



Resilience to Variable Renewable Energy Lulls

5th November 2025





We acknowledge the Traditional Custodians of the land, seas and waters across Australia. We honour the wisdom of Aboriginal and Torres Strait Islander Elders past and present and embrace future generations.

We acknowledge that, wherever we work, we do so on Aboriginal and Torres Strait Islander lands. We pay respect to the world's oldest continuing culture and First Nations peoples' deep and continuing connection to Country; and hope that our work can benefit both people and Country.

'Journey of unity: AEMO's Reconciliation Path' by Lani Balzan

AEMO Group is proud to have delivered its first Reconciliation Action Plan in May 2024. *'Journey of unity: AEMO's Reconciliation Path'* was created by Wiradjuri artist Lani Balzan to visually narrate our ongoing journey towards reconciliation – a collaborative endeavour that honours First Nations cultures, fosters mutual understanding, and paves the way for a brighter, more inclusive future.

Read our RAP



Speakers



Melanie Koerner

General Manager | ASL



Shira Samocha

Senior Manager, Modelling | ASL



Dominic Price

Manager, Modelling | ASL



Stuart Browning

Climate Scientist | Risk Frontiers

Introduction

Building resilience to VRE lulls

What is a VRE lull?

- VRE lulls are periods with sustained low output from wind and solar generators.

Why are VRE lulls important?

- The electricity system is becoming increasingly dependent on the weather, and the weather is changing with climate change.

What is ASL's role?

- As the NSW Consumer Trustee, ASL has a system planning role for NSW.
- Published in August, the 2025 Infrastructure Investment Objectives (IIO) report sets out the 20-year development pathway and 10-year tender plan for NSW generation, long duration storage and firming infrastructure.
- As per regulations, the IIO report is required to include an assessment of the **resilience** of the electricity system, in relation to **VRE lulls**, with reference to **climate modelling**.

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Literature review

Literature review

The use of climate data to inform system planning is evolving

Energy market:

- **Gilmore et al (2022)**: analysed **42-year** historical dataset back to 1980 to quantifying the risk of renewable energy droughts.
- **NSW OECC (2023)**: analysed **42-year** historical dataset back to 1979 and compared with AEMOs 10-year dataset.
- **AEMO ISP (2024)**: system planning with a **14-year** historical dataset back to 2011, with additional stress test analysis.
- **Reliability Panel AEMC (2024)**: analysed **83-year** historical weather dataset, accompanied by synthetic demand traces.
- **AEMO ESOO (2025)**: reliability study using **20-year** historical weather dataset tracing back to 2003.
- **ASL IIO (2025)**: climate projections with **280-year** weather samples for each forecast years, to study impact of climate change on VRE lulls.

Climate science:

- **ESCI (2021)**: sets out a framework for understanding climate risk and recommends the use of four region climate models.
- **Poddar et al (2021; 2023)**: used regional climate models to study solar intermittency.
- **Kapica et al (2023)**: impact of climate change on European renewables
- **Richardson et al (2023)**: used **62-year** historical dataset back to 1959 to analyse compound VRE lulls in Australia.
- **Kittle et al (2024)**: describes two approaches to VRE analysis.

02

Modelling methodology

Climate data sources

The analysis utilises long-term climate projections rather than historical weather

The analysis uses the BARPA regional climate model, calibrated to the BARRA historical dataset, both of which are produced by the Bureau of Meteorology.

| Dataset | Description | Time period | Resolution |
|----------|---|-----------------|--------------------|
| BARRA-C2 | Reanalysis dataset across Australia | 1979 to present | 4 km ² |
| BARPA-R | Regional climate model consisting of 7x global climate models, 2x climate warming scenarios and a 20-year rolling window (280 sample weather years for each forecast year). | 1979 to 2100 | 17 km ² |

Utilising long-term climate projections rather than historical weather data provides two advantages:

1. the ability to capture the potential impact of climate change,
2. the ability to project a larger sample of possible weather patterns, and therefore more accurately understand the probability distribution of extreme VRE lulls under the current climate.

Definition of a VRE Lull

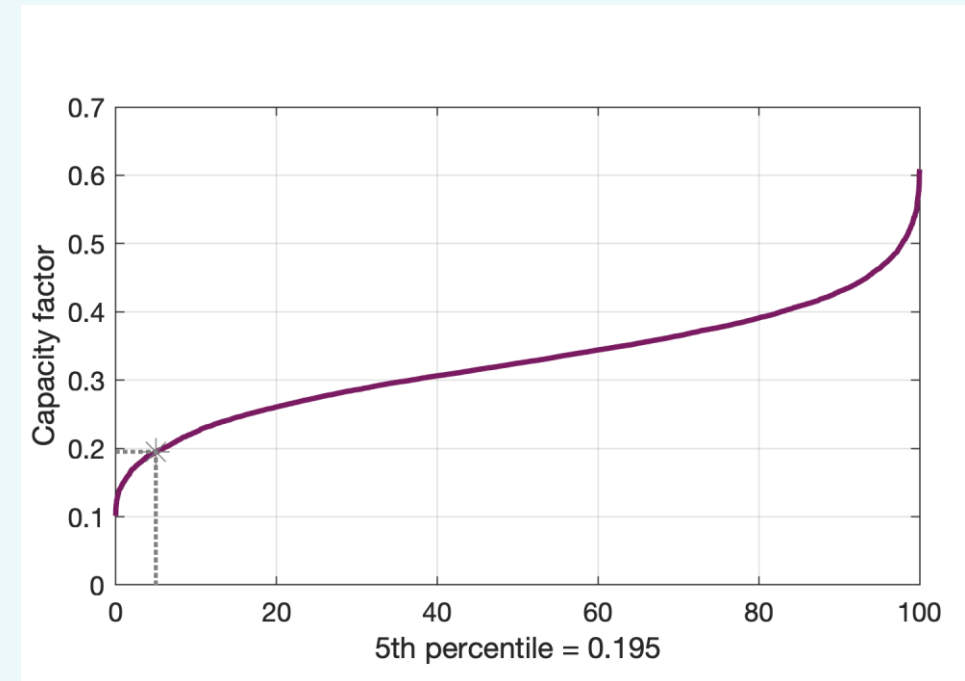
Our definition of VRE lulls are multi-day events where wind and solar output across the NEM is sustained below the fifth percentile based on recently observed history.

This definition results in VRE lulls which range in duration from 4 days (the 1-in-2-year events) to 12 days (the 1-in-50-year events).

This definition is applied differently across the VRE lulls analysis:

- Part 1: When analysing the impact of climate change on VRE lulls, this definition is applied to weather data.
- Part 2: When analysing the resilience of the development pathway to VRE lulls, this definition is applied to generation data.

Figure: The daily NEM-wide VRE availability capacity factor



Definition of resilience

Our definition of resilience is the ability of the electricity system to limit the severity and duration of system degradation following an extreme VRE lull event

The VRE lulls analysis explores:

- The ability of the system to operate reliably, and
- More broadly, the implications associated with relying on other sources of generation, and the impact of VRE lulls on NSW wholesale prices.

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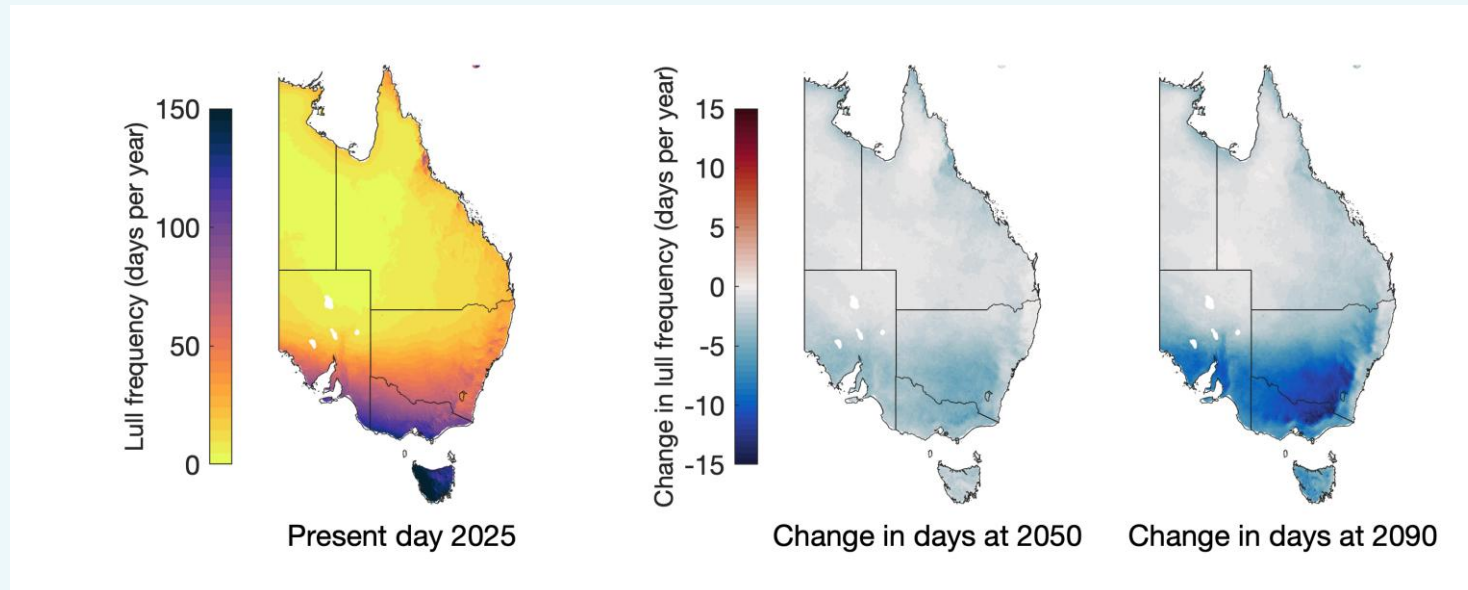
The impact of climate change on VRE lulls

Projected changes to solar irradiance

There is a projected decrease in local solar lulls, particularly in the southern area of Australia

- Solar irradiance is less in the southern area of Australia, particularly during winter, due to the low angle of the sun and increased cloud cover.
- The climate projections show an increase in sunny days and a decrease in cloudy days, particularly in the southern area of Australia.

Figure: Average frequency of local solar lulls

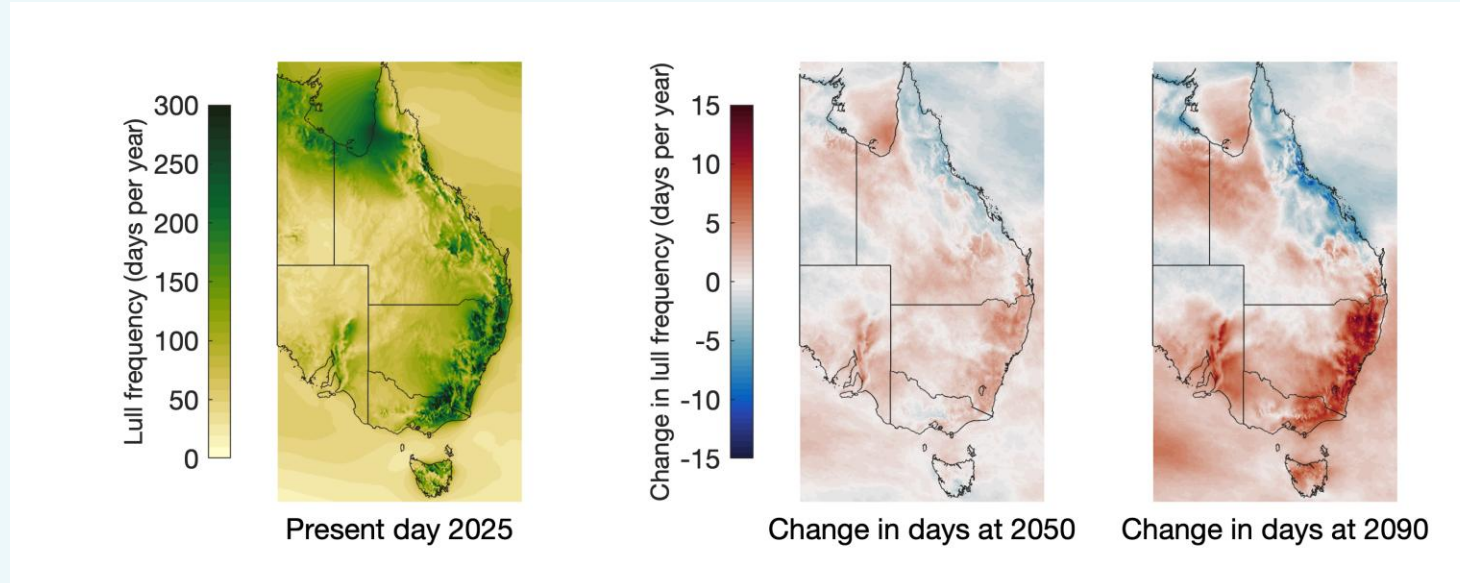


Projected changes to wind speeds

There is a projected change in wind speeds, depending on location

- Wind speeds are influenced by a combination of factors, including latitude, proximity to the coast and local topography.
- The climate projections show a change in wind speeds, with less wind in southern areas and more wind in northern areas.

Figure: Average frequency of local wind lulls



Projected changes to VRE lulls

The average frequency of solar lulls is projected to decrease, whilst the average frequency of wind and compound lulls is not projected to change

The results show that throughout the remainder of the century there is:

- a **projected decrease** in the average frequency and duration of NEM-wide **solar lulls**, and
- no projected change in the average frequency and duration of NEM-wide wind and compound lulls.

Figure: Average frequency of widespread wind and solar lulls

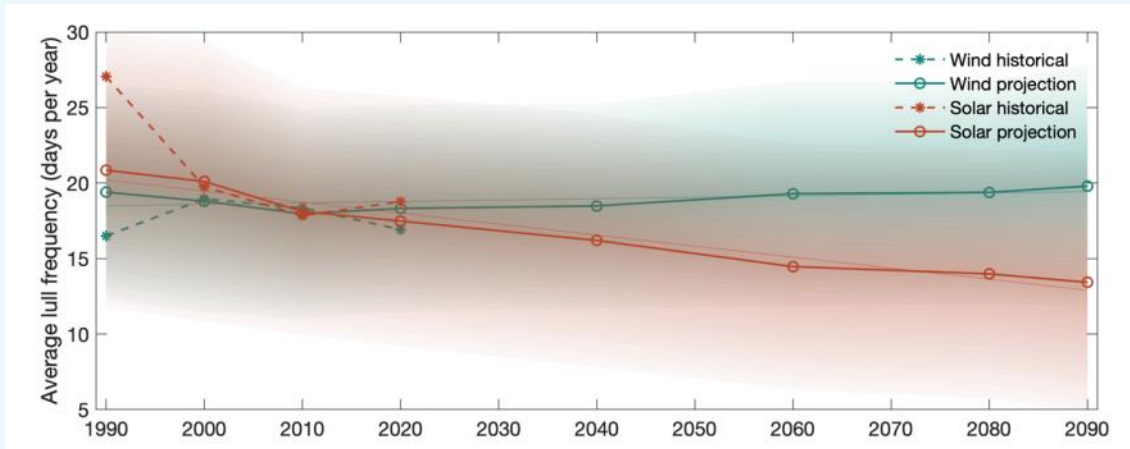
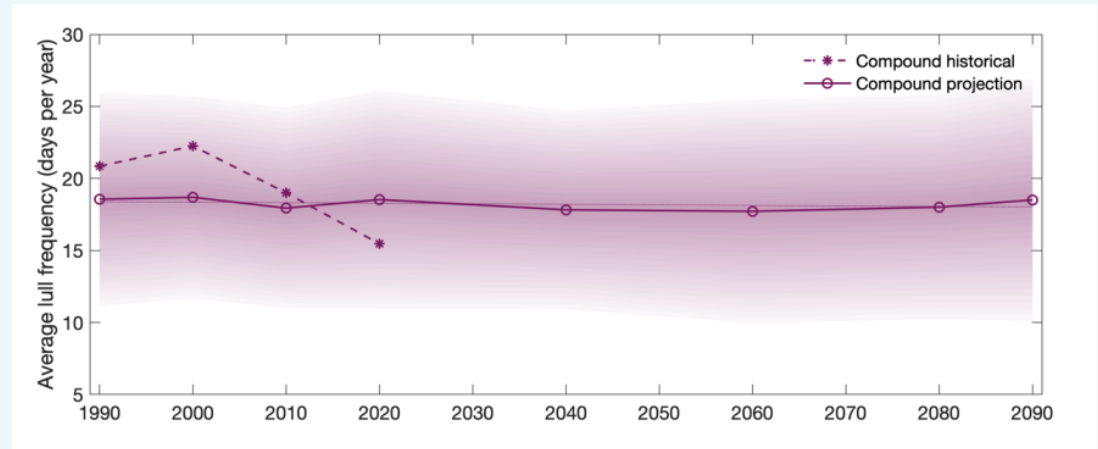


Figure: Average frequency of widespread compound lulls

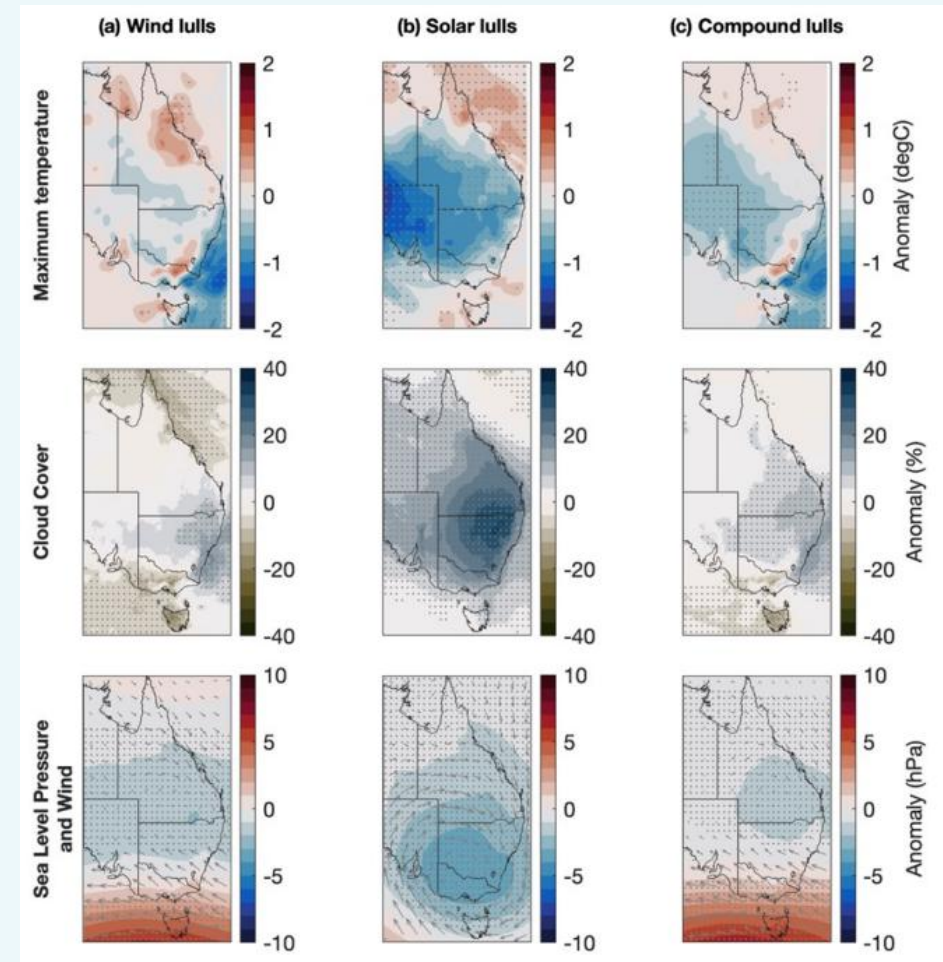


Weather patterns during VRE lulls

Still days are typically sunny, whilst cloudy days are typically windy.

- Fortunately, the weather patterns responsible for solar lulls are typically different to those responsible for wind lulls.
- Compound lulls are associated with low daytime temperatures over inland Australia, increased cloud cover over most of NSW and QLD, and a high-pressure system to the south of Australia.
- For each one-degree reduction in NSW maximum temperature during winter, demand can increase by between 3% and 7%, primarily due to the use of heating.

Figure: Synoptic weather chart during typical VRE lulls

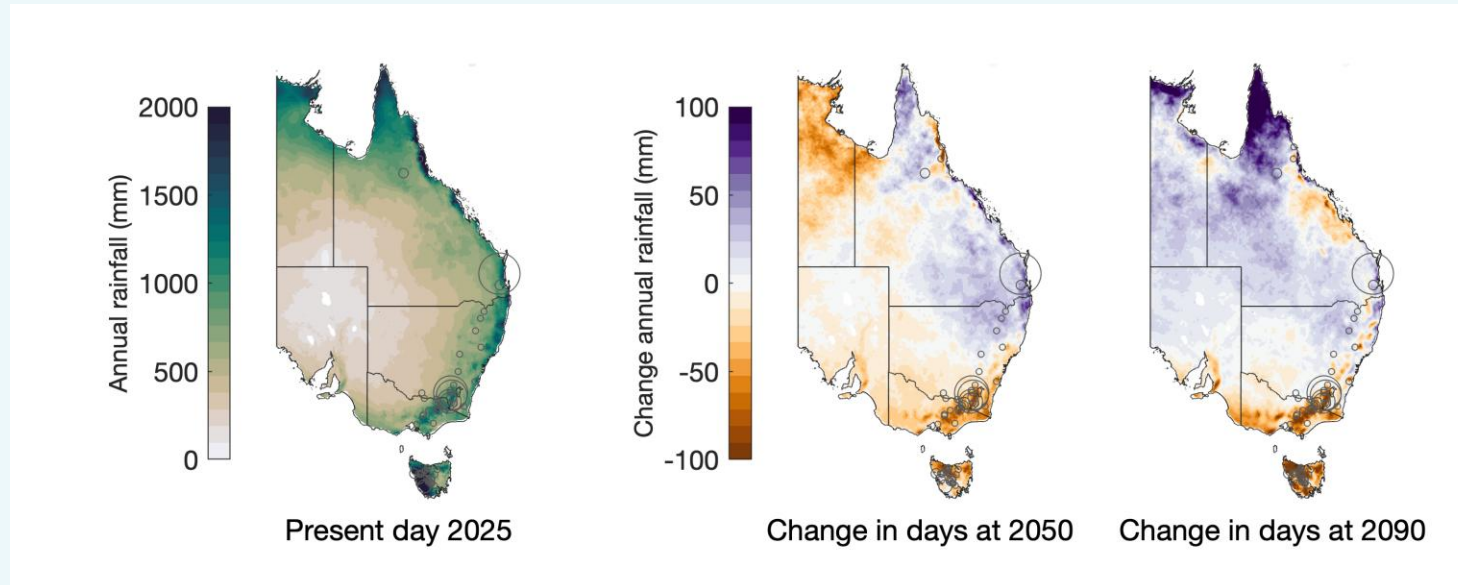


Projected changes to rainfall

There is a projected decrease in rainfall in the Snowy region and Tasmania

- This has implications on the ability of hydro power stations to provide generation during VRE lull events.
- These findings also support the need for improved short-term forecasting of VRE lulls and appropriate water reservoir management throughout the year.

Figure: Annual rainfall projection



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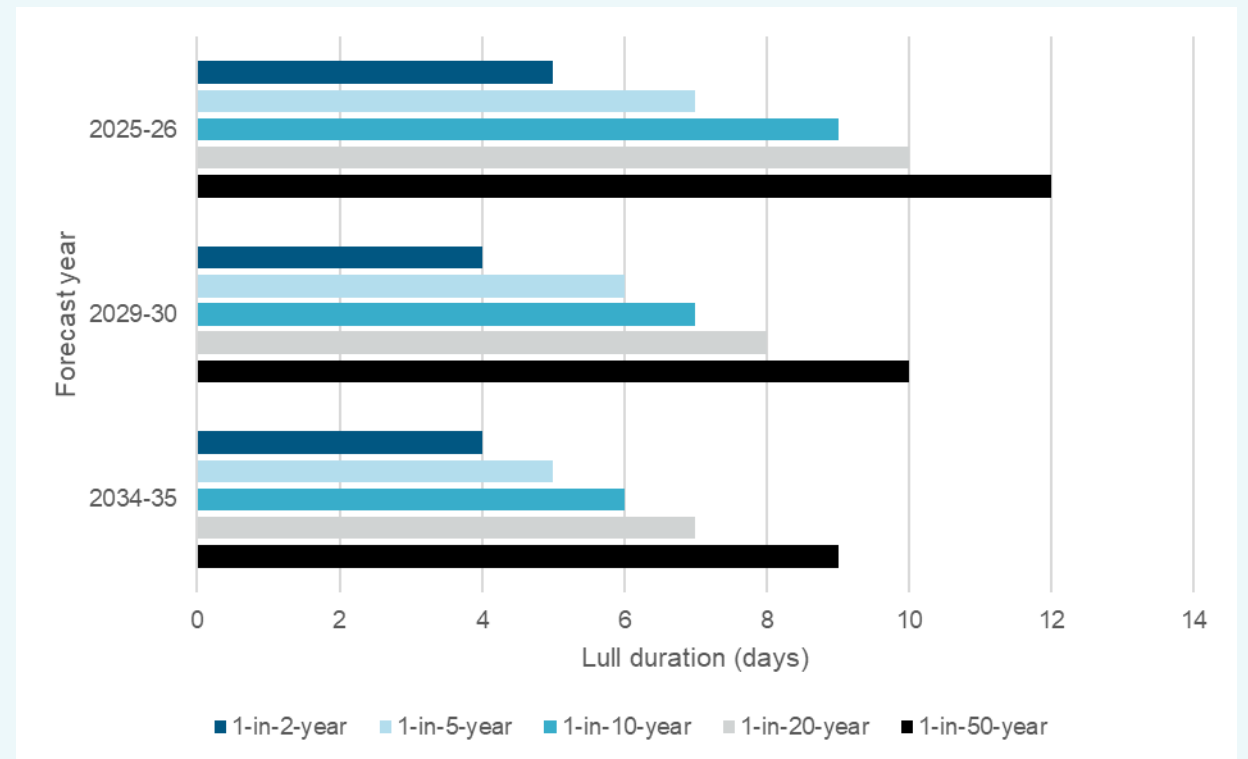
The resilience of the Development Pathway to VRE lulls

Increasing diversity of VRE

As the diversity of VRE increases, the duration of VRE lulls is forecast to reduce

- There are 15 VRE lulls selected across the next decade with consideration of both climate projections and forecast capacity mix of VRE.
- These reflect a range of durations from 4-days long (1-in-2-year event) to 12-days long (1-in-50-year events).
- There is a reduction in VRE lull duration across forecast years, primarily driven by increases in geographic and technological diversity of VRE.

Figure: Duration of VRE lulls



Case study: 7-day VRE lull projected for June 2035

VRE is primarily replaced by hydro, gas, battery and imported energy

- During this 7-day period, the capacity factor of VRE was 13% across the NEM and 11% across NSW, far less than what is typical.

Figure: NSW dispatch during typical weather conditions

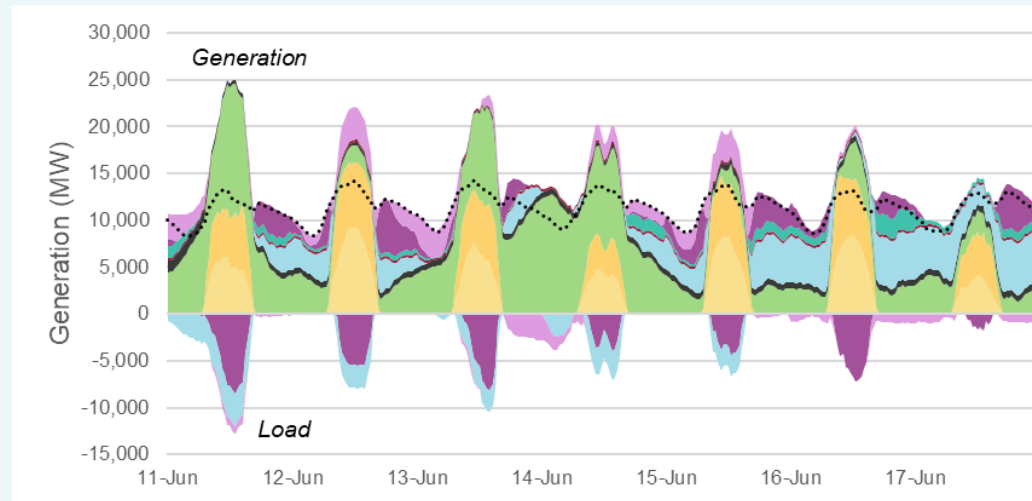
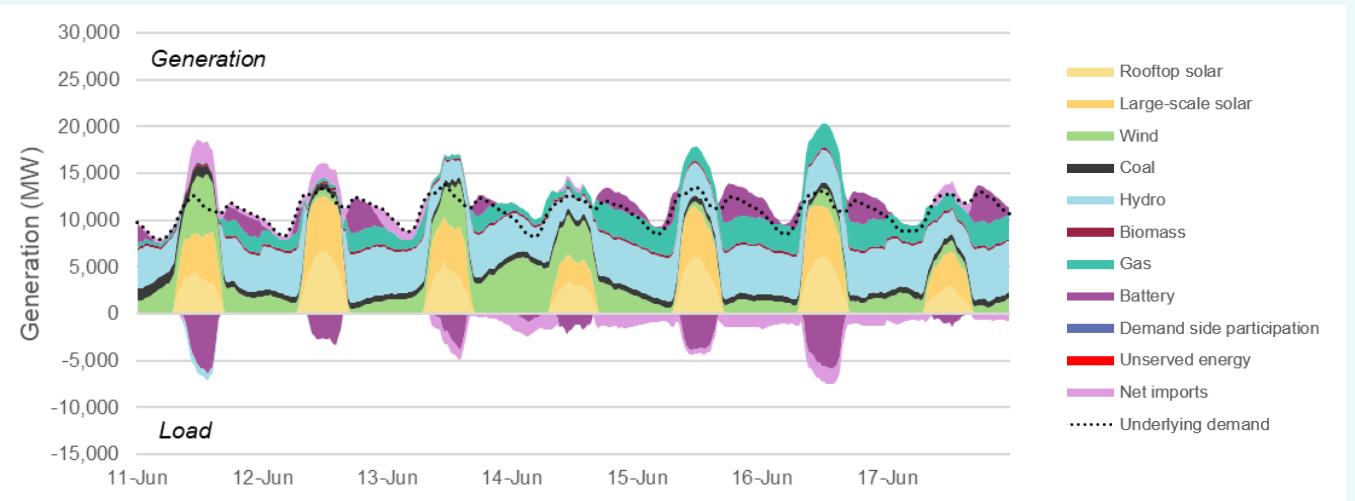


Figure: NSW dispatch during VRE lull



Reliance on hydro and gas generation

Hydro and gas need to operate with minimal constraints to provide resilience

- Hydro generation plays a significant role during the VRE lull, with high sustained output and minimal pumping. Across the seven days, the reservoir storage levels of the hydro and pumped hydro power stations only drop by 10%.
- Gas generation plays a significant role during the VRE lull. The modelled level of gas output exceeds the current capability of the gas system in NSW and required onsite secondary fuels.

Figure: NSW dispatch during typical weather conditions

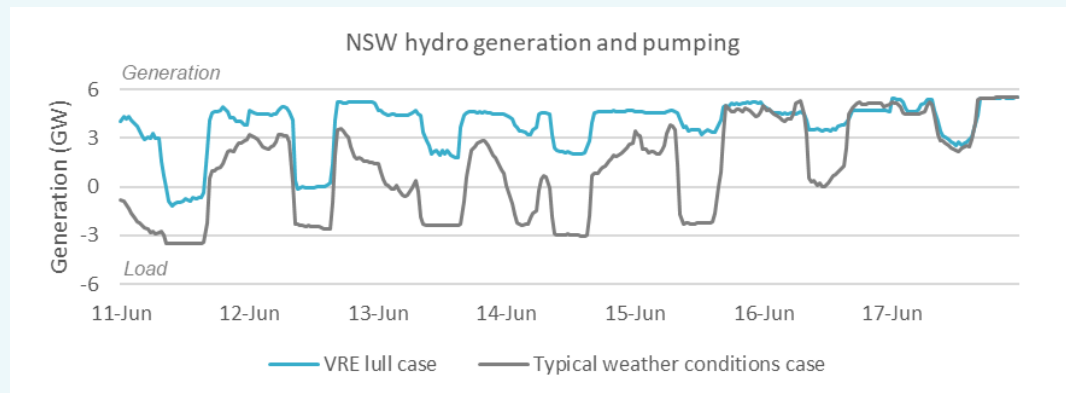
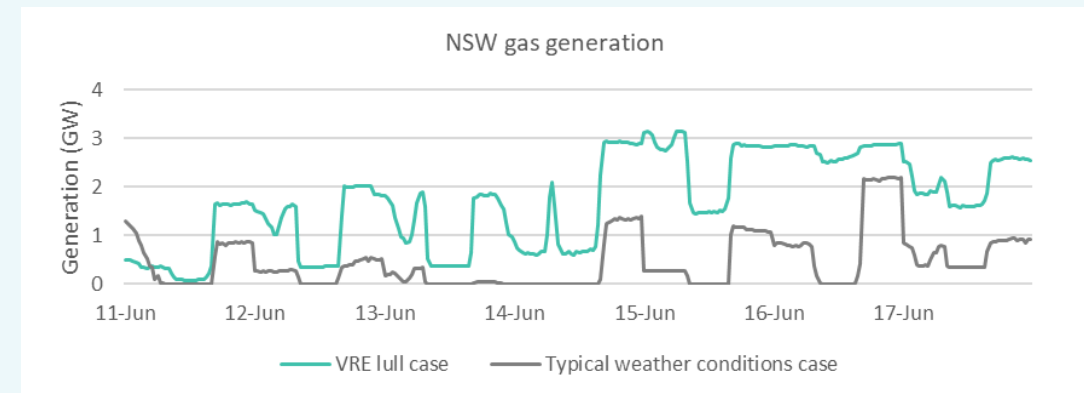


Figure: NSW dispatch during VRE lull

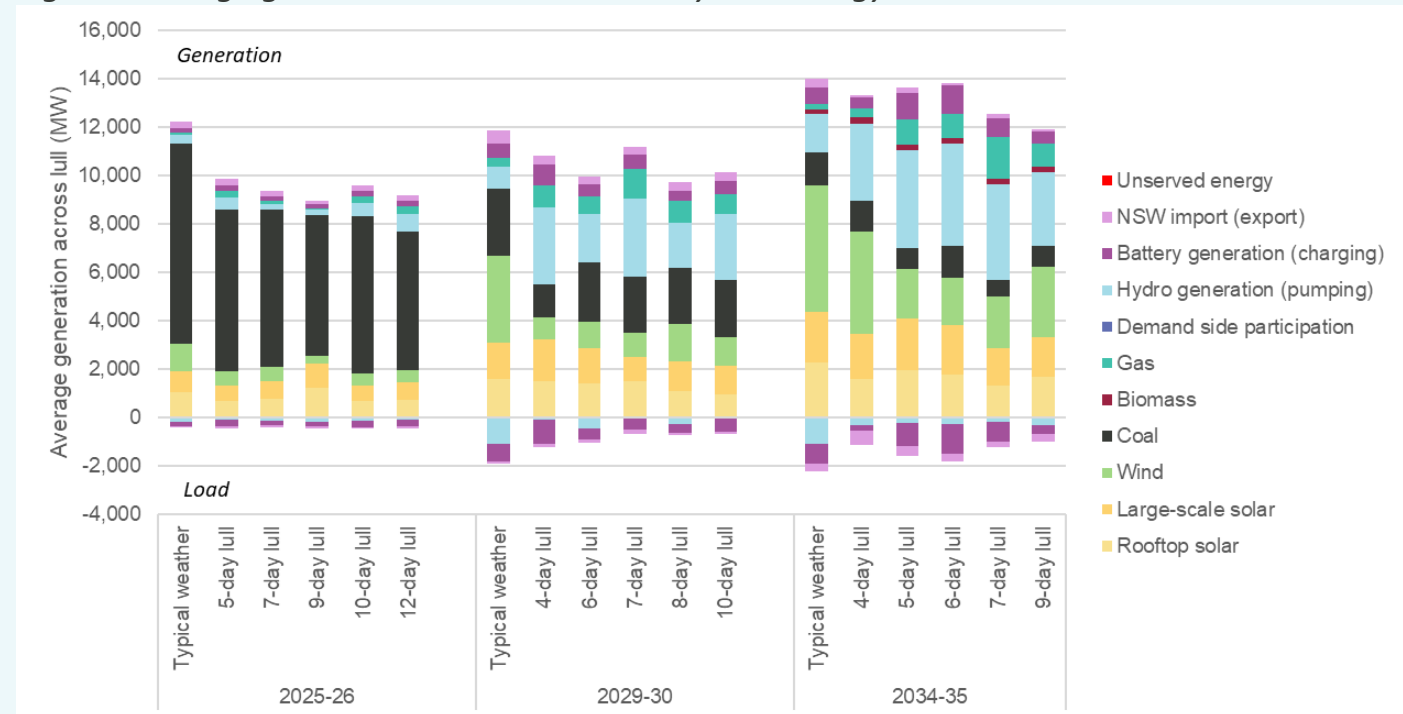


Modelling VRE lulls against the development pathway

During VRE lulls projected for 2035, VRE still contributes to about half of NSW demand

- The contribution from coal generation reduces over time as plants are assumed to gradually retire in NSW. Other technology types – particularly hydro, gas, battery and imported energy – provide the additional generation required to meet NSW demand.
- There is a small amount of unserved energy observed in one case, the 10-day lull in 2025-26, which does not breach the relevant reliability standard.

Figure: Average generation across VRE lulls by technology in NSW



Modelling VRE lulls against the development pathway

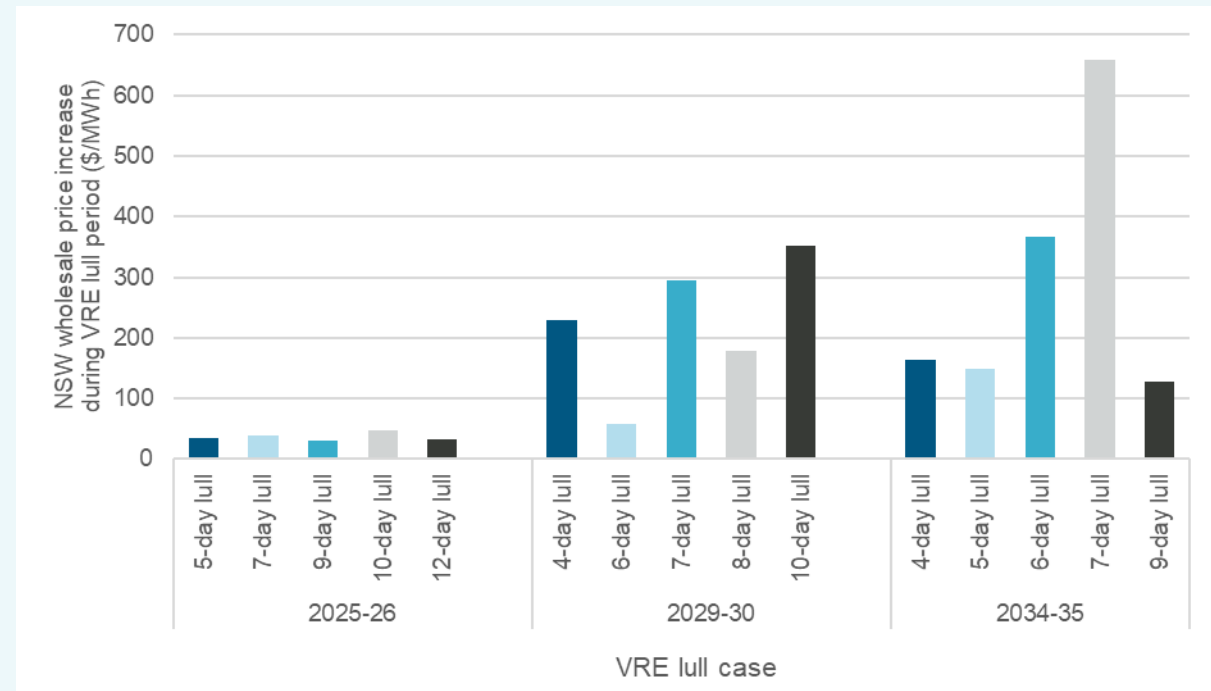
VRE lulls materially increase NSW wholesale prices

The impact on NSW wholesale prices during the VRE lull events generally increases with the length of the lulls.

There are some exceptions to this, driven by characteristic not captured with VRE lull duration:

1. The depth of the VRE lull below the 5th percentile,
2. The electricity demand during the VRE lulls, and
3. The VRE conditions in NSW compared to other regions in the NEM.

Figure: Increase to NSW wholesale price during VRE lull period compared to typical weather conditions



Resilience to VRE lulls

The development pathway maintains resilience to various severities of VRE lulls, but there are limitations to this analysis which leave risks

Resilience to VRE lulls is supported by three main drivers:

- 1. Increase in VRE diversity over time**
- 2. Increase in network capacity over time**
- 3. Increase in storage and firming infrastructure over time**

This analysis makes assumptions in how VRE lulls are represented and in how the NEM is dispatched during VRE lulls. Some of these assumptions are uncertain which leads to the following limitations:

- General modelling limitations: Uncertainty in climate projections, and the use of perfect foresight in dispatch modelling.
- Methodology limitations: Demand during the VRE lulls, continuous gas and hydro generation during the VRE lulls, simplified representation of the NEM

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Community of practice

Community of practice

ASL is seeking passionate individuals to join a 'Climate Science for Electricity System Planning' community of practice

Key question:

- How can climate science be effectively utilised in electricity system planning to ensure resilience?

Objectives are to foster:

- Collaboration, particularly between electricity market modelling and climate science modelling communities,
- Innovation, to support the continuous development of system planning approaches, and
- Learning, to benefit all stakeholders who are tackling this challenge.

Target membership:

- A group of passionate individuals across academia, governments, market bodies and industry.

Format and structure:

- Meetings, communication channels and activities to be established at the inaugural meeting.



To register interest for the Community of Practice, scan the QR code or contact us at engagement@asl.org.au



Thank you

