMO activated 68MW of reserve via RERT and a further 300MW were pre-activated. • LOR 2 cancelled at 9:45pm[98]. • 43 MW of customer load shed in southern NSW[99].	• The significance of this event **highlights the need for a mechanism to consider network diversity and locational considerations of reserves**. • Further the limitations on generators' technical performance with respect to temperature during heatwaves is paramount. **Existing and ageing thermal generation assets paid via a market-based mechanism would be ill-suited to mitigate the impacts of bushfire and coinciding heatwave events**.
NEM Market Suspension June 2022 Gas supply shock.	• Weeks to a month prior: Gas pricing peaks at $55/GJ in Victoria, LNG exports increased in QLD, gas price caps imposed in VIC, NSW, QLD on May 30. Subsequent gas supply guarantee was triggered on June 1 [100]. • Weeks to months prior: meteorology forecasts of above average winter-spring rainfall with continuing La Nina[101]. • Cumulative price threshold reached in QLD on June 12. • Market suspension commenced June 15.	• It is difficult to ascertain the loss of supply due to fuel shortages in gas and flooding of coal stockpiles given La Nina rainfall, however these are known factors to have contributed[102]. • 3GW of coal-fired generation was reported as unplanned outages[103]. • Hydro generation availability was also impacted by full reservoir levels given rainfall, with Tumut 3 constrained given risk of Blowering reservoir spilling[104]. • Forecast but averted load shedding at various times throughout this event, however RERT activated for 8 hours, the longest duration of activation on record[105] . • Other contributing factors surrounding the NEM market suspension and administrative pricing events are not considered resilience events.	• Of the impacts relevant to the underlying resilience event in this case, **an out of market standing reserves and hence further fuel reserves merits consideration to better mitigate against a gas crisis and La Nina rainfall impacts to in-market generation fuel stockpiles**.

Millennium Drought 1997 – 2010 Prolonged drought.	• Unlike 'shock' resilience events, the prolonged impact of the millennium drought period suggests a warning period of months to years ahead of the peak of water shortage observed in 2007-8.	• A prolonged impact to hydro generation across the NEM, an example being Tumut 3 generation limited to <20% of available capacity with reservoir levels in Lake Eucumbene reaching close to 10% in 2007-8[106]. • Operation of hydro was further impacted by controlled water releases for downstream irrigation or environmental considerations. • Thermal generation was also impacted by availability of cooling water[107].	• The prolonged duration of drought periods extending across years poses a different impact to NEM resilience, most severely limiting hydro and pumped hydro storage availability. • The merit in 'screening' this event highlights the threat of a myopic view should hydro resources be heavily relied upon as reserves. Further **compounding HILP events of drought, heatwaves and bushfires pose a serious risk to the available capacity of large, centralized hydro and thermal generation**.
Callide C event May 25, 2021 Coal unit outage.	• There was relatively no warning period for the Callide C turbine hall fire event. • The event, albeit largely a system security one, is considered to have commenced at 1:33pm on May 25, 2021 upon Callide C4 no longer generating, rather motoring asynchronously[108].	• A cascading impact of Callide C resulted in; an estimated 2.7GW of customer load interruption predominantly through underfrequency load shedding, supply loss of 9 major generation units, and subsequent tripping of QNI further islanding QLD albeit briefly. • Sustained supply impact, a reduction of 2.9GW, was noted as actual LOR1 and LOR2 notices in QLD and NSW. Total duration of which extended from 3:30pm to 7:30pm. • Additionally, 15MW of RERT was activated in QLD from 5pm to 7:45pm given the eventuation of LOR2. • Following the reconnection of QNI (after a brief islanding), transfer limits restricted import flows to QLD on both QNI and Directlink[109].	• A need for flexible and diverse reserves both technologically and geographically is justified to mitigate the effects of cascading plant trips. **Network diversity in this regard would help mitigate intraregional supply disruptions**. • The **limitation on supply from neighbouring regions following islanding emphasizes the considerations for a jurisdictional reserve mechanism**.

[91] Ning Lin, 'The Timeline and Events of the February 2021 Texas Electric Grid Blackouts' (University of Texas at Austin, July 2021), https://energy.utexas.edu/ercot-blackout-2021.
[92] Joshua Busby, 'Cascading Risks: Understanding the 2021 Winter Blackout in Texas', *Energy Research & Social Science* 77, no. 102106 (July 2021), https://doi.org/10.1016/j.erss.2021.102106; Ning Lin, 'The Timeline and Events of the February 2021 Texas Electric Grid Blackouts'.
[93] Jacob Mays et al., 'Private Risk and Social Resilience in Liberalized Electricity Markets', *Joule* 6, no. 2 (16 February 2022): 369–80, https://doi.org/10.1016/j.joule.2022.01.004.
[94] Paul McArdle, 'More Details on the Bushfire-Driven Extremes in the NSW Region of the NEM on Saturday 4th January', *WattClarity*, 4 January 2020.
[95] Australian Energy Market Operator, 'RERT Quarterly Report: Q1 2020', May 2020.
[96] Australian Energy Market Operator.
[97] Paul McArdle, 'More Details on the Bushfire-Driven Extremes in the NSW Region of the NEM on Saturday 4th January'.
[98] Australian Energy Market Operator, 'RERT Quarterly Report: Q1 2022'.
[99] AEMO, 'Final Report New South Wales and Victoria Separation Event on 4 January 2020', September 2020.
[100] Daniel Westerman, AEMO CEO, speaks at the Clean Energy Summit, 19 July 2022, https://aemo.com.au/newsroom/news-updates/aemo-ceo-speaks-at-the-clean-energy-summit.
[101] Australian Government Bureau of Meteorology, 'Climate Driver Update: Models Indicate Increased Chance of Negative Indian Ocean Dipole for Winter', 24 May 2022, http://www.bom.gov.au/climate/enso/wrap-up/archive/20220524.archive.shtml.
[102] Paul McArdle, 'Trucking Coal from Callide to Millmerran, as a Result of the La Nina Rain Event', *WattClarity*, 3 May 2022.
[103] Daniel Westerman, AEMO CEO, speaks at the Clean Energy Summit, 19 July 2022, https://aemo.com.au/newsroom/news-updates/aemo-ceo-speaks-at-the-clean-energy-summit.
[104] Snowy Hydro, 'Snowy Hydro Water Releases from Tumut 3 Power Station', 6 March 2022, https://www.snowyhydro.com.au/news/snowy-hydro-water-releases-from-tumut-3-power-station/.
[105] AEMO, 'Reliability and Emergency Reserve Trader (RERT) Contracted on Friday 17 June 2022', 7 November 2022.
[106] Paul McArdle, 'How the Drought of 2007 Affected Specific Power Stations', *WattClarity*, 20 October 2010.
[107] John Radcliffe, 'The Water Energy Nexus in Australia – The Outcome of Two Crises', *Water-Energy Nexus* 1 (2018): 66–85.
[108] Australian Energy Market Operator, 'Trip of Multiple Generators and Lines in Central Queensland and Associated Under-Frequency Load Shedding on 25 May 2021', October 2021.
[109] Australian Energy Market Operator.

2.3.3 Limitations for further consideration

c) Supply-demand resilience is a subset of power system resilience

We stress that our proposal would only be able to address supply-demand resilience, a subset of broader power system resilience. In particular, **neither the supply-demand resilience mechanism nor the ESB's proposed capacity mechanism can significantly improve the resilience of distribution and transmission networks** (though additional resources that are distributed across the network may leave greater headroom on bottleneck lines). While transmission network resilience can be improved to some degree through protected and indistinct event frameworks, **a more holistic approach to resilience should consider how resilience can be incorporated into planning and investment timeframes.** This is crucial because, as AEMO notes, control/software solution can only compensate for investments in physical infrastructure to some degree before introducing additional failure modes or fragility[110]. Given the radial nature of distribution networks, distribution network resilience has received far more attention under the umbrella of network reliability - however, appropriate mitigation measures need to be enabled by regulatory frameworks.

It is also vital to emphasise that a supply-demand resilience mechanism **does and should not guard against all possible HILP events. Rather, the mechanism we propose would select a portfolio of resources that form the best all-round (strictly, the least-regrets) "hedge" against a variety of possible events**. Given the asymmetry between the costs of mitigation strategies and the cost of market and power system failure, and the non-linearities that dominate the dynamics and operation of the power system, we are of the view that modest investment in such a hedge could mitigate, if not prevent, huge direct and broader social costs.

d) Timeframe of the mechanism

If the supply-demand resilience mechanism is implemented, some resources could be deployed and available as standing reserves sooner; others may take years. It seems likely that the supply-demand resilience mechanism would only **reach its full potential once a complete suite of resources could be deployed, which could take a number of years. Staged deployment of diverse resources within a JSR may help** – some may be available within as little as a year, others within five to ten years.

e) Longevity of the mechanism

It is unclear whether investments in JSR resources will be justified by the time they are operational. While this is true, **it should be noted that in-market resources are being deployed with little to no consideration of supply-demand resilience**. The possibility of a cost asymmetry, which we have raised repeatedly in this submission, is the primary reason why the risk of over-investment should be borne.

Moreover, an important consideration is **whether a supply-demand resilience mechanism forecloses the potential for alternative energy futures** that may deliver greater resilience at lower cost. **One example is a grid architecture that leverages resilience from microgrids** (systems that have the capability to operate whilst grid-connected and also when islanded from the main power system). Such a solution addresses more facets of power system resilience, particularly for the communities serviced by the microgrid.

We note there is still a lack of clarity and regulatory barriers surrounding the operation of grid-connected microgrids, including issues pertaining to ring-fencing regulations limiting Network Service Providers (NSPs) from owning generating assets and the challenges of continued performance penalties during islanded operation. Rather than considering microgrids (as defined above, noting that they can be grid-connected), the AEMC has instead focused on standalone power systems (SAPS, which are off-grid).

[110] Australian Energy Market Operator, '2020 ISP - Appendix 8 . Resilience and Climate Change', 2020, 8.

ARENA currently has a funding round open for microgrids in regional areas to address these regulatory barriers limiting investment certainty[111].

We are of the view **that it is not an "either-or" choice between our proposal and other mechanisms (such as progressing the regulatory viability of microgrids), but rather that multiple solutions can be pursued**. While social, regulatory and technical work is underway to pave the way for the implementation of other architectures, the supply-demand resilience mechanism can serve as a stopgap solution, particularly as conventional generation begins to leave the NEM *en masse*.

Finally, **could the market-based mechanisms be employed to improve the efficiency of resiliency solutions?** This is dependent on two factors:

1. **Can HILP events be defined, predicted and modelled?** This is an open question and may remain so unless further strides are made in weather forecasting and tractable power system modelling. At least in the short term, it is more likely that certain events will be selected and tested (e.g. General Power System Risk Review), and that a decision-making framework (e.g. least-regrets) will need to be employed to select solutions.
2. **Can HILP events be incorporated into a market framework?** One potential avenue is an insurance overlay for energy-only markets, with consumers buying insurance from an insurer (which could be the system operator) that maintains a portfolio of strategic reserves[112]. Such a mechanism could enable tail risks to be managed vis-à-vis strategic reserves investment based on insurance industry best-practice. However, the implementation of such a mechanism would likely take several years (due to telecommunications infrastructure roll-out, development of regulatory frameworks, etc.). Furthermore, there are serious equity concerns with such mechanisms (i.e. should in-market investment under-deliver, access to reliable electricity may be restricted to those who are able to pay for insurance products). Moreover, the success of such a mechanism is reliant on Point 1 – that is, the management of tail-risks requires the characterisation of their likelihood and consequences.

f) Resilience of a market-based system for energy

Our submission has primarily focused on "physical" supply-demand resilience. If we expand the focus of resilience to include the resilience of the market itself**, there is scope for market reconfiguration or additional schemes that could better "insure" the NEM against phenomena that threaten market stability** (and by extension, the provision of affordable and reliable electricity).

While previous reviews have done much work to highlight potential weaknesses[113], the **recent June 2022 energy crisis has highlighted that there is still much to do in this space**. In our view, two longer-term issues of note are:

1. Aligning compensation frameworks that may be in effect at the same time (i.e. compensation under administrative pricing and when resources are directed by AEMO).

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111 Australian Renewable Energy Agency, 'Regional Australia Microgrid Pilots Program: Guidelines', September 2021, https://arena.gov.au/assets/2021/09/regional-australia-microgrid-pilots-program-guidelines.pdf.

112 Farhad Billimoria et al., 'An Insurance Mechanism for Electricity Reliability Differentiation under Deep Decarbonization', *Applied Energy* 321 (September 2022): 119356, https://doi.org/10.1016/j.apenergy.2022.119356.

113 Australian Energy Market Commission, 'NEM Financial Market Resilience', AEMC, accessed 19 July 2022, https://www.aemc.gov.au/markets-reviews-advice/nem-financial-market-resilience.

2. Better management practices for energy-limited resources, potentially under normal operation but especially once “circuit-breaker” provisions have come into effect. A related matter is for compensation frameworks to better consider the costs incurred by storage (particularly battery energy storage systems) during market suspension.

Such measures could ensure that, if practicable, electricity supply continues despite market turbulence. Further work will be required to determine how, if at all, market resilience during normal operation can be enhanced (e.g. protection against sustained high prices). As discussed earlier in this submission and as is reflected in what we see as potential solutions to current challenges and issues (Section 1.3), our view is that **“patchwork” solutions solely focused on market and grid operations will only be able to compensate for investments in infrastructure to a limited extent.**

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The views presented in this submission are solely those of the authors, and don't necessarily represent the views of the Digital Grid Futures Institute or, more generally, UNSW Sydney.