Recent Developments in Probabilistic Forecasts

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Operational Forecasting

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Themes & Topics

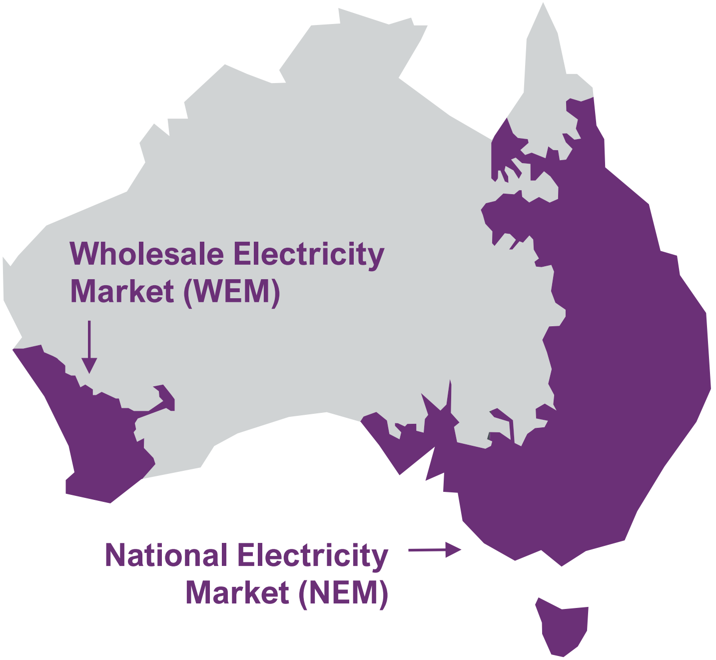
- Operational Forecasting at AEMO
- Maintaining System Security and Reliability with Probabilistic Methods
- Managing Increased Risk from Weather Uncertainty

Operational Forecasting at AEMO

About AEMO

- AEMO is a member-based, not-for-profit organisation.
- We are the independent energy market and system operator for the National Electricity Market (NEM) and the WA Wholesale Electricity Market (WEM), and system planner for the NEM.
- We also operate retail and wholesale gas markets across south-eastern Australia and Victoria's gas pipeline grid.
- Main functions are energy market and system operations, forecasting, planning, market design and reform.

Electricity



Gas

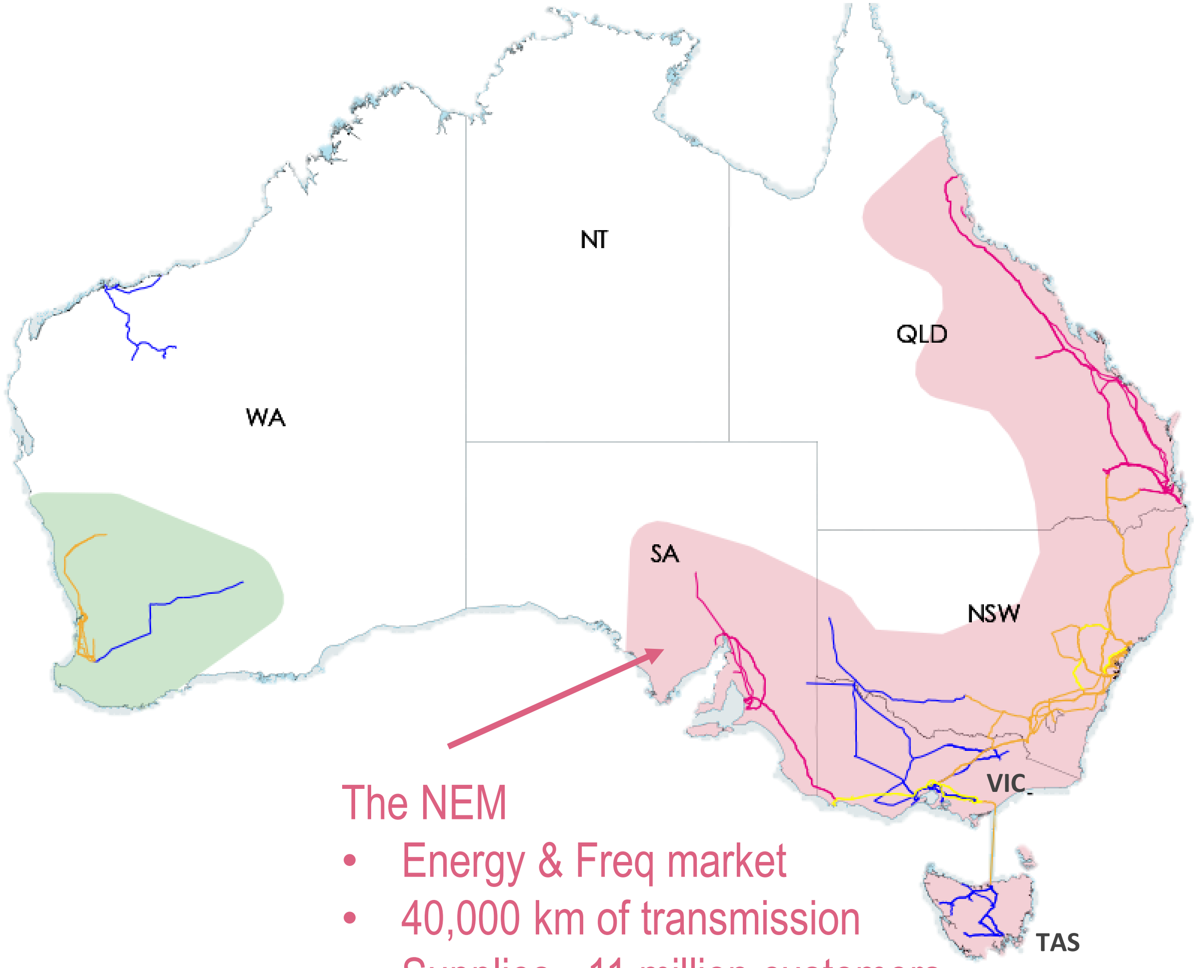
Declared Wholesale Gas Market (DWGM)

Short Term Trading Market (STTM)

and

Gas Supply Hub (GSH)

National Electricity Market (NEM)



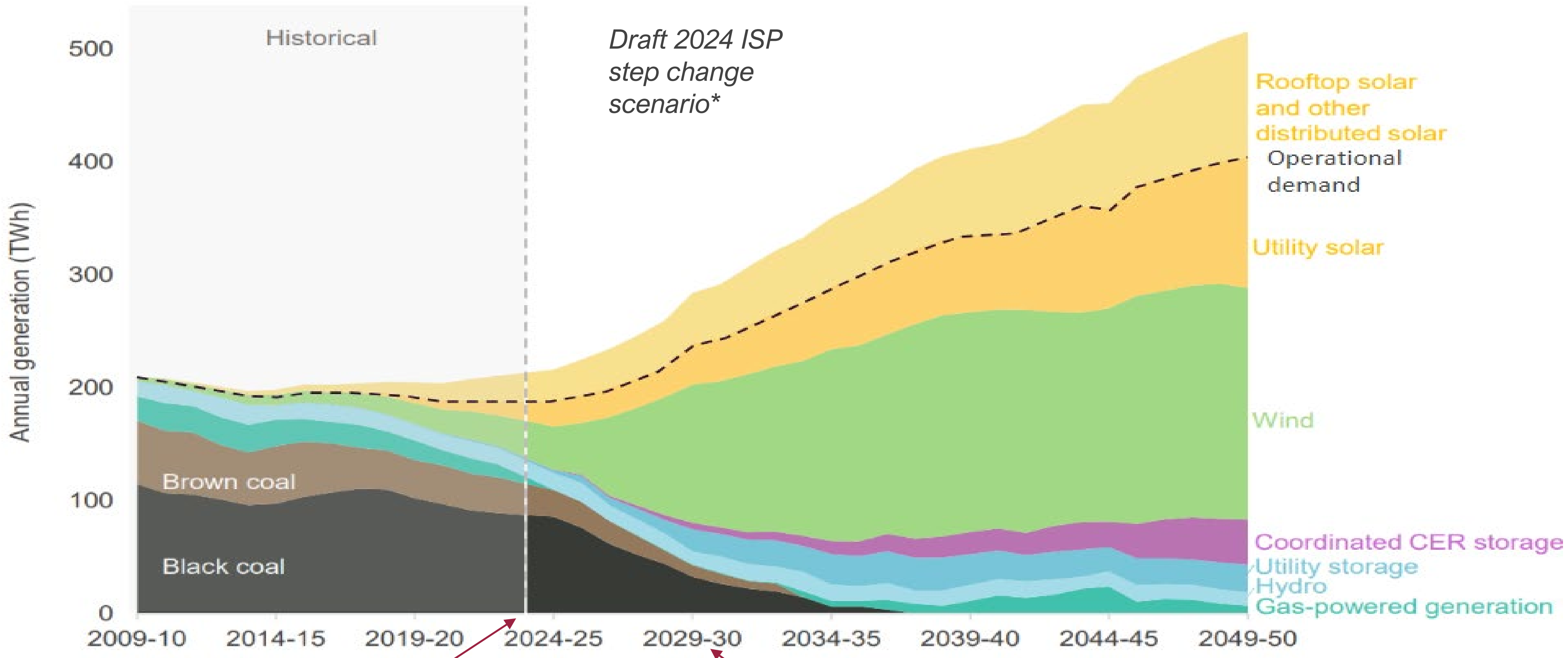
The NEM
- Energy & Freq market
- 40,000 km of transmission
- Supplies ~11 million customers
- 71 GW on generation capacity

Population **22.8 million**

NEM Max Demand **35,796 MW**
NEM Min Demand **11,009 MW**
Wind Capacity **11,392 MW**
Solar Capacity **9,644 MW**
Rooftop Solar Capacity **19,895 MW**

Approximately **3 million** homes have a solar system

Impact of The Energy Transition on Operational Forecasting

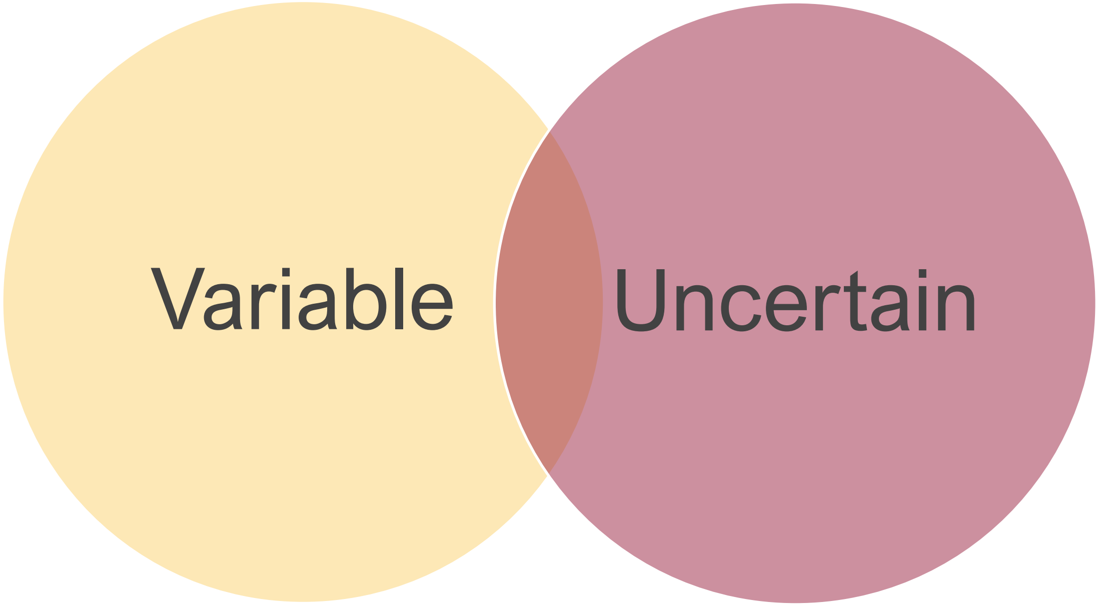


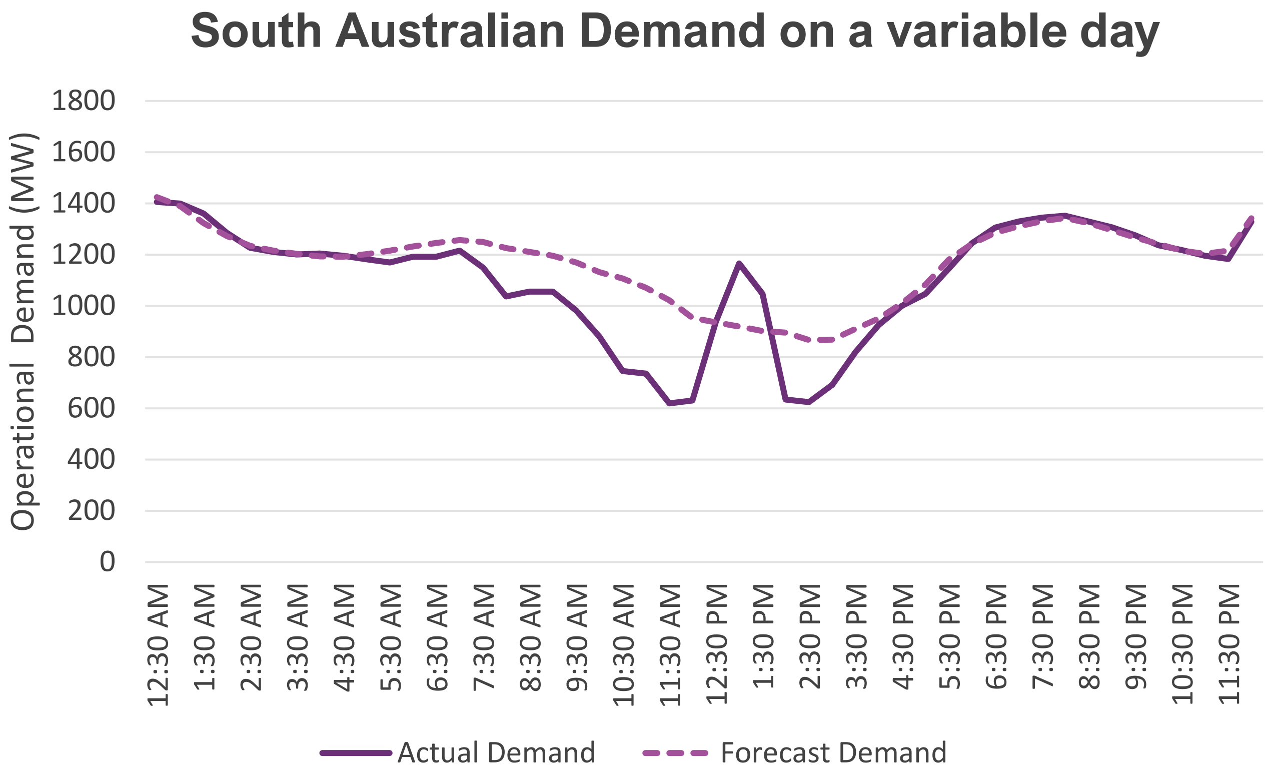
Today, around 25% of operational demand is met by large-scale VRE

By 2030, close to 80% will be met by large-scale VRE (directly or stored), increasing the reliance on VRE forecasts

Increasing Variability & Uncertainty

- The power system is operating under considerable variability.
- Power system operators need sufficient control to manage an increasing dynamic system.

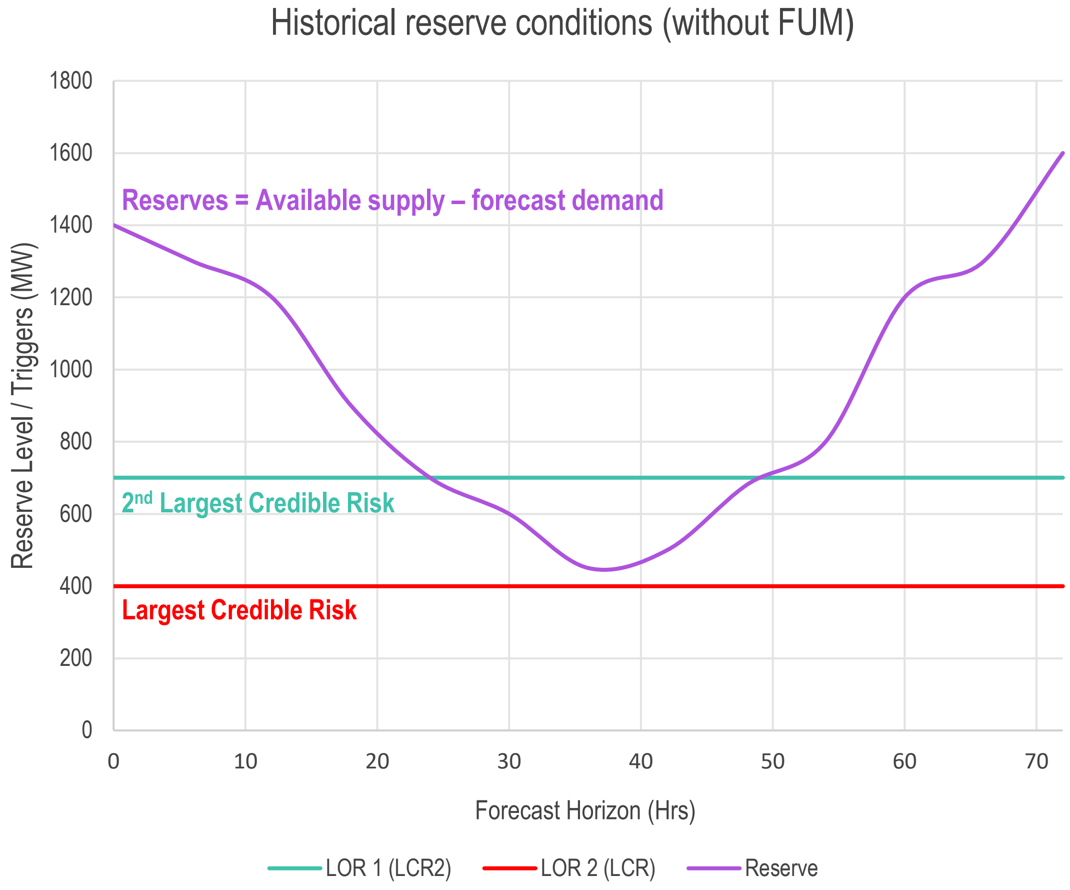


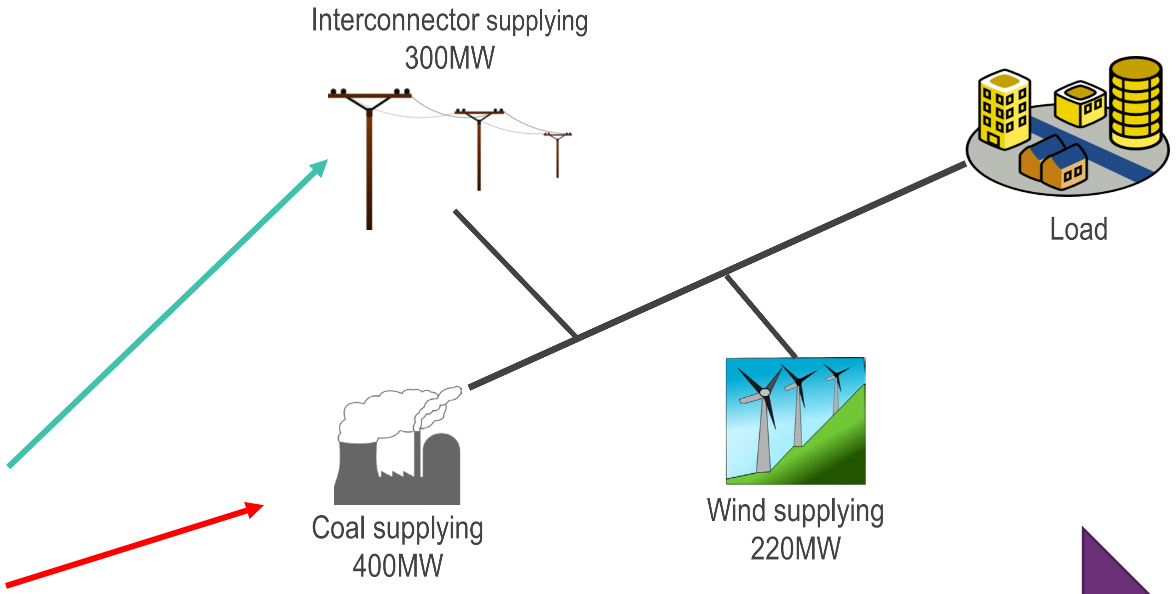


Maintaining System Security and Reliability with Probabilistic Methods

Supply Reserve Levels in the NEM

Reserve levels were historically set based on the largest supply to the system.



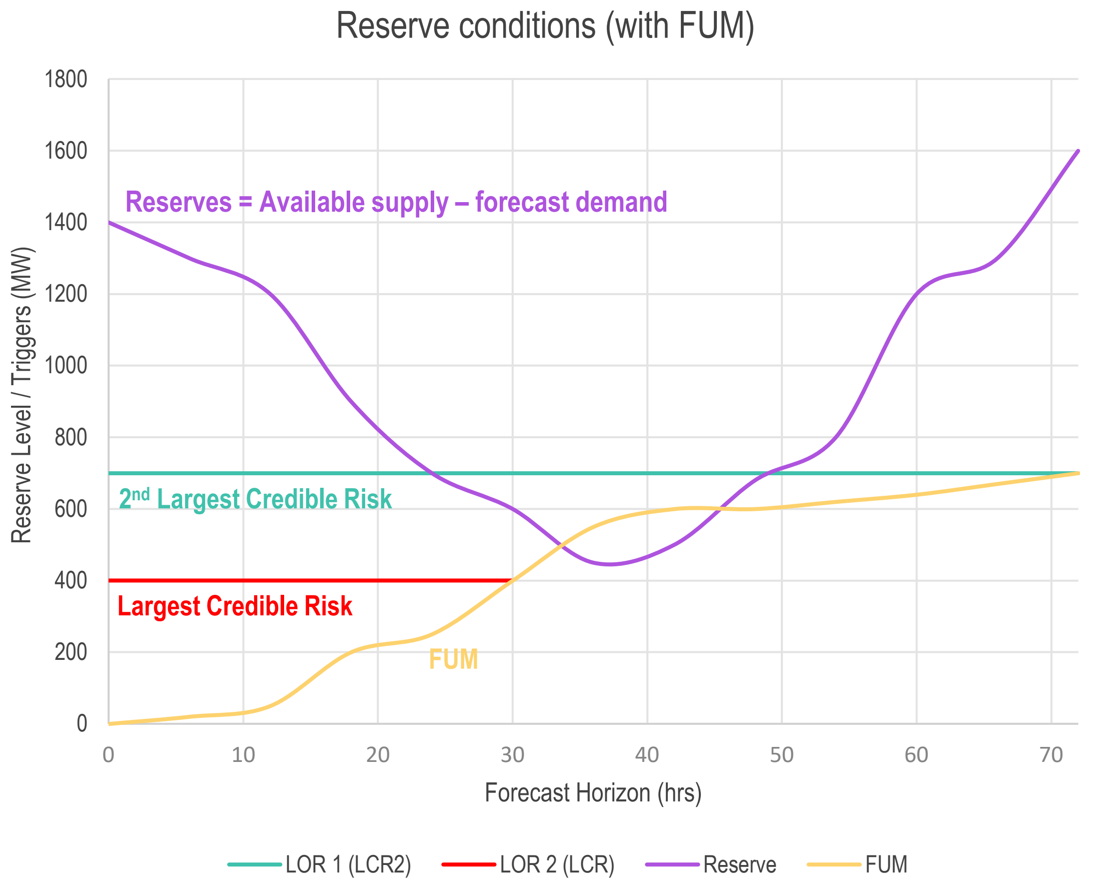


To address dynamically evolving reserves in the NEM, AEMO introduced the Forecast Uncertainty Measure (FUM)

Forecast Uncertainty Measure (FUM)

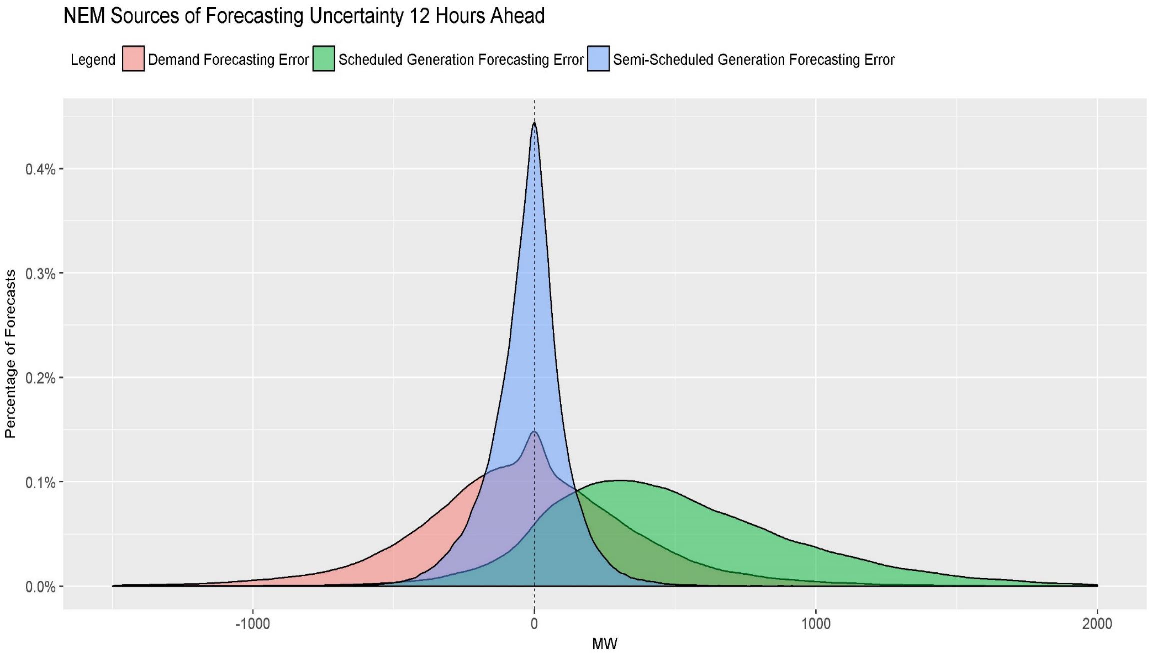
The FUM Model is trained on historical forecasting errors and situational conditions present at time forecast was produced. These can include weather and time of day.

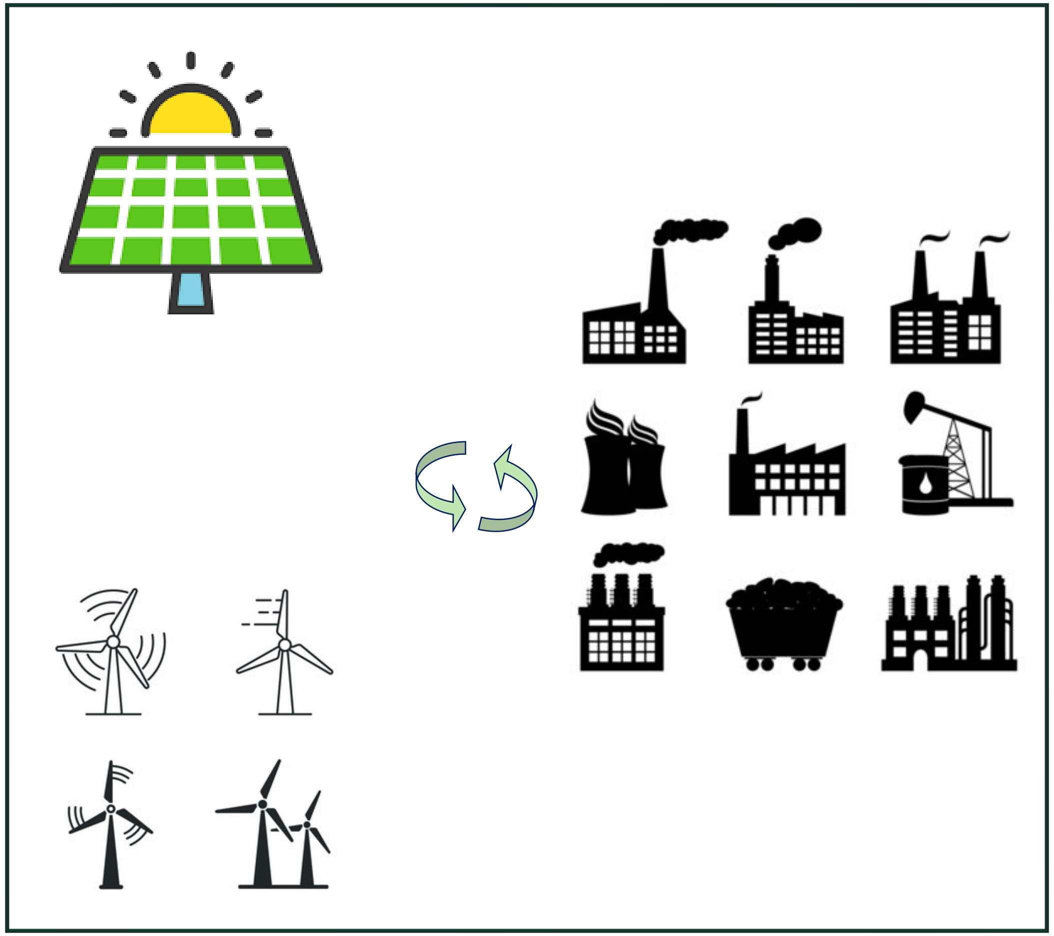
- Deployed in 2017
- This forecasts reserve levels using sophisticated Machine Learning models.
- Acts as a mechanism to address demand and supply uncertainty over 72 hours.
- Over 1 billion forecasts are used to train the network using advanced AI techniques
- Retrained quarterly



How to Improve the FUM Approach

Disaggregate FUM & Sources of Uncertainty for more intuitive and improved decision making





ST PASA Replacement

This project is part of the **Operations Technology Program (OTP)** - an enduring program that seeks to address the challenge of maintaining system security and reliability in an increasingly complex network

Opportunity/Challenge: Pre-Dispatch (PD) and ST PASA (Projected Assessment of System Adequacy) are core systems that warn of any power system reliability issues in the PD and Short-Term (ST) time frame and are used by AEMO to maintain NEM power system security and reliability, and by market participants to make commercial decisions and co-ordinate planned outages. The current PASA system doesn't have the required flexibility and under certain scenarios is unable to produce usable results. New technologies such as battery storage, Virtual Power Plants (VPPs) and Distributed Energy Resources (DER) cannot be easily modelled in the current system.

Project Objective: Replace the current PD and ST PASA with a new ST PASA. As the energy sector evolves, the ST PASA system will also evolve from using a current region-based model to using a grid (nodal) network model, allowing AEMO to continue to provide accurate power system security and reliability information.

Benefits:

- Reduces risk
- Full nodal network
- Accurate power system security and reliability information
- More informed decision making
- Enables AEMO to match rapidly evolving power system

Solution Overview: This will include development of:

Security Constrained Economic Dispatch (SCED) engine

Procurement and development of the Security Constrained Economic Dispatch (SCED) engine that will work with a full network model to optimise the dispatch of energy resources and determine any load deficits at each node in the network.

Pre & Post Processing Systems

Pre-processing will extract standing and real time data from the grid and market systems and process them to be fed into the SCED engine.

Post-processing will convert the outputs from the SCED engine into useful information to be consumed by internal and external stakeholders.

Uncertainty Margins

Uncertainties in predicting certain inputs used to forecast reliability need to be accounted for in load, variable renewable energy and scheduled unit availability forecasts at the nodal level.

Representation of uncertainties in the new system will be via inputs into ST PASA, rather than applying uncertainty measures based on post-processing.

Business Process Transformation

Business processes will be transformed to support the NEM Rule changes where the definition and specification of the reserve management process is modified.

More granular information provided through the shift to a nodal projection will be supported.

AEMO will continue to collaborate with industry to gain insight on their use of PD and ST PASA information and consult on procedures and guidelines.

A note about Uncertainty and Confidence Levels

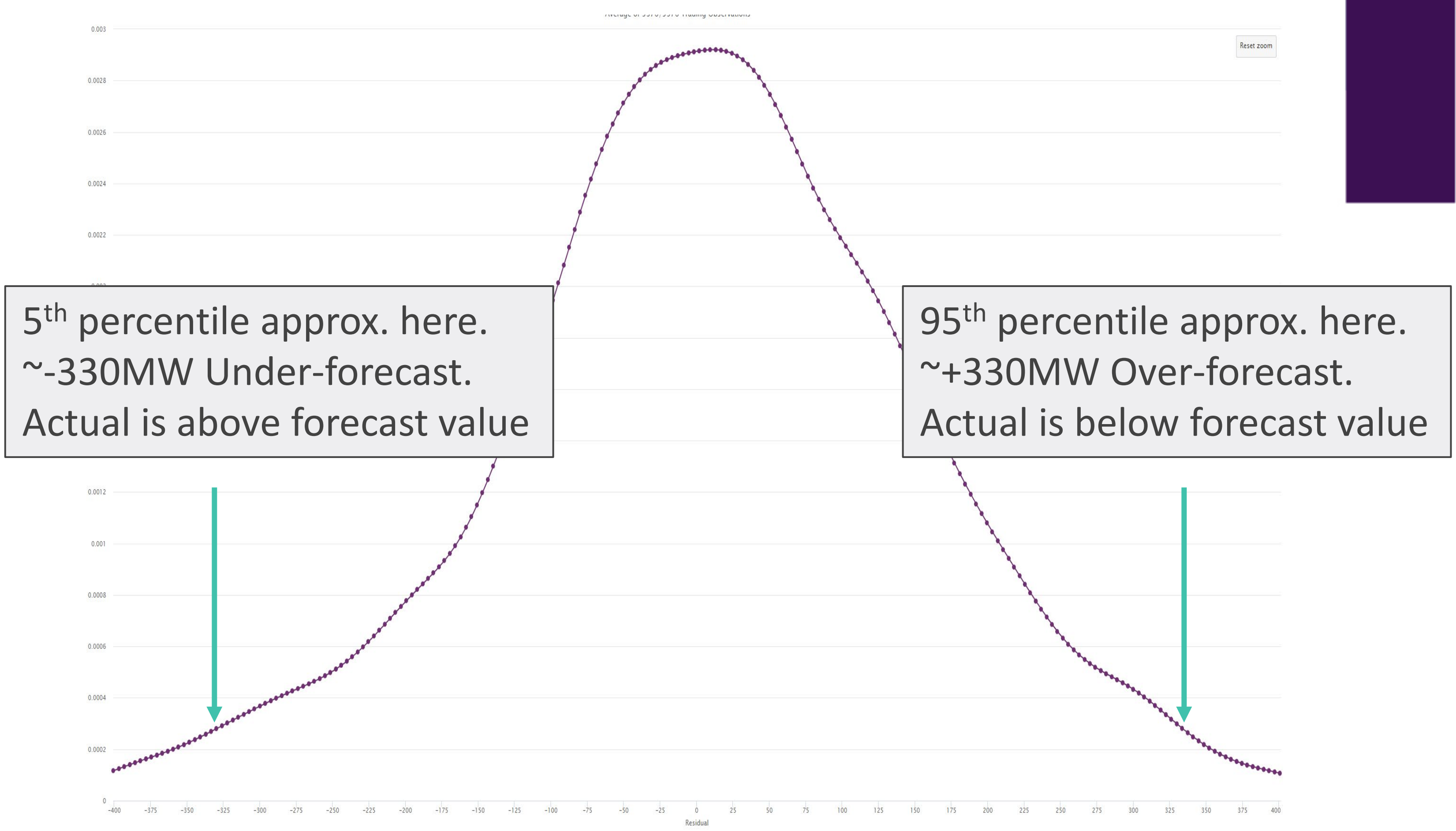
The convention used to define uncertainty (forecast error) is *Forecast minus Actual*

This convention means that the 95th percentile of uncertainty is an Over-forecast, i.e. the actual is below the forecast value.

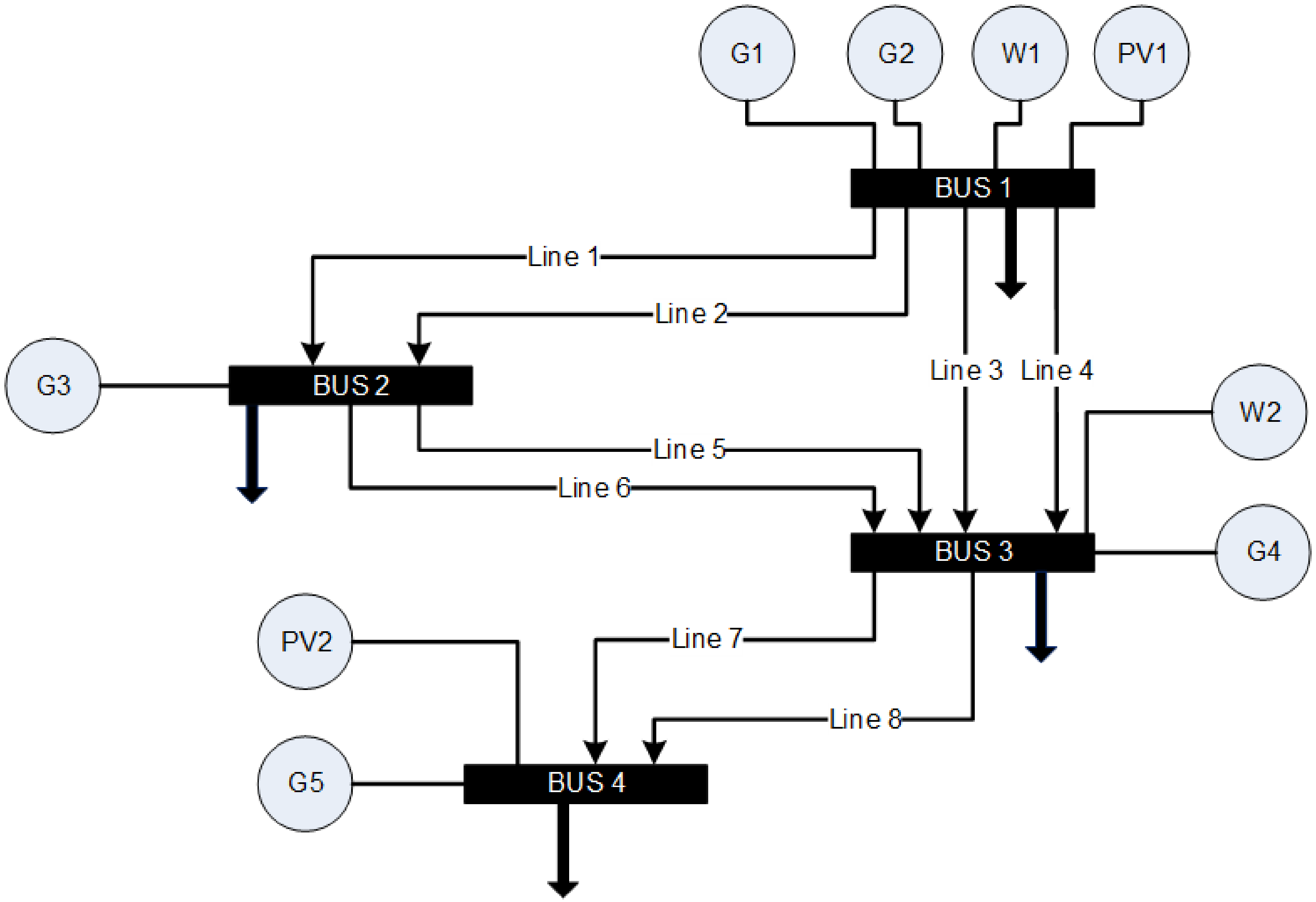
This is appropriate for Supply because we are interested in cases Supply does not meet the expected level.

However, this is not appropriate for Demand because we are interested in cases where Demand exceeds the expected level.

To correct this, while ensuring consistency when referring to Confidence Levels for Demand we actually take the "1 minus Confidence Level" percentile in order to convert to the Under-forecast uncertainty. E.g. if we are taking the 95th percentile Confidence Level, we actually take the 95th percentile of Supply uncertainty but take the 5th percentile of Demand uncertainty.

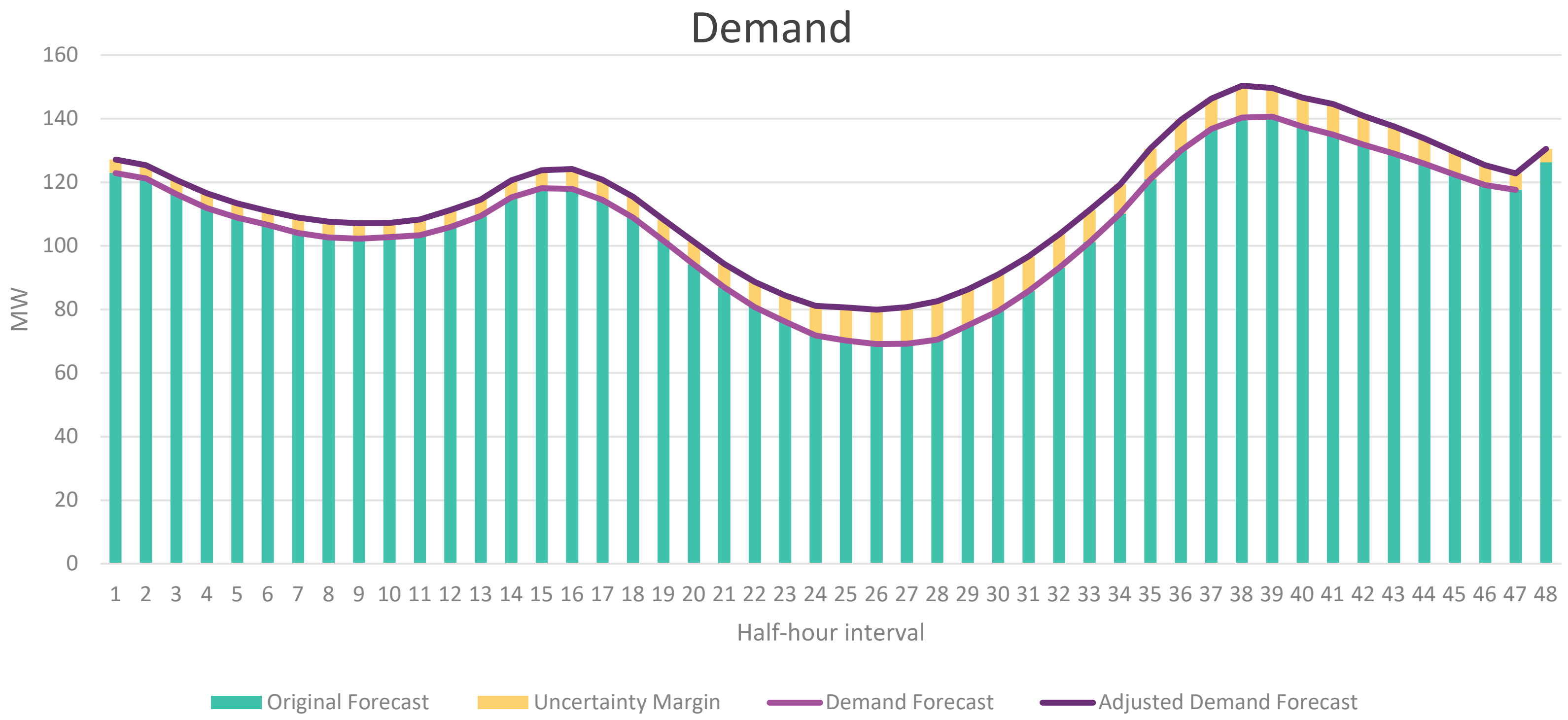


Uncertainty Margin example



Uncertainty Margin example

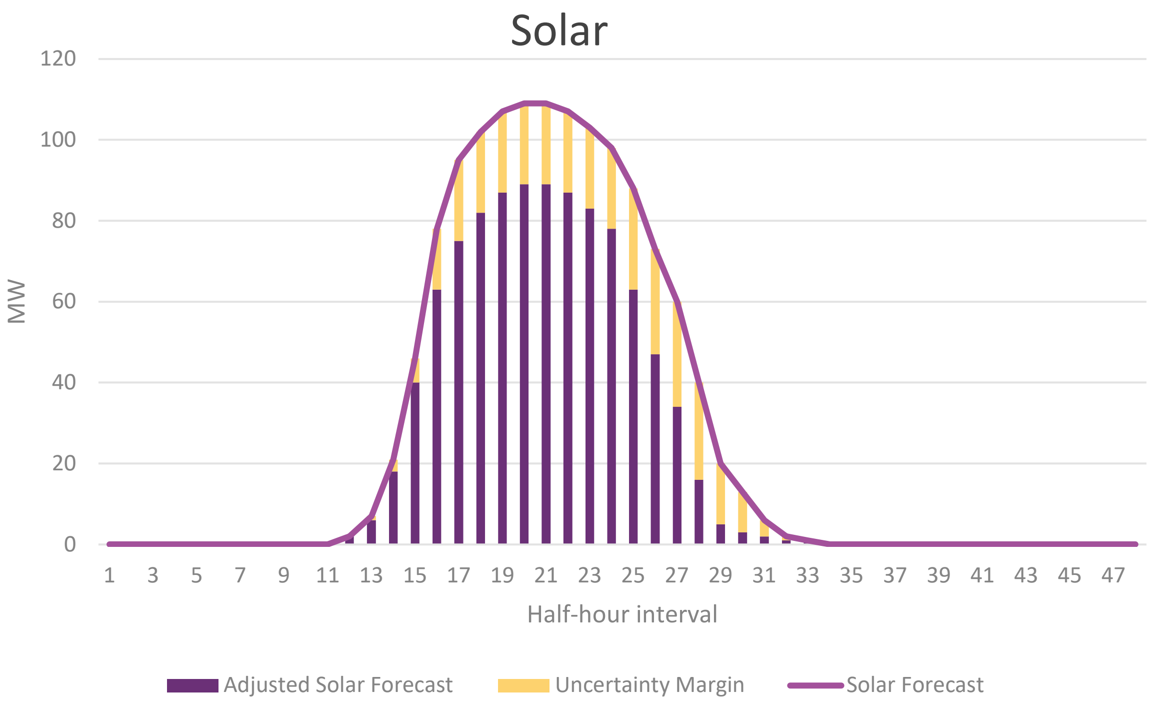
- Adjust demand forecast by **<u>adding</u>** corresponding Uncertainty Margin. Repeat for each load on each bus.

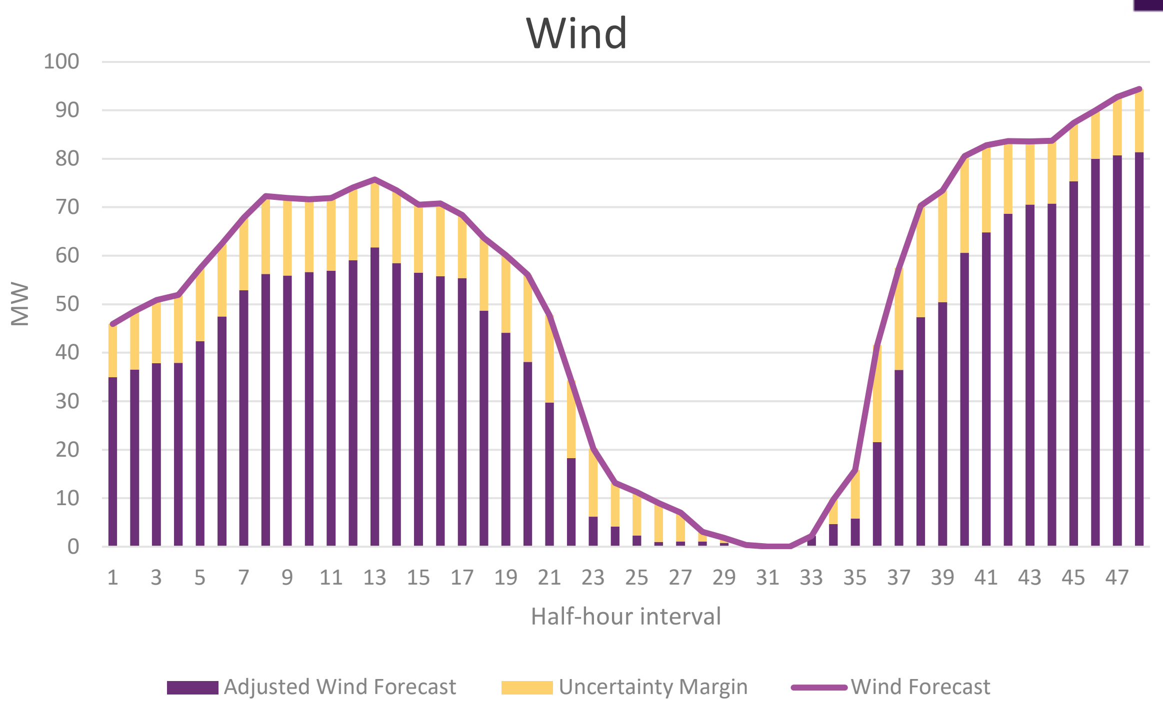


The Uncertainty Margins in this example are indicative only and do not reflect the size of expected Uncertainty Margins

Uncertainty Margin example

- Adjust unit VRE forecast by **<u>subtracting</u>** corresponding Uncertainty Margin. Repeat for each VRE unit.

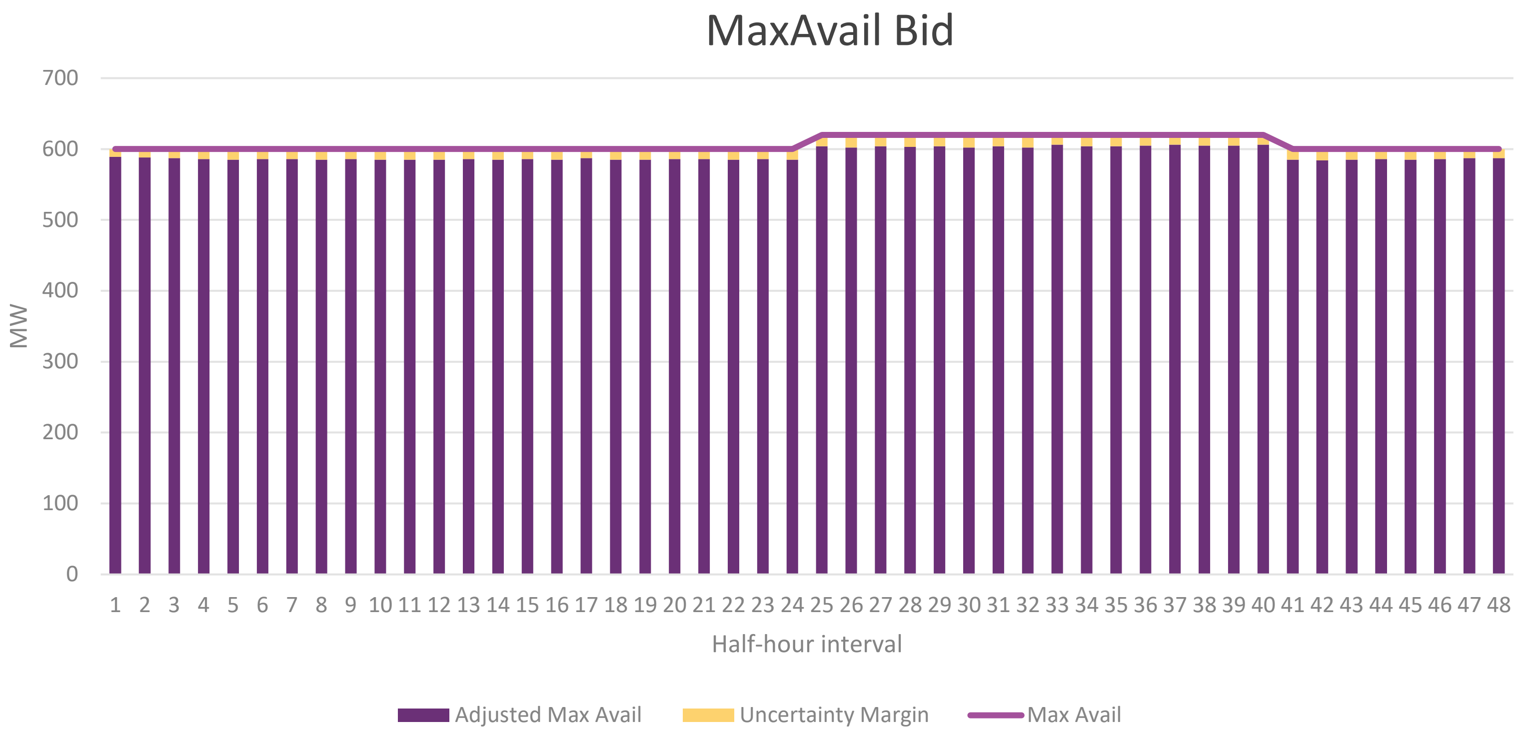




The Uncertainty Margins in this example are indicative only and do not reflect the size of expected Uncertainty Margins

Uncertainty Margin example

- Adjust scheduled generator MaxAvail by **<u>subtracting</u>** corresponding Uncertainty Margin. Repeat for each scheduled generator.



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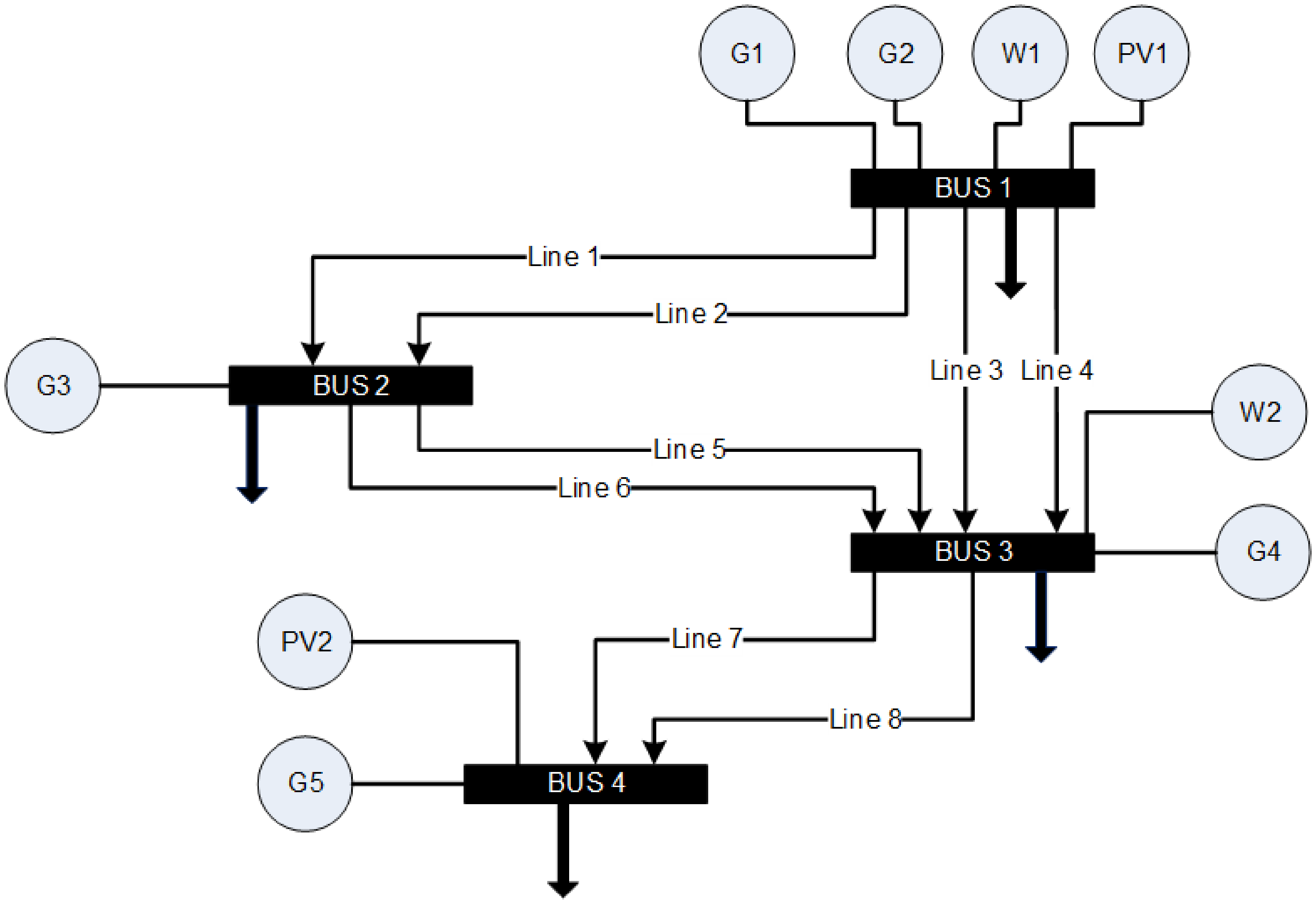
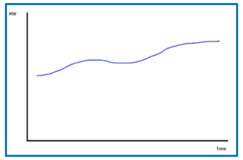
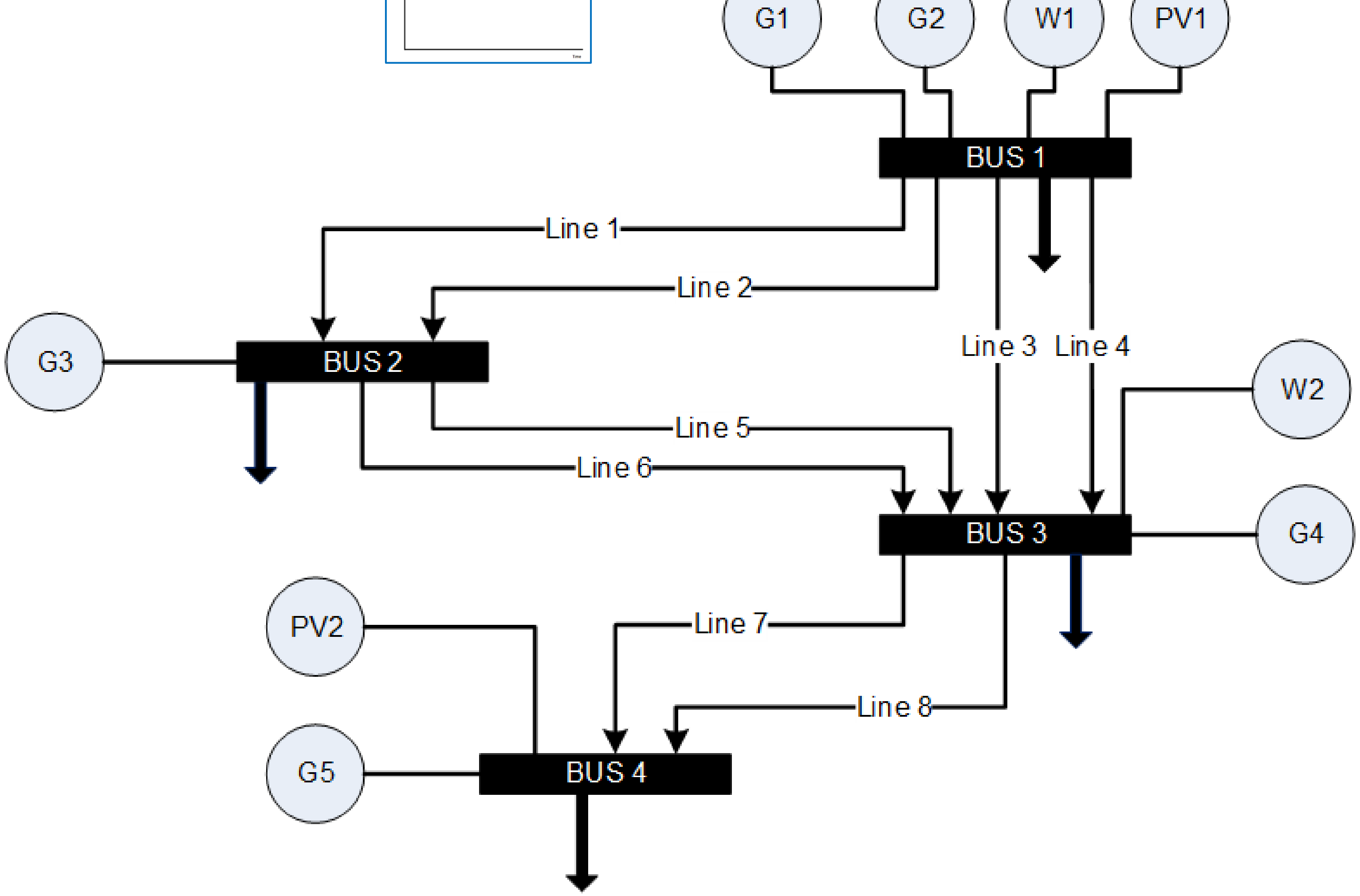
Uncertainty Margin example



Uncertainty Margin example

Step 1: Determine total (regional) Uncertainty Margins

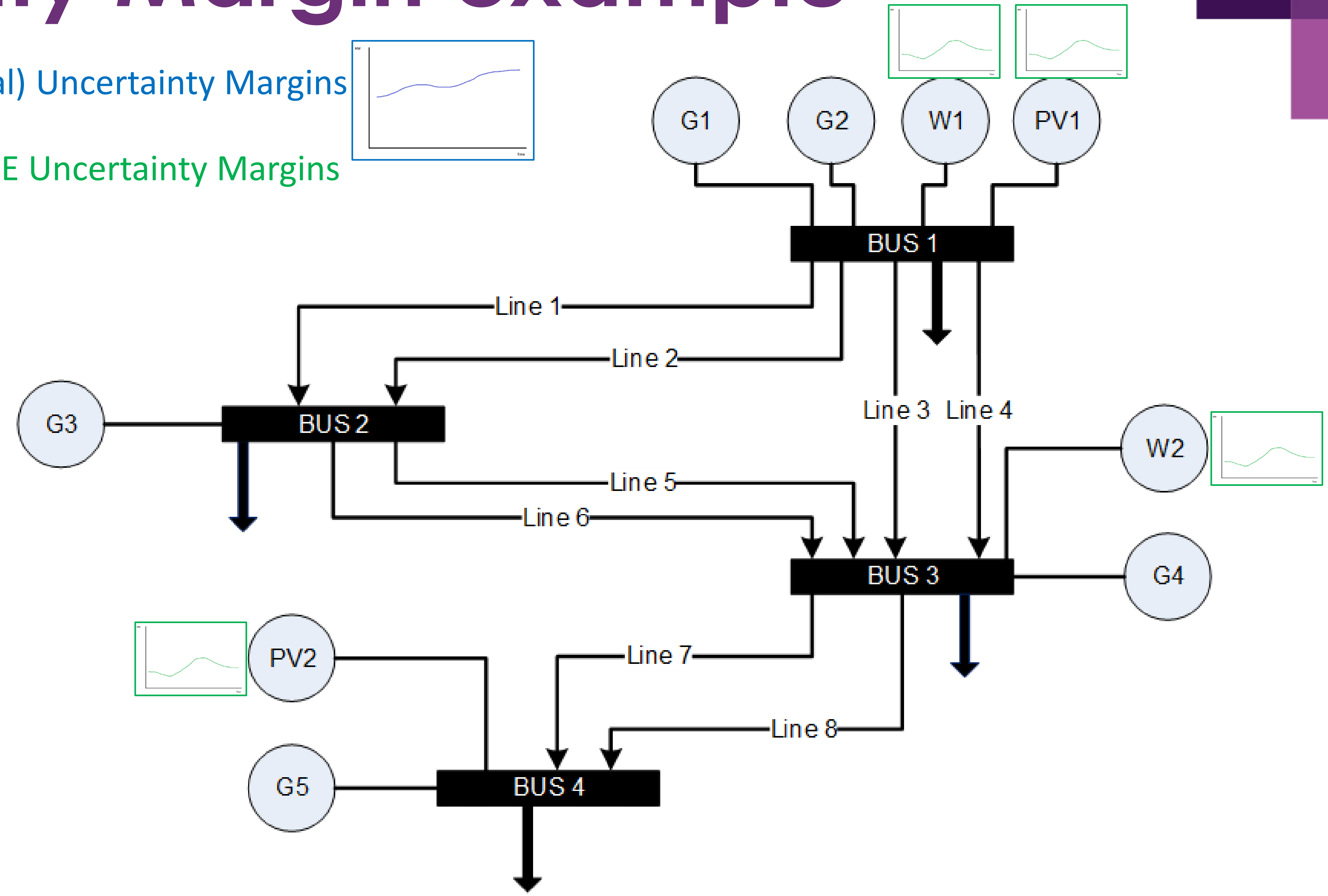




Uncertainty Margin example

Step 1: Determine total (regional) Uncertainty Margins

Step 2: Determine individual VRE Uncertainty Margins

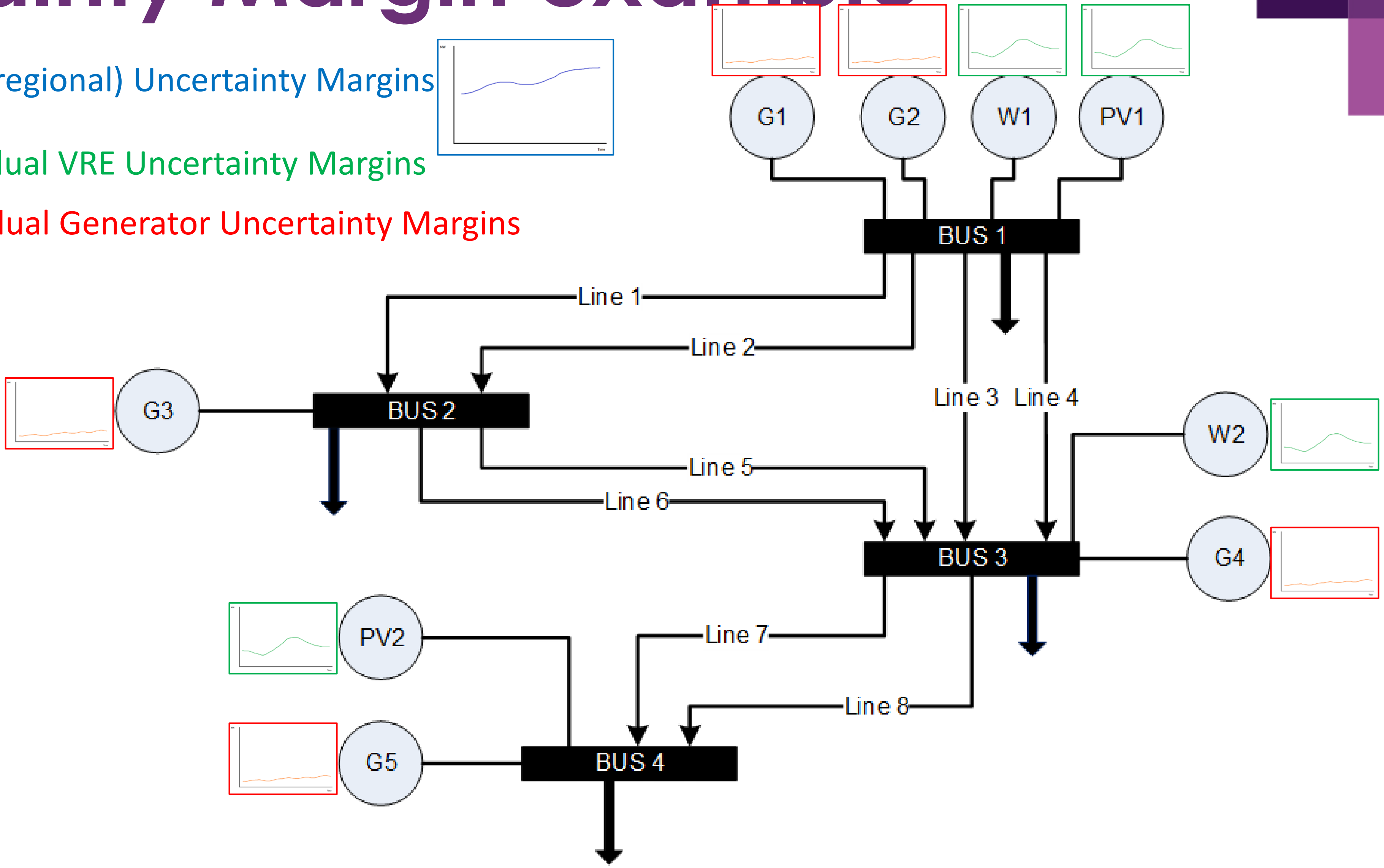


Uncertainty Margin example

Step 1: Determine total (regional) Uncertainty Margins

Step 2: Determine individual VRE Uncertainty Margins

Step 3: Determine individual Generator Uncertainty Margins



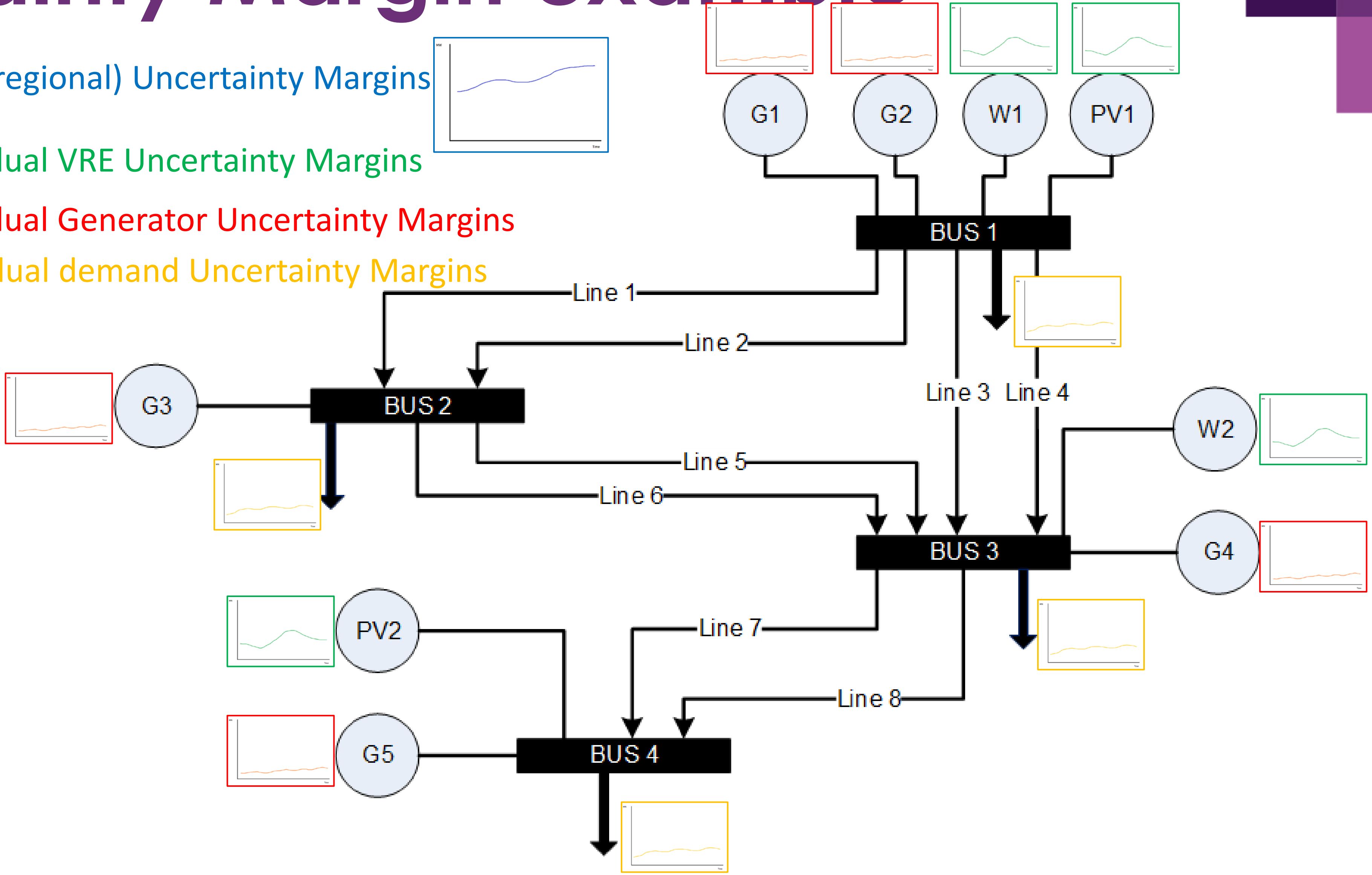
Uncertainty Margin example

Step 1: Determine total (regional) Uncertainty Margins

Step 2: Determine individual VRE Uncertainty Margins

Step 3: Determine individual Generator Uncertainty Margins

Step 4: Determine individual demand Uncertainty Margins



Uncertainty Margin example

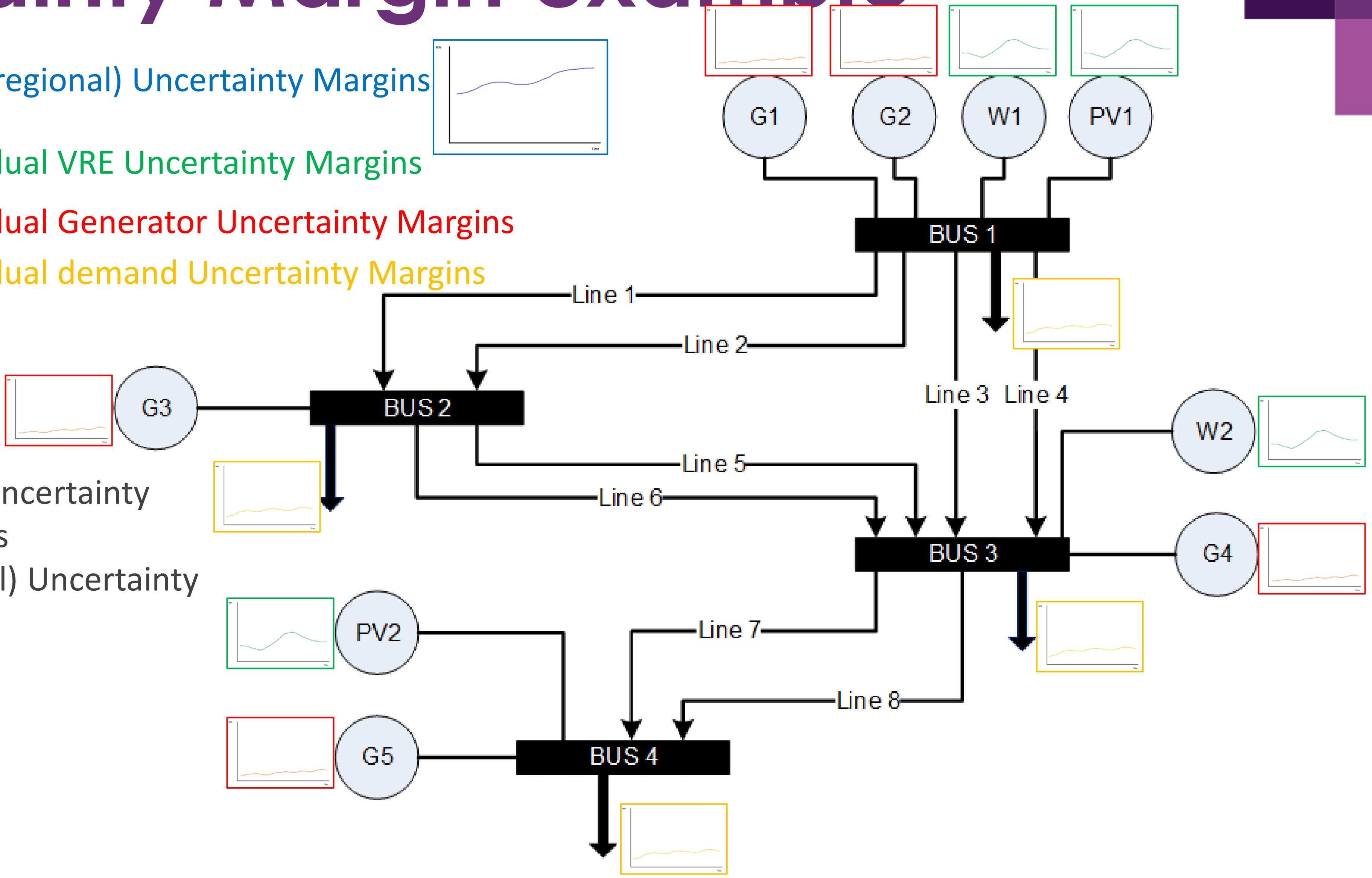
Step 1: Determine total (regional) Uncertainty Margins

Step 2: Determine individual VRE Uncertainty Margins

Step 3: Determine individual Generator Uncertainty Margins

Step 4: Determine individual demand Uncertainty Margins

Step 5: Scale individual Uncertainty Margins so that sum does not exceed total (regional) Uncertainty Margin



Uncertainty Margin example

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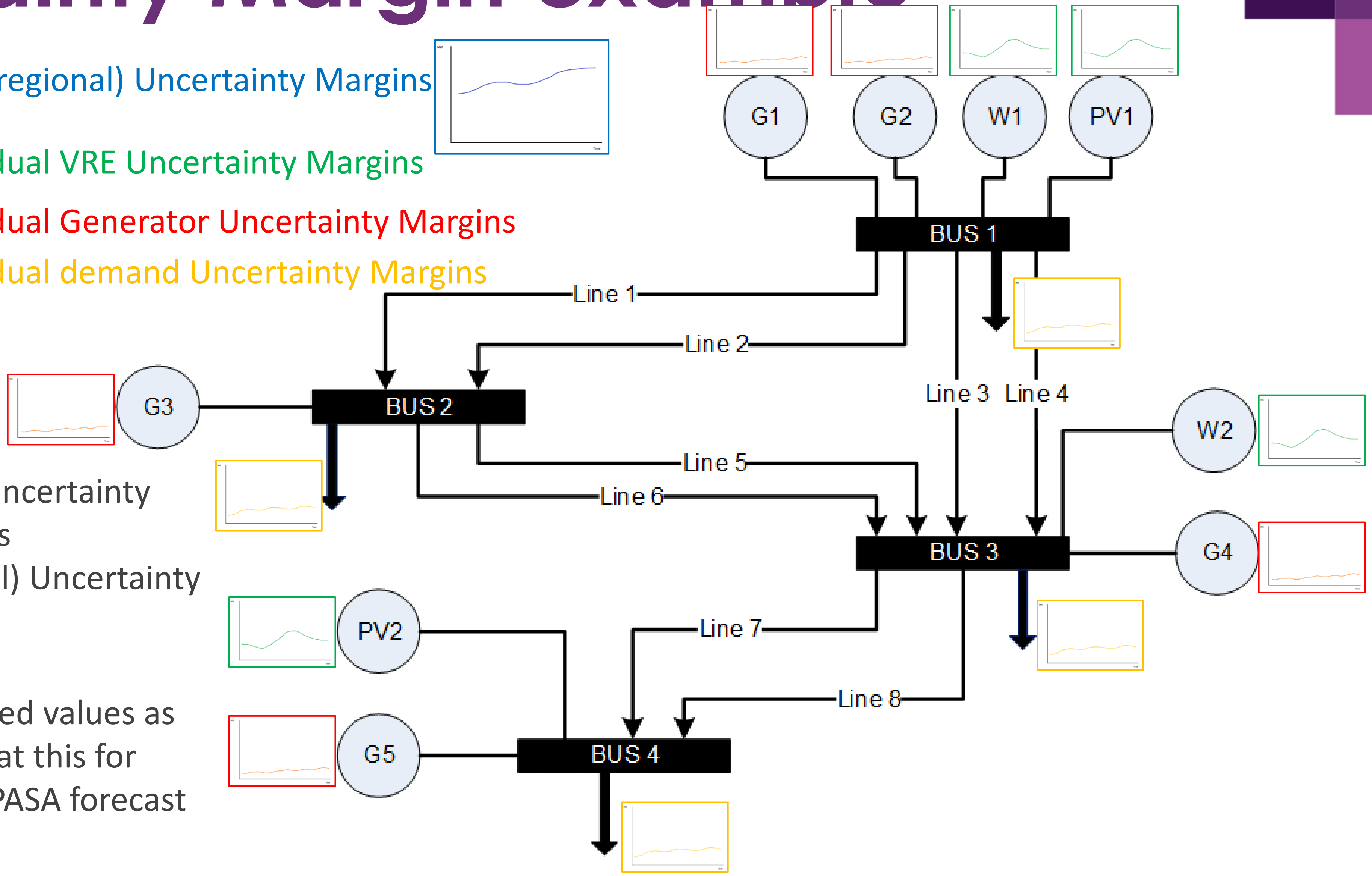
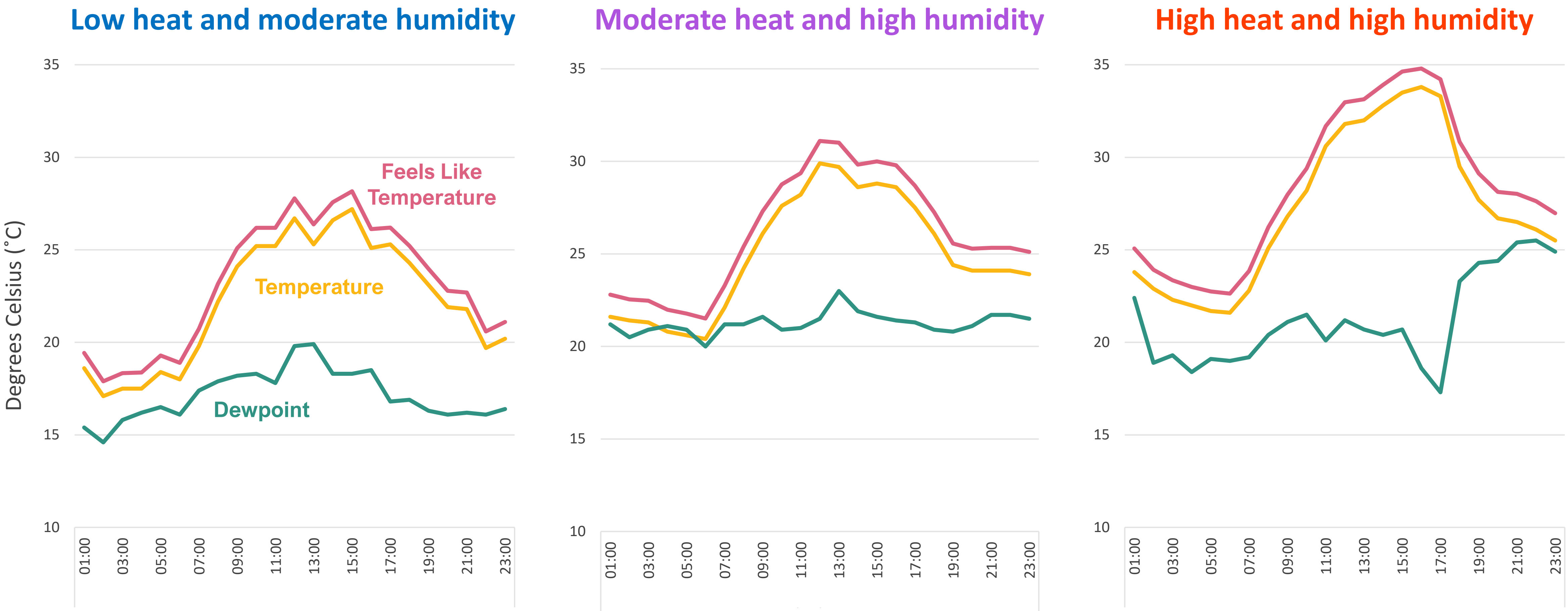


Step 5: Scale individual Uncertainty Margins so that sum does not exceed total (regional) Uncertainty Margin

Step 6: Supply the adjusted values as inputs to the SCED. Repeat this for every timestep in the STPASA forecast horizon.

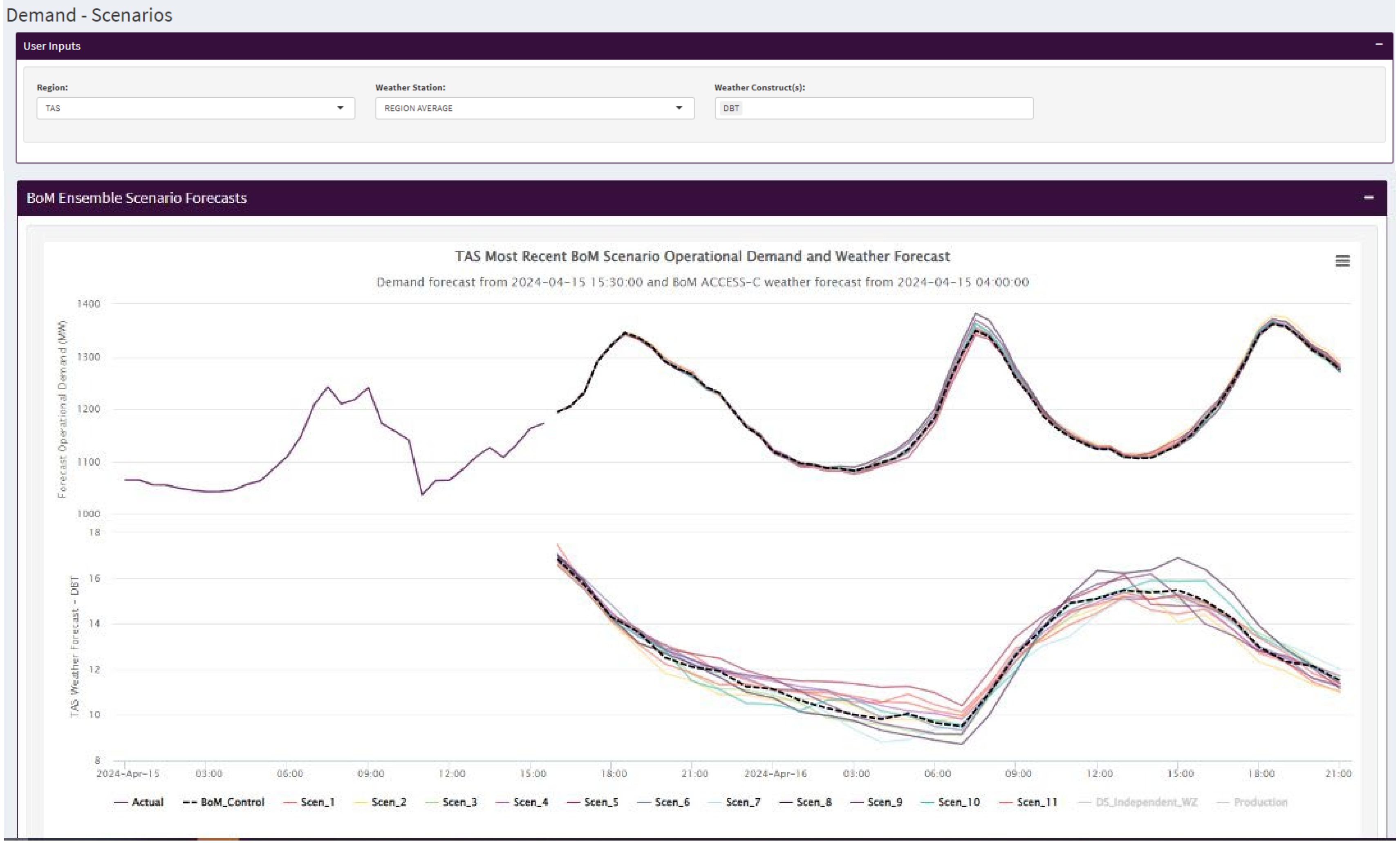
Managing Increased Risk From Weather Uncertainty

Reconciling Different Weather Outlooks & Uncertainty in Forecasts



Weather Scenario Tool

A novel method to translate the operational impact of each Weather Scenario for increased situational awareness and preparedness.



Weather Scenario Case Study NSW – March 14th

Heat in Sydney/Bankstown tomorrow:

- An inland trough extends heat towards the NSW coast once more.
- **ePD Tmax expectations have dropped again in this update.**
    - Bankstown and Sydney Obs Hill are most likely to see a Tmax of 32-33°C and 30-31°C, respectively.
    - S-SE winds are expected to develop in the afternoon, most likely from 2-4 PM.
- **However, there is a 1 in 4 chance of Tmax > 35°C**, which represents a higher probability than in the ePD table below.
    - A high-resolution model depicts the mercury reaching 35-36°C over inland parts of the Sydney Basin (including Bankstown) before winds shift S-SE at around 3-4 PM.
- **6 PM temperatures are likely to be unremarkable**, with virtually all models having an established S-SE flow by this time.
    - Apparent temperatures should be below 24°C at 6 PM.
- Mostly sunny morning, with **cloud cover expected to increase through the day** (deteriorating rooftop solar) and an evening shower or two.

Likelihood of Extreme High Maximum Temperatures.

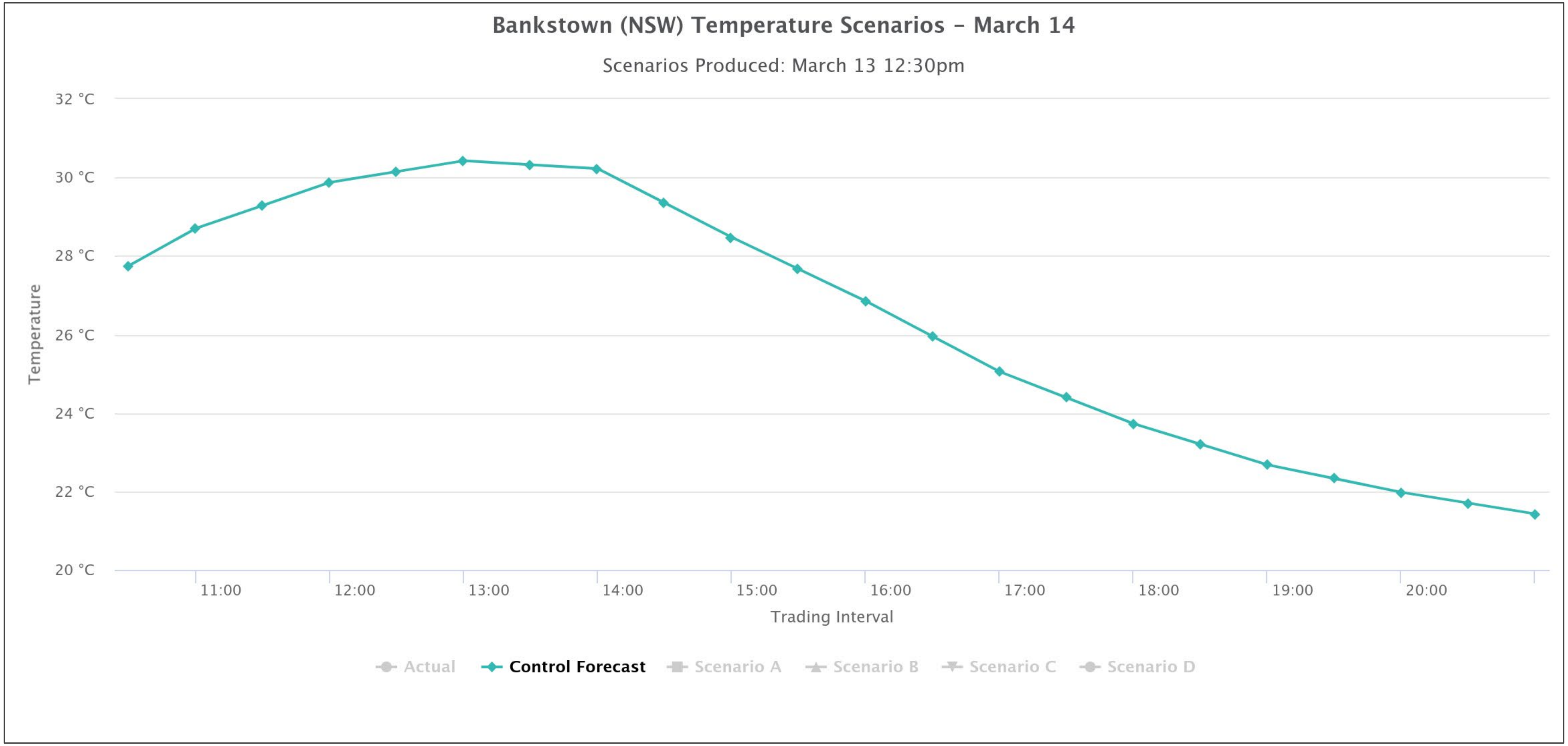
Forecast Daily Maximum Temperatures and the probability that Tmax will be higher than 35.0C. Days where this probability threshold is greater than 50%, are highlighted in dark red.

Date	Wed 13-Mar	Thu 14-Mar	Fri 15-Mar	Sat 16-Mar	Sun 17-Mar	Mon 18-Mar	Tue 19-Mar	Wed 20-Mar	Thu 21-Mar	Fri 22-Mar	Sat 23-Mar	Sun 24-Mar	Mon 25-Mar	Tue 26-Mar
Archerfield	29.3 0%	29.4 0%	30.9 0%	28.3 0%	28.5 0%	28.1 0%	28.9 0%	29.9 1%	29.6 1%	29.4 1%	29.5 1%	29.0 1%	28.2 0%	28.7 0%
Brisbane	29.0 0%	29.1 0%	30.7 0%	28.6 0%	28.2 0%	28.0 0%	28.9 0%	29.8 0%	29.4 0%	29.1 0%	29.3 1%	29.3 0%	28.2 0%	28.7 0%
Bankstown	29.9 0%	32.1 8%	24.1 0%	23.5 0%	24.6 0%	26.6 0%	29.0 1%	28.4 4%	25.8 1%	26.9 2%	25.8 1%	23.7 0%	25.5 1%	26.1 1%
Observatory Hill	28.8 0%	30.6 1%	24.8 0%	23.9 0%	24.6 0%	25.9 0%	27.6 0%	27.0 0%	25.2 0%	26.2 1%	25.5 1%	23.7 0%	25.1 0%	25.4 0%
Melbourne	20.5 0%	21.8 0%	27.2 0%	26.3 0%	28.7 0%	31.0 3%	28.7 5%	19.9 0%	20.7 0%	20.0 0%	19.2 0%	21.0 0%	21.2 0%	22.0 0%
Adelaide	31.9 4%	25.8 0%	28.3 0%	31.6 4%	32.2 13%	32.6 25%	27.3 2%	22.0 0%	23.5 0%	22.2 0%	21.9 0%	22.1 1%	22.8 0%	24.2 1%

Days where models are flagging a heat risk are highlighted by the green boxes.

Notably cooler conditions in the south from the middle of next week.

Weather Scenario Case Study NSW – March 14th



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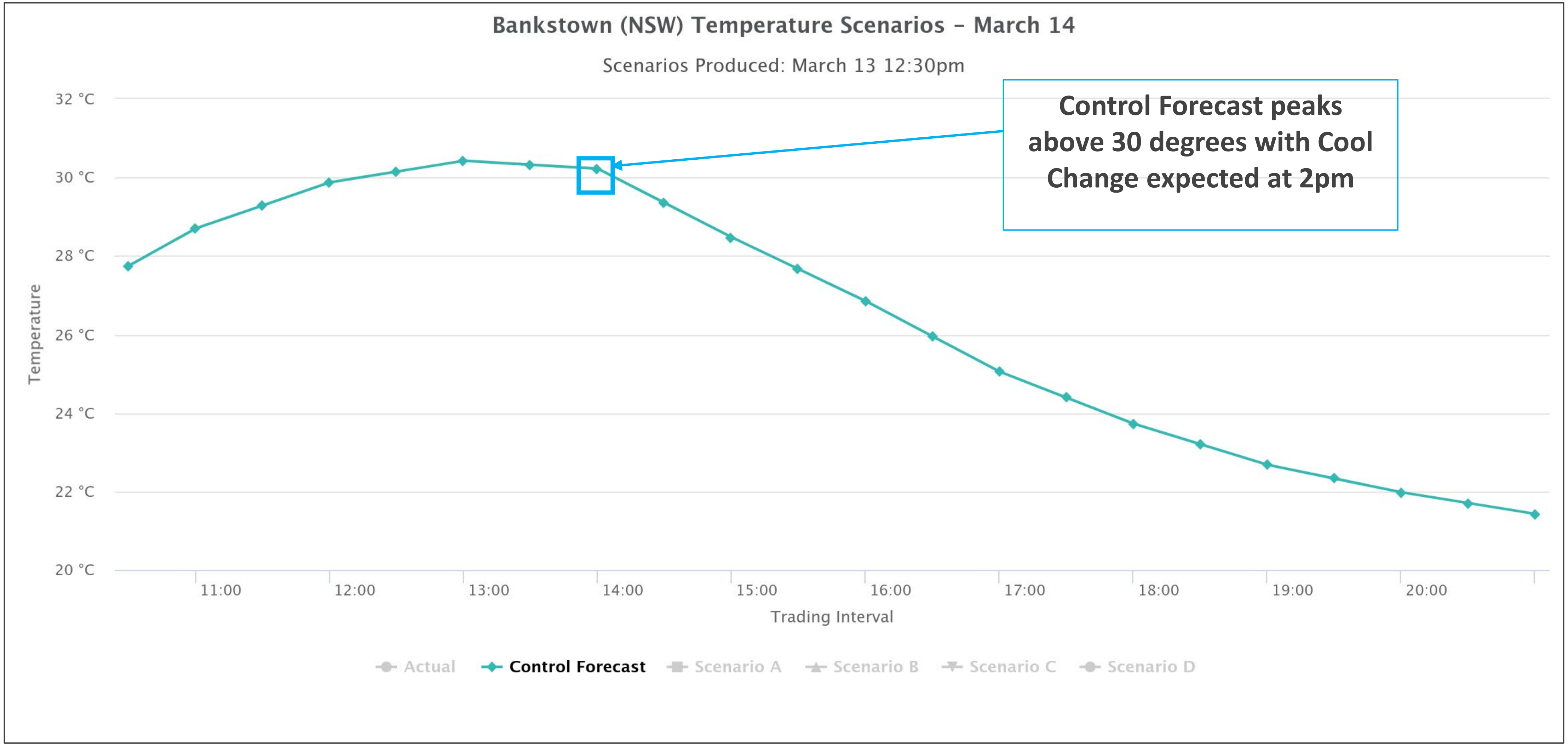

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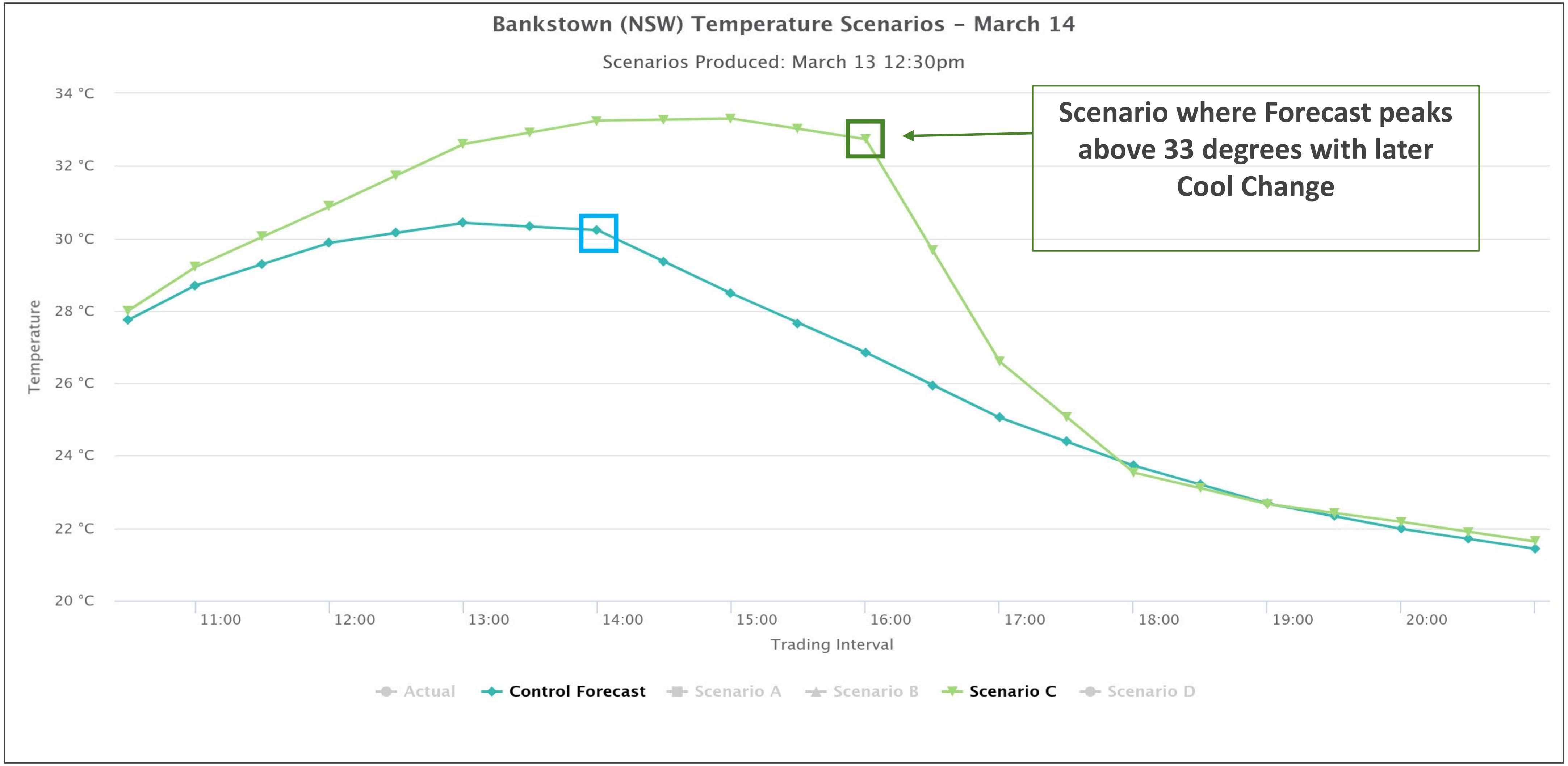

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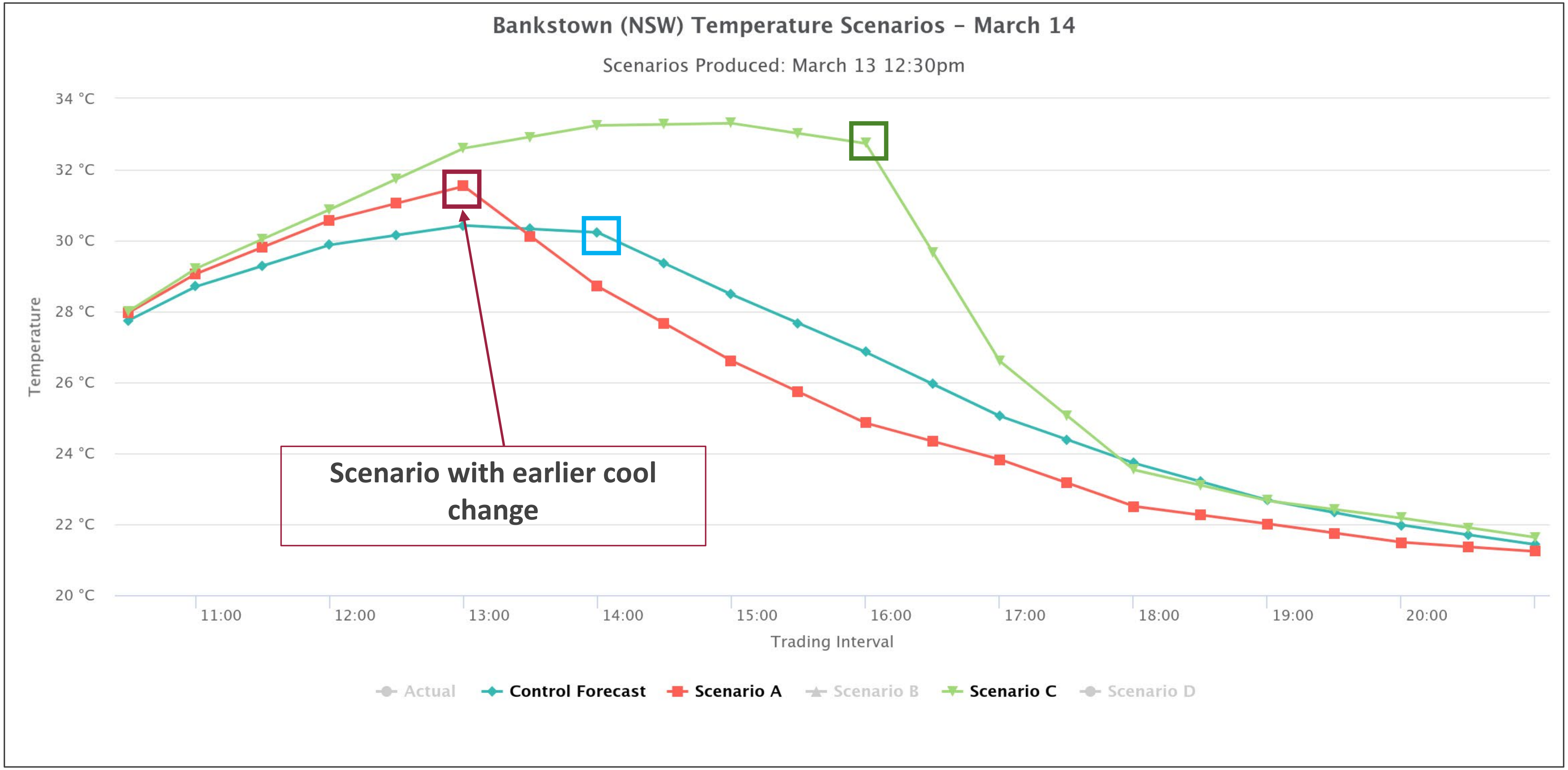

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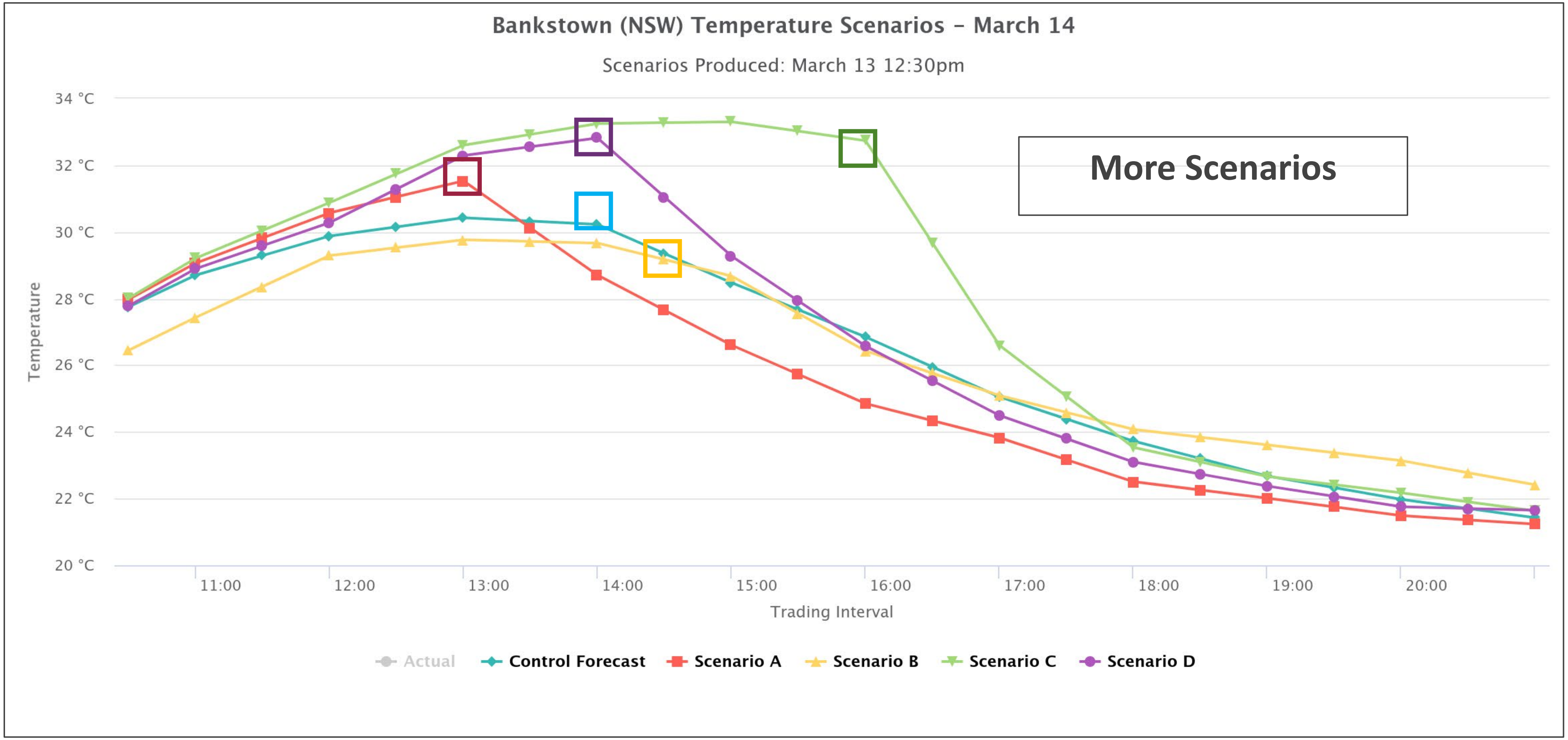

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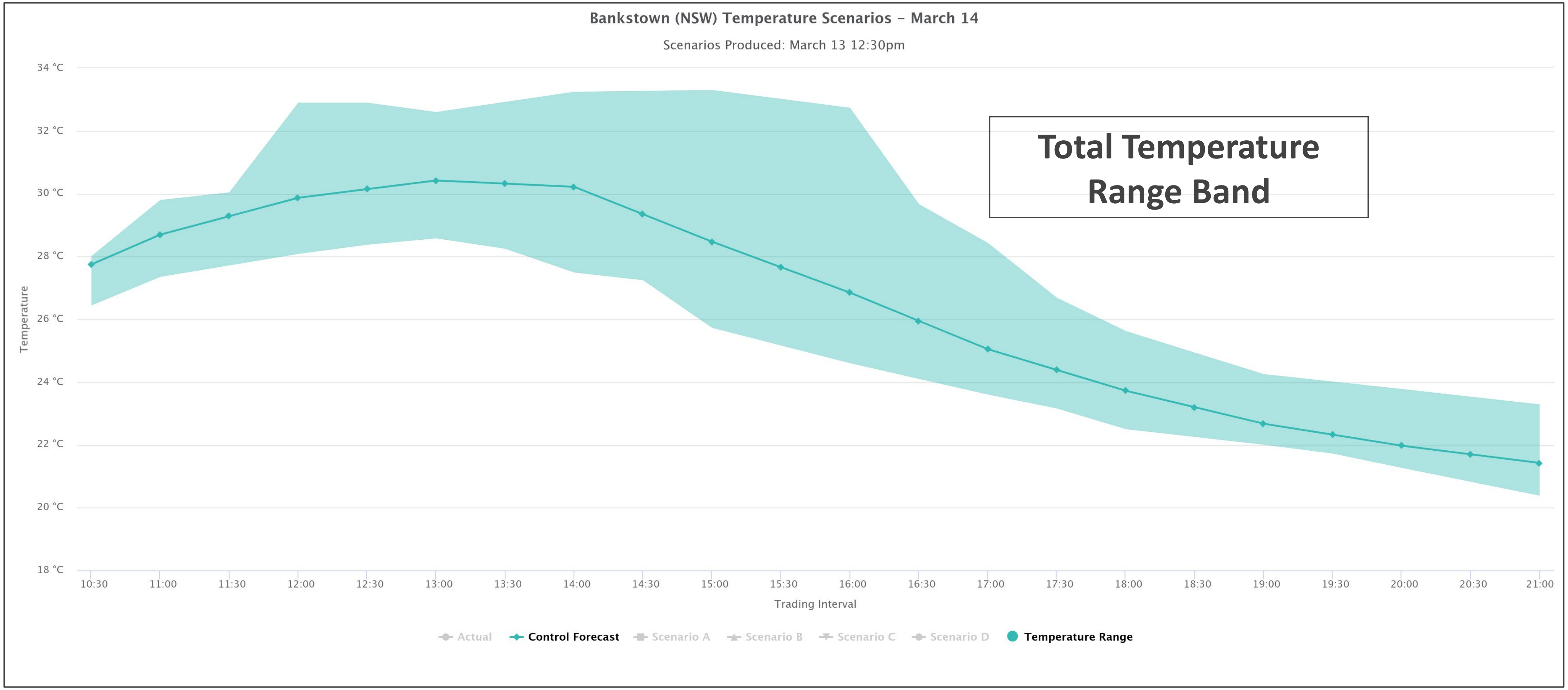

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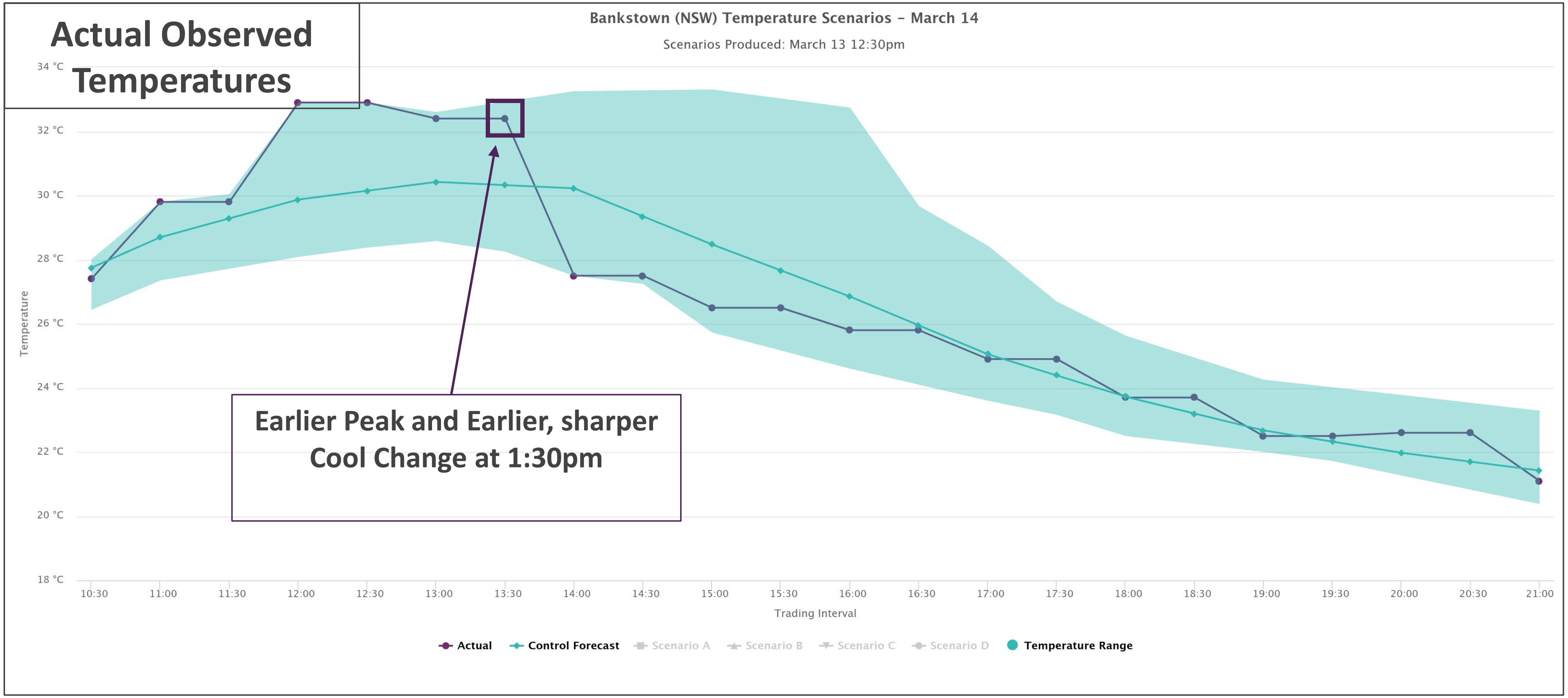

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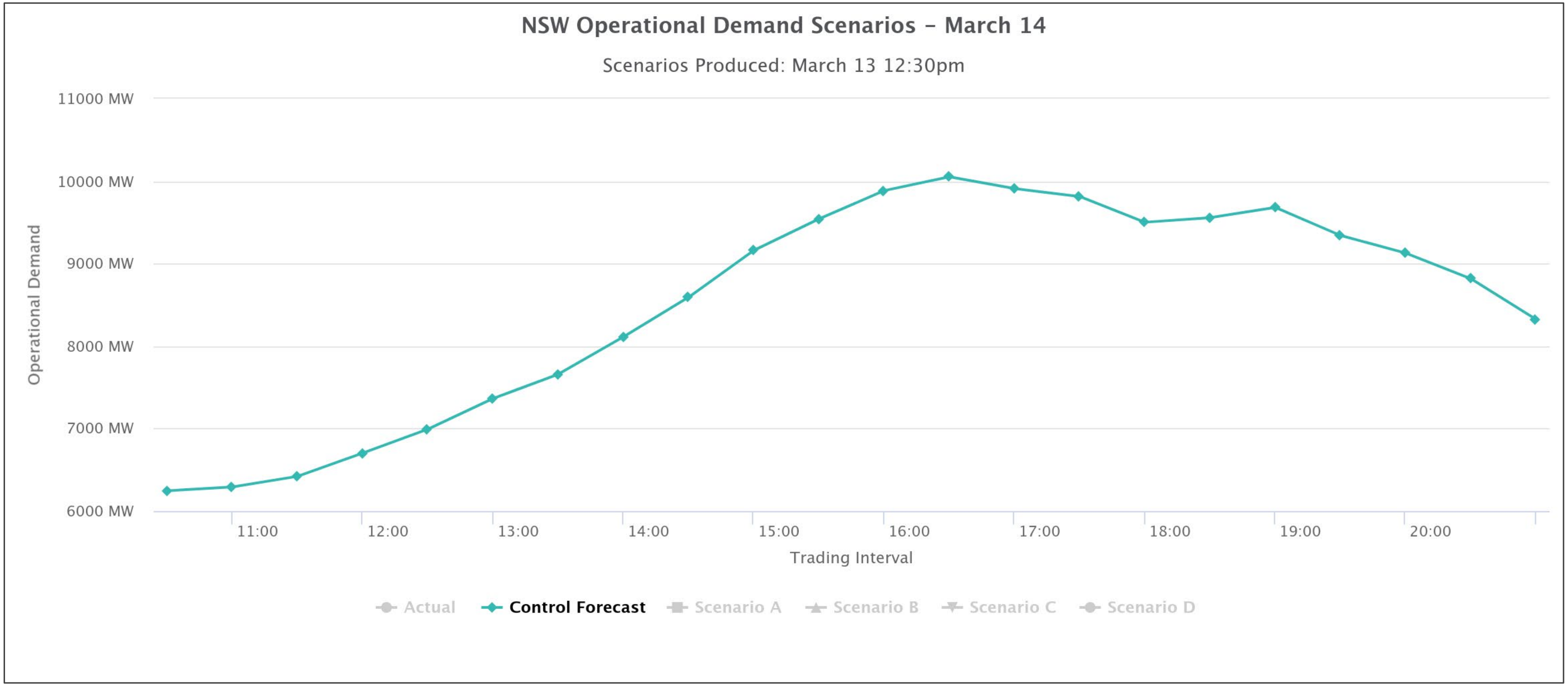

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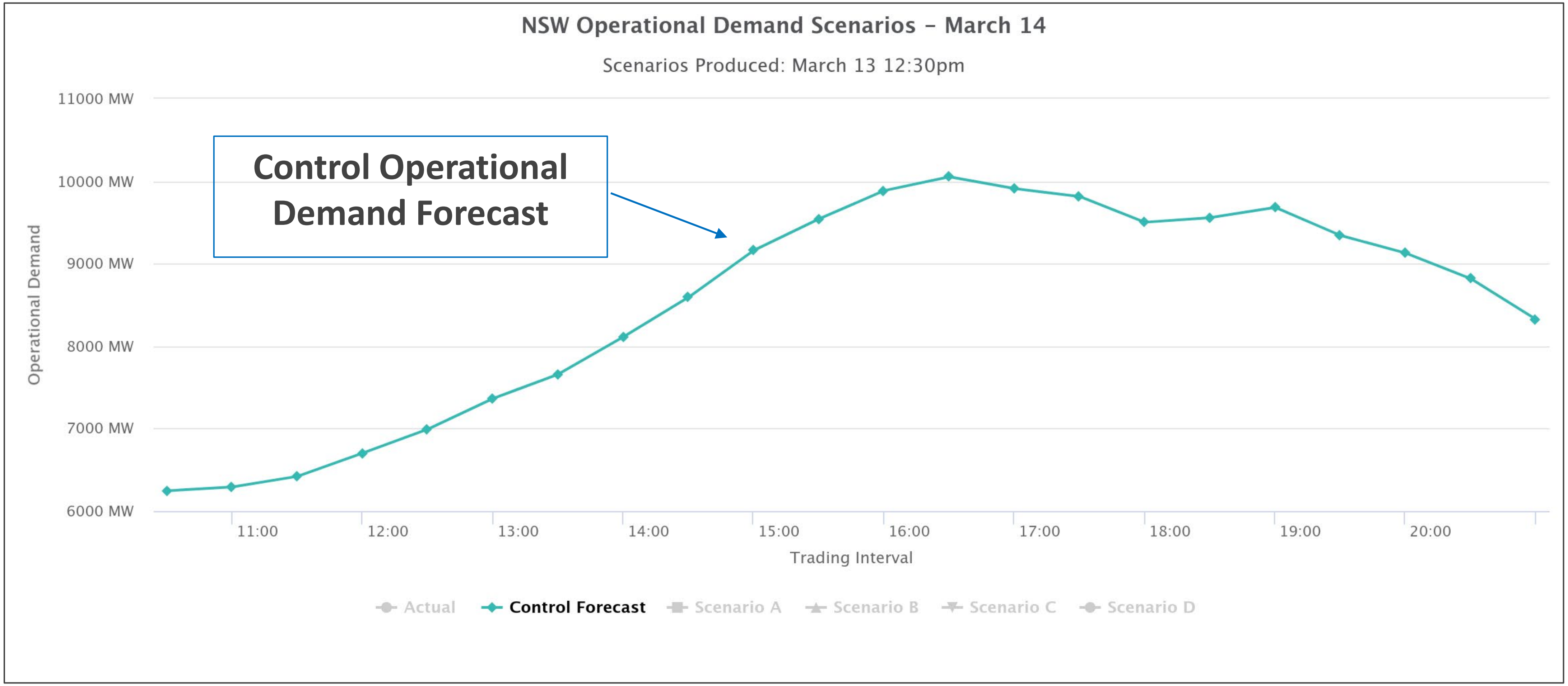

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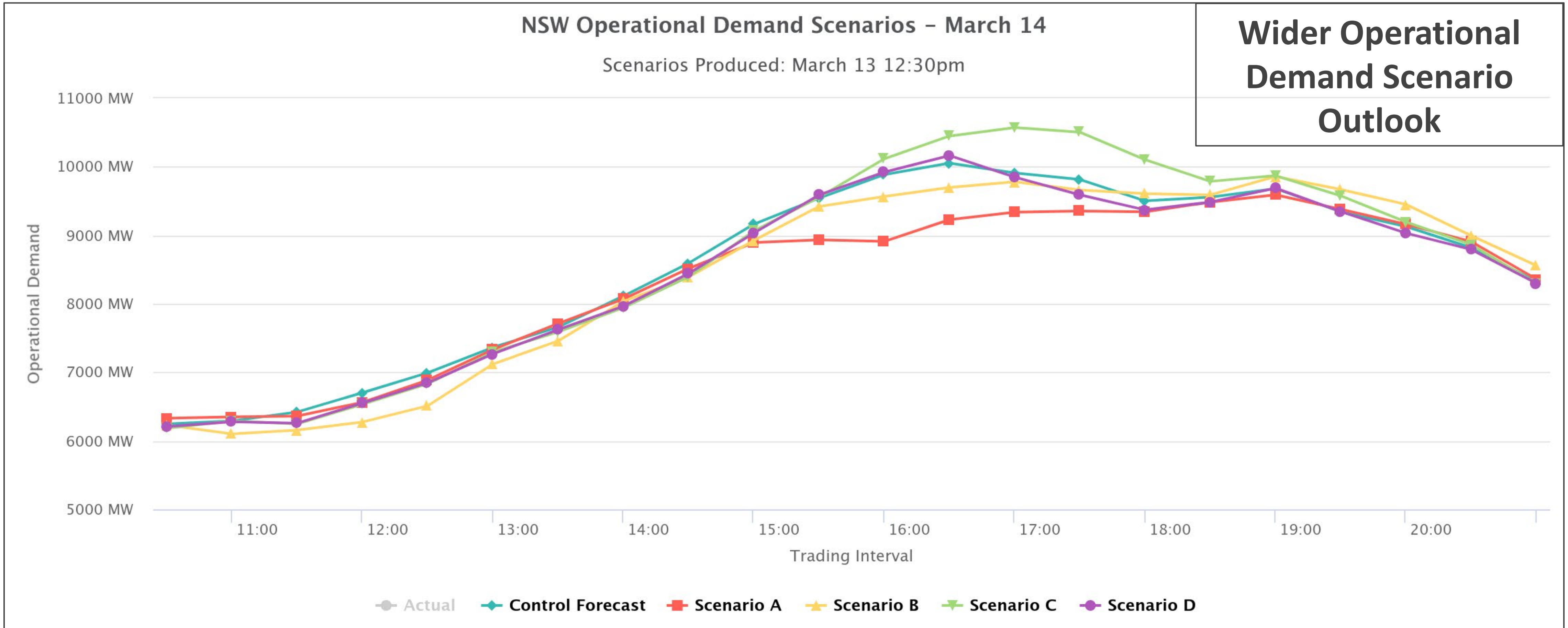
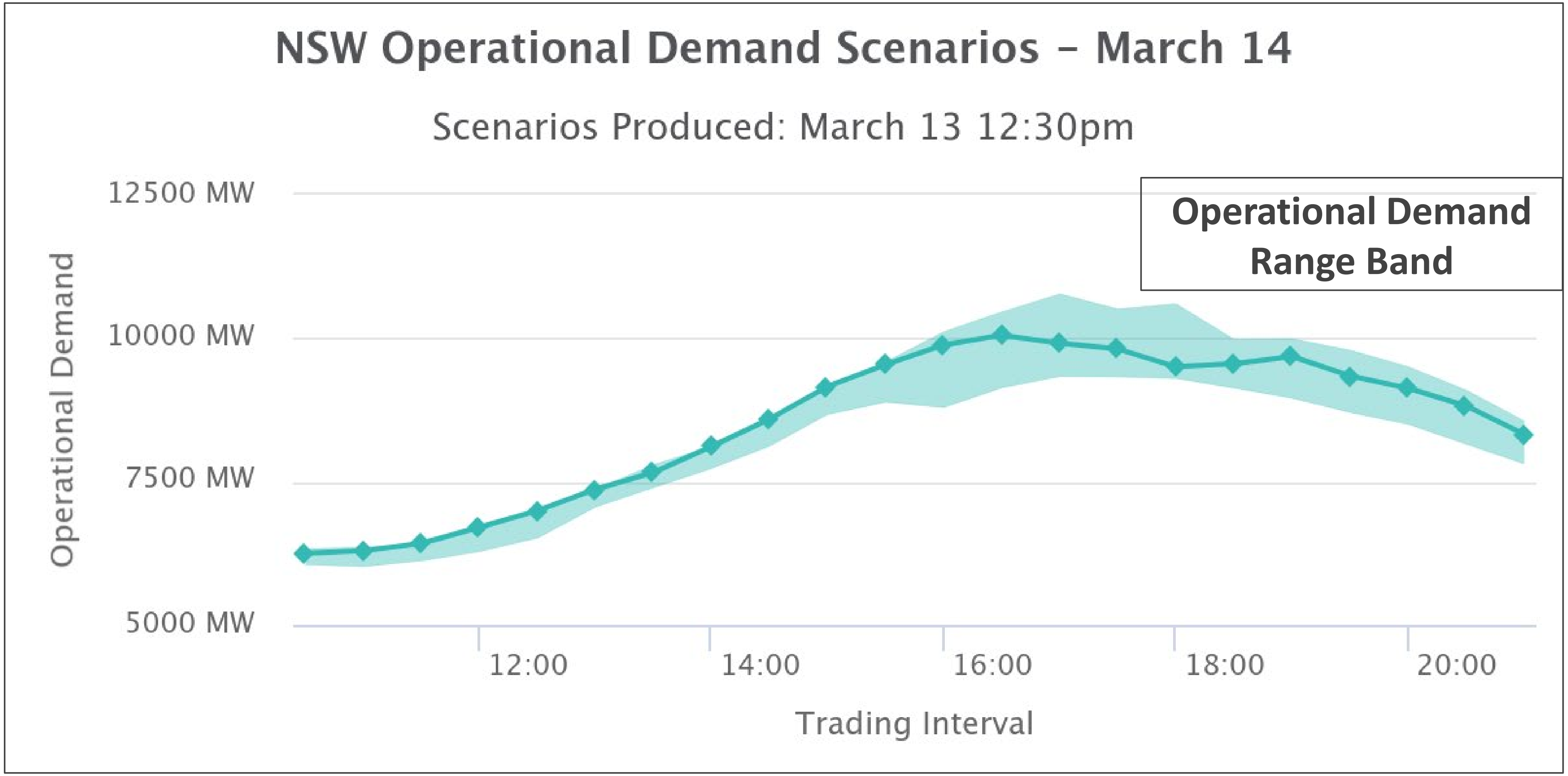


Wider Operational Demand Scenario Outlook

Weather Scenario Case Study
NSW – March 14th



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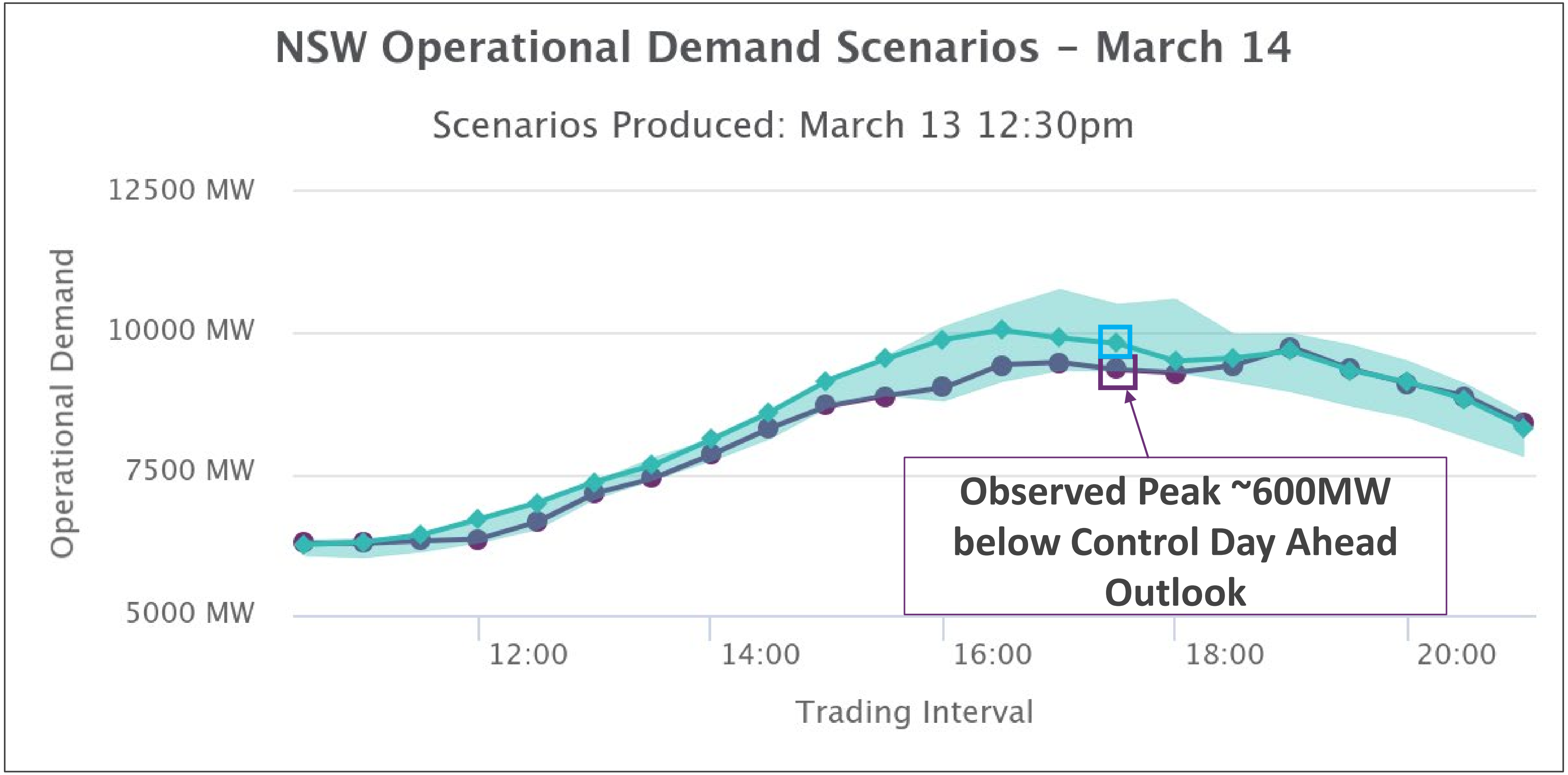
NSW – March 14th



Weather Scenario Improvements & Next Steps

- Improved Visualizations and Features
- Extended Horizons beyond 36 hours out
- More Ensembles
- Likelihoods
- PV & Solar Irradiance
- Bias correction of ensemble forecasts between ACCESS-C runs

Thank You

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