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Operation of large-scale energy storages under imperfect foresight

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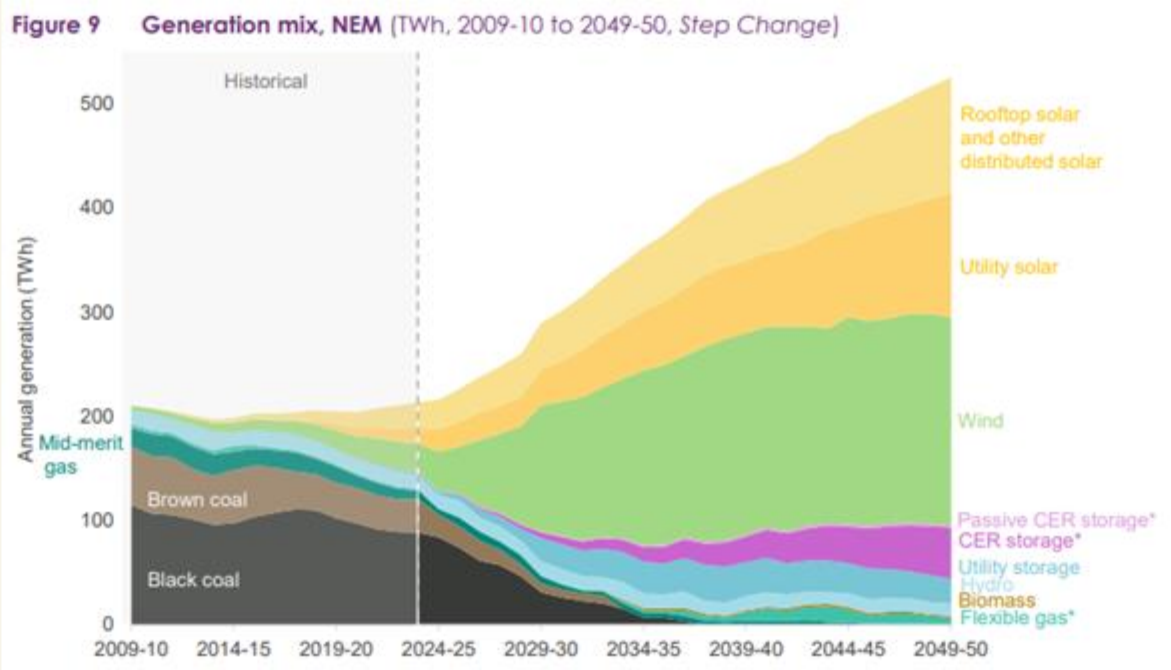
Overview

How do we design and manage a weather-dependent energy system?

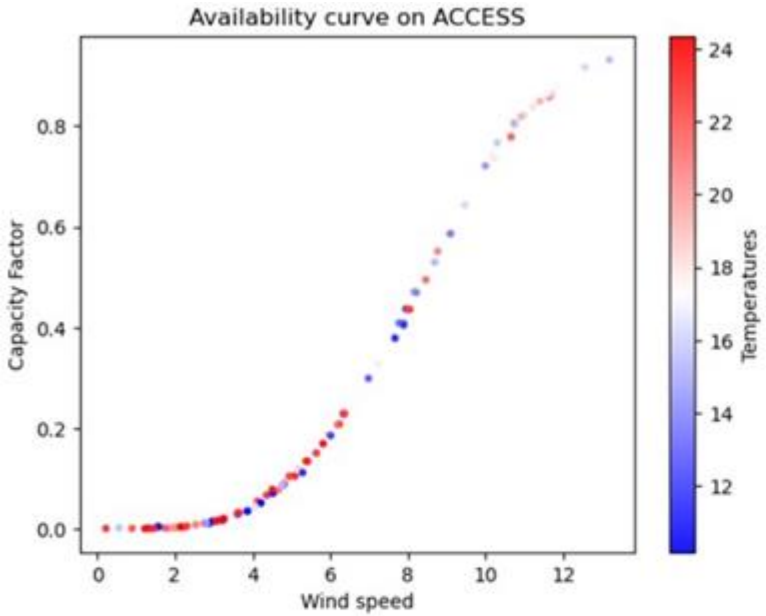
- As high levels of renewable generation connect to the network, managing **weather related risk is increasingly important** for power system operation.
- Accurate **forecasting will be key to managing the variability of wind and solar**: maximising the value of energy storage and ensuring system reliability.
- **Decisions are made under uncertainty**, but these risks are not well represented in the optimisation models used to inform power system planning.

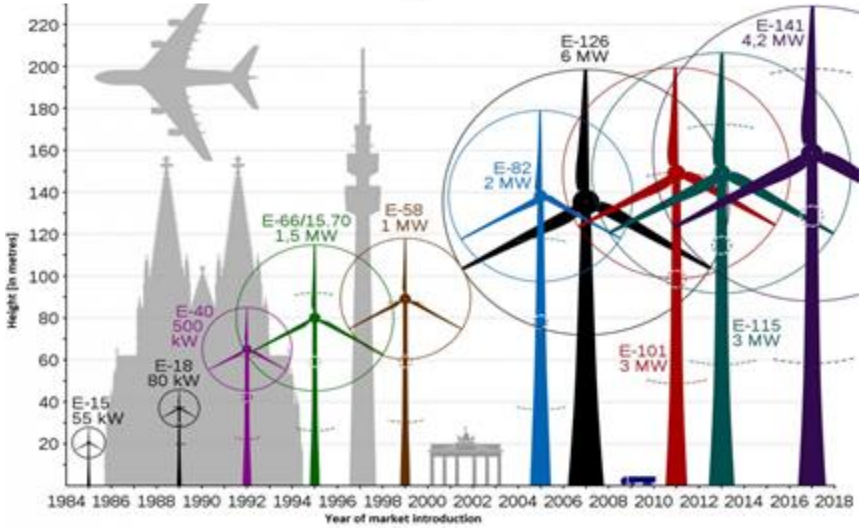


Outline

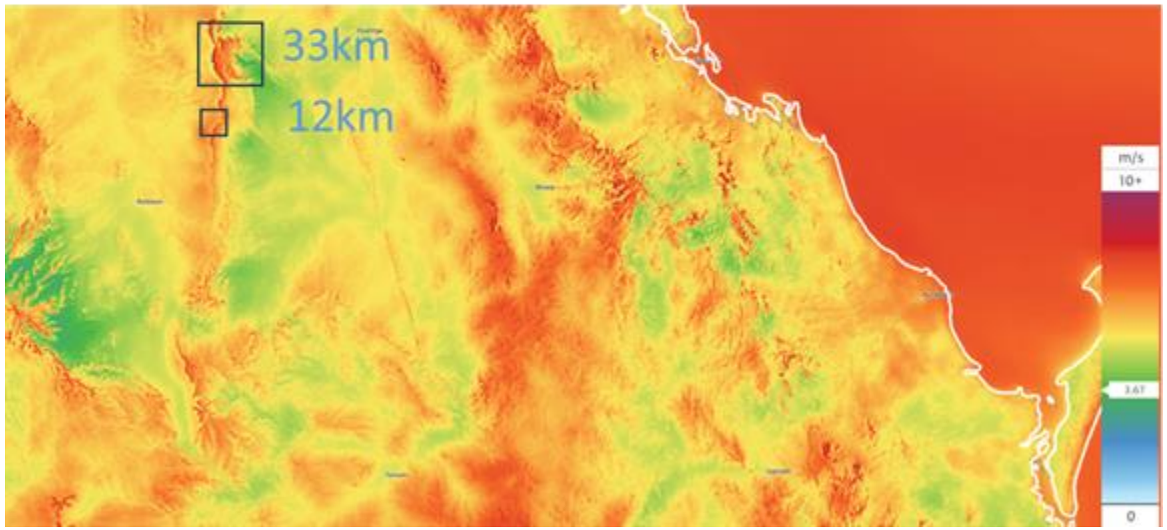
1. The use of weather data in energy market modelling
2. Analysis of historical ACCESS and ACCESS-E forecasts for renewable generation sites
3. The effects of limited foresight on energy storage
4. Case studies: operating a highly renewable system under forecast uncertainty

Weather data usage in market modelling





- Data requirements
  - Historical customer needs -> dense population centres, mostly surface-level data
  - Current PLQ needs -> REZs/regional areas, wind turbine height-level data
  - Ease of access, minimal manipulation required
  - Probabilistic/bounded forecasts (ensembles)
- Use cases
  - Forecasts/hindcasts to understand impact of weather uncertainty on models
  - Historical actuals (reanalysis) to assess quality and diversity of renewable resources
  - Better anticipate weather droughts

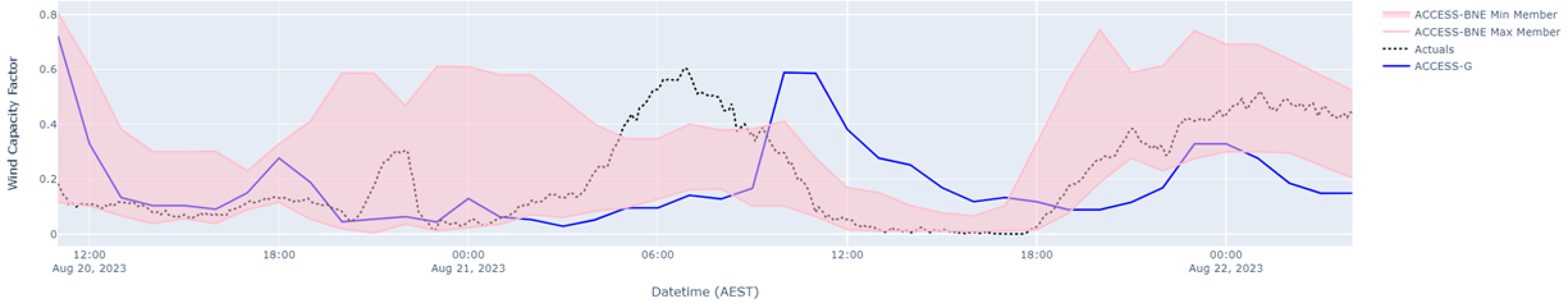


Sample of forecasts and actuals at VRE sites (170m)

Wind ACCESS-BNE and ACCESS-G Forecast vs Actuals (Coopers Gap)

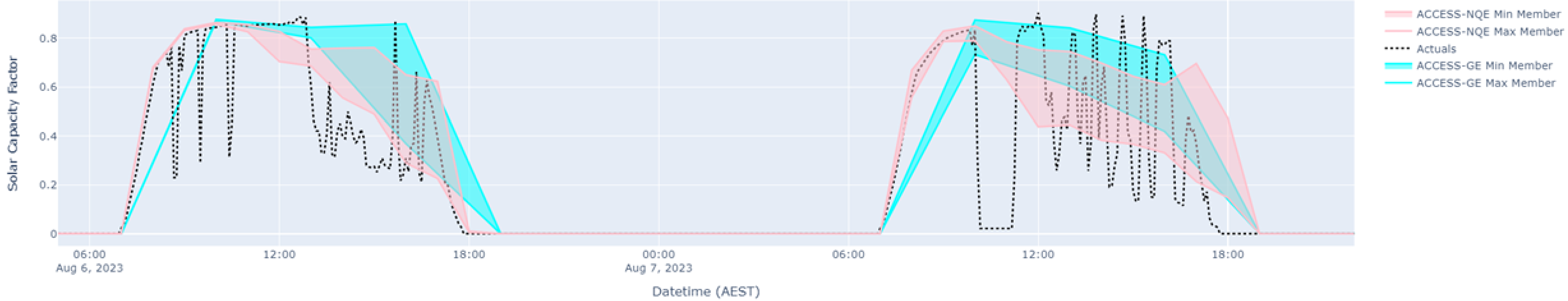
0000z cycle

NOTE: ACCESS-G wind capacity factors derived from wind speeds extrapolated via estimation function due to unavailability of data at 170m altitude

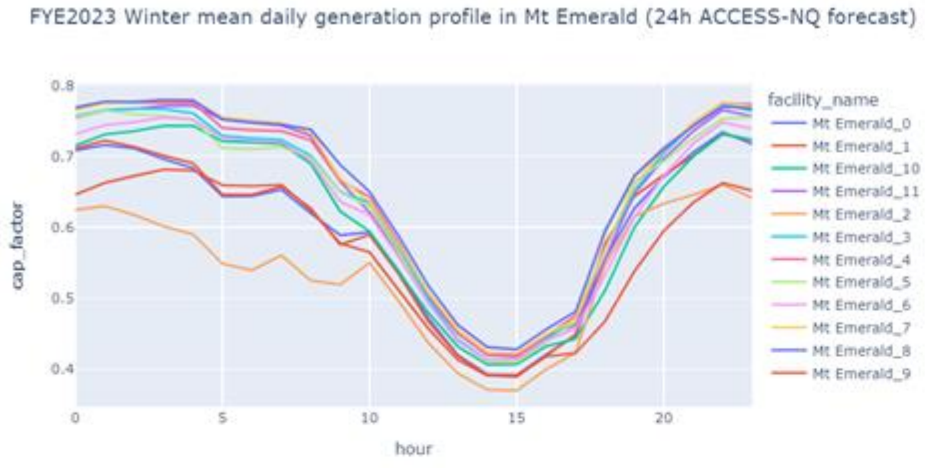


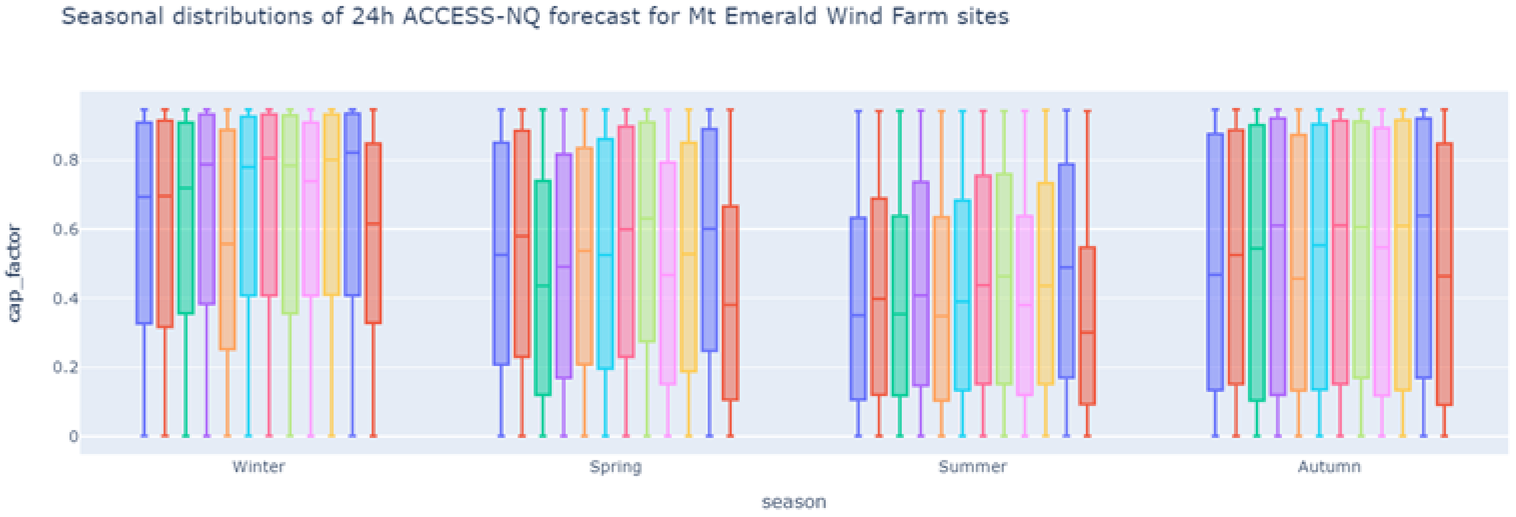
Solar ACCESS-NQE and ACCESS-GE Forecast vs Actuals (Clare)

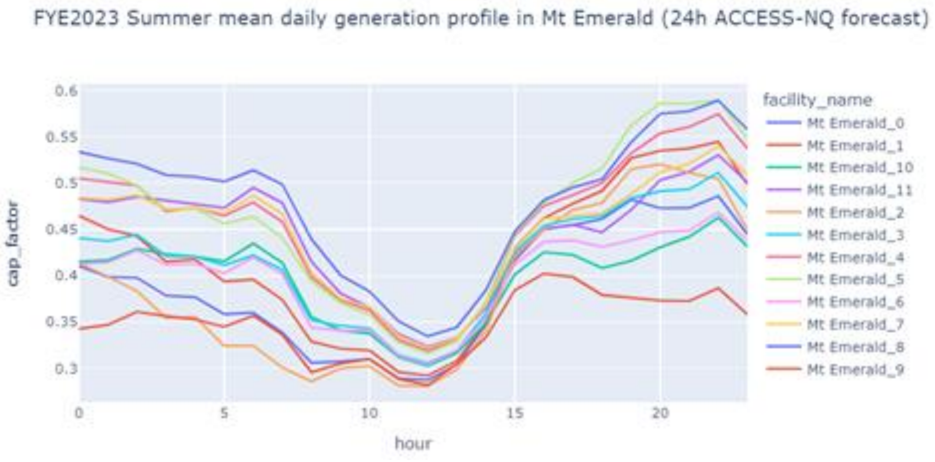
1800z cycle

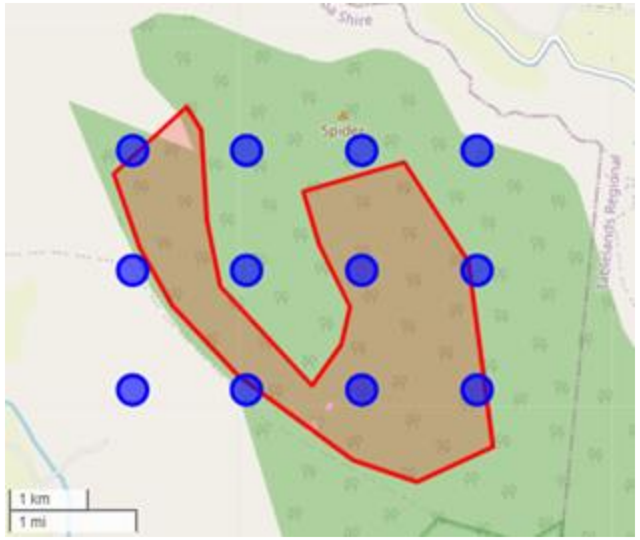


Mt Emerald wind forecast traces









- Forecasts obtained for 12 uniformly spaced locations (sites 0 – 11) using non-interpolated (raw) ACCESS-NQ coordinates
- Capacity factors measured at 170m altitude (from ground)

Operational time frame of energy storages

Batteries (& demand response)

Timeframe: intra-day energy shifting

Issues: timing of weather, unexpected cloud cover, etc.

Pumped hydro (existing + new)

Timeframe: days to weeks

Issues: operate under growing forecast uncertainty

Conventional hydro

Timeframe: months to years, driven by aggregate inflows

Issues: climate outlook and confidence

Project methodology and progress

Extract historical ACCESS and ACCESS-E forecasts

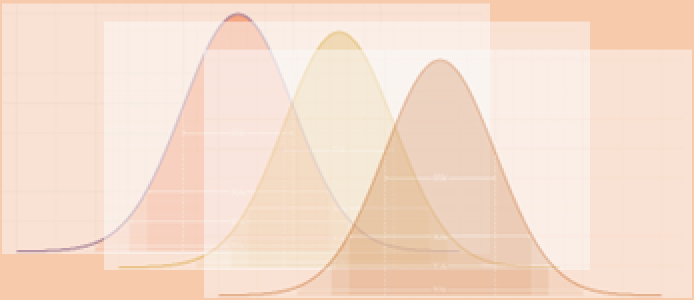
Transform weather parameters into wind and solar power capacity factors

Model future system dispatch under forecast uncertainty

Deterministic forecast: 10 day look ahead, updated every 6 hours

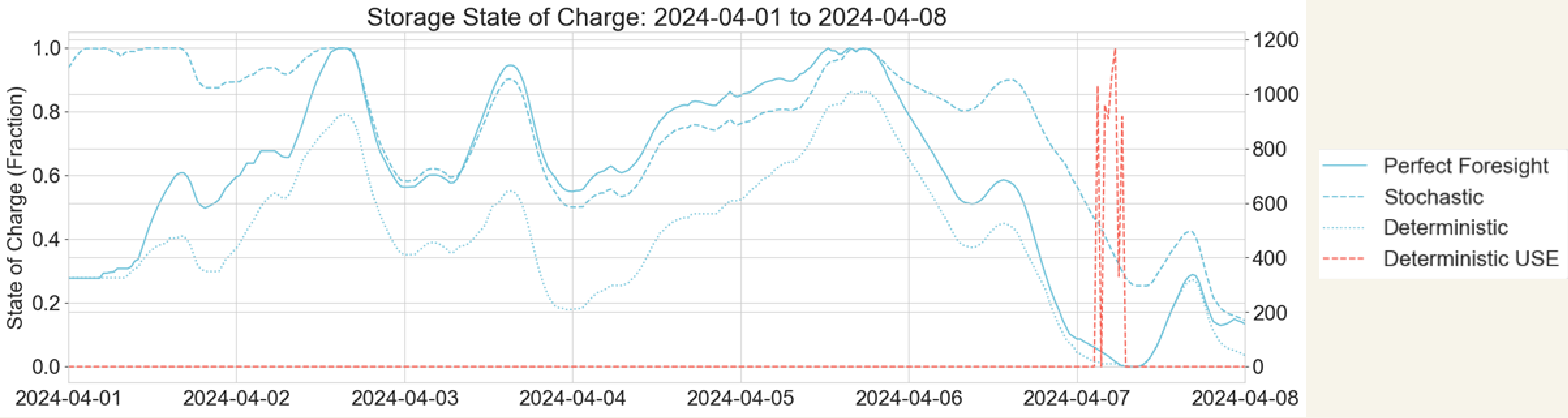
Commit	Plan next 10 days
Commit	Plan next 10 days
Commit	Plan next 10 days

Ensemble forecast: Minimise expected cost across a range of possible outcomes



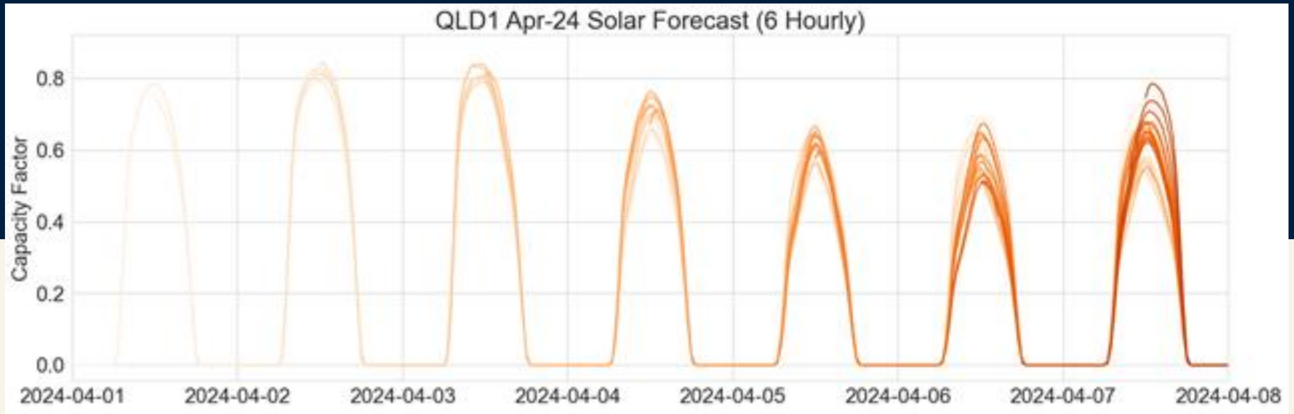
Case study: FY24 wind, solar, demand forecasts

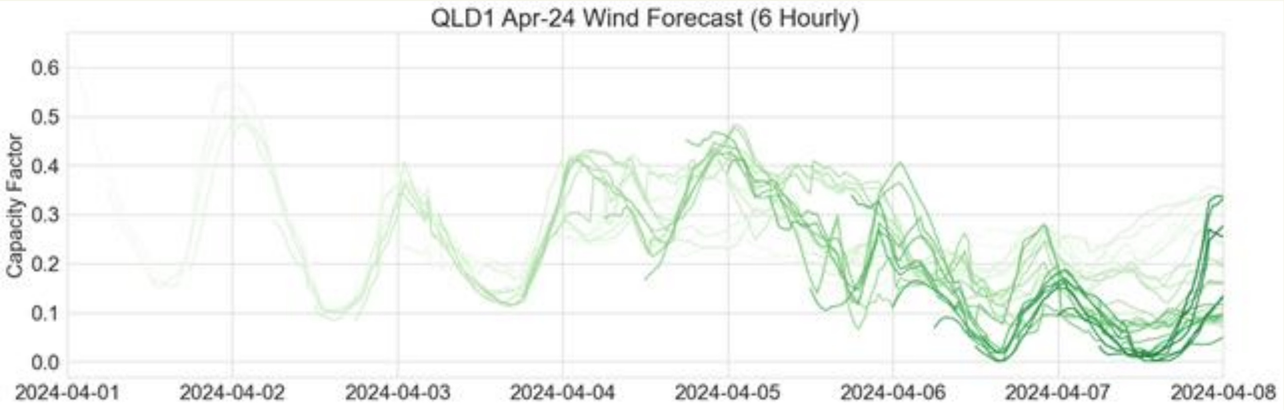
- **Modelled a highly renewable QLD system**, using results from the 2024 ISP (2035 capacity expansion)
  - 17 GW of Wind + 9 GW of Utility-Scale Solar
  - Firmed by 4.5 GW of Batteries , 2.8 GW of Pumped Hydro and 4 GW of Gas
- Dispatched **using actual weather and demand data for FY24**, as well as historic point in time forecasts
  - Can we operate the system using what was known at the time?

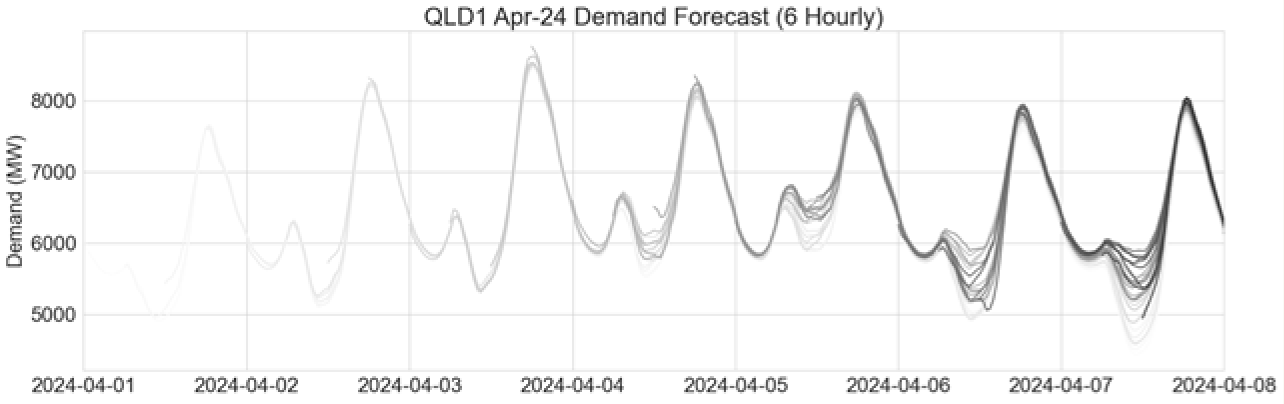


Illustrative results

- **Cost of ignoring uncertainty is very high**
    - Particularly if you do not have enough backup generation.
- **High value in perfect information**
    - Reducing uncertainty allows more efficient operation.
- **Consecutive days of high demand and low evening wind are the most difficult** for all models.
    - Energy storages are quickly depleted overnight.
- System risks are asymmetrical, over-forecasting was quite costly in the deterministic case.

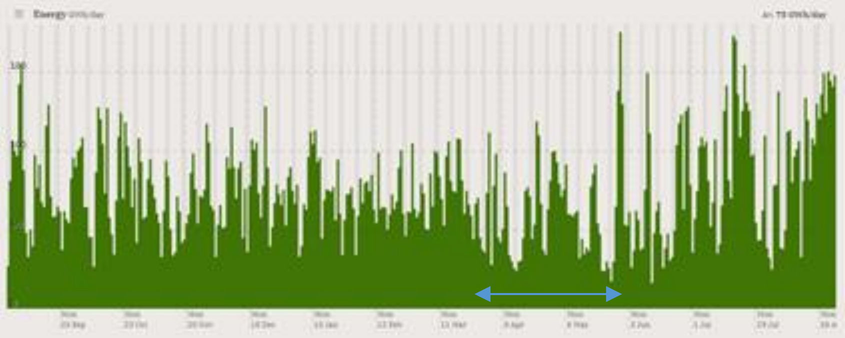


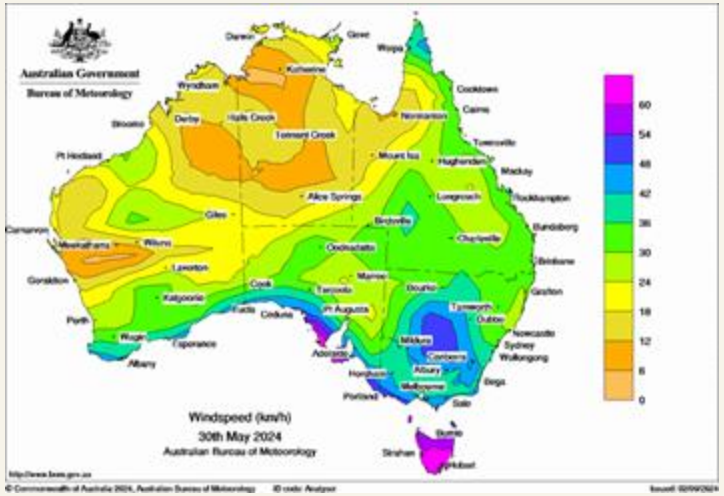


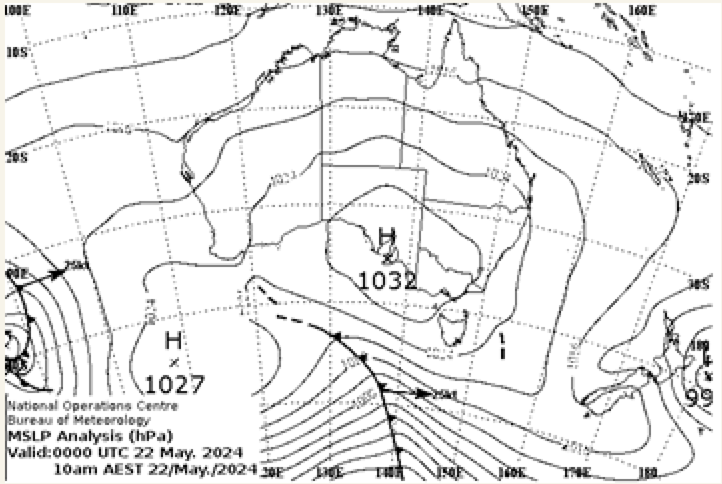


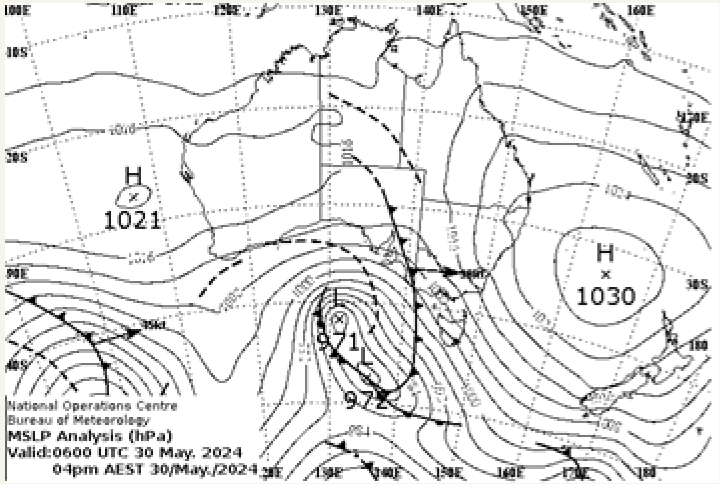
Example wind drought: May 22-28

- High pressure systems blocked wind patterns across the NEM for much of April and May 2024.
- Final week of May saw VIC, SA, NSW, TAS low wind yield.
- NEM then saw an all-time maximum on Thursday 30th May.
- How could we have managed this event?



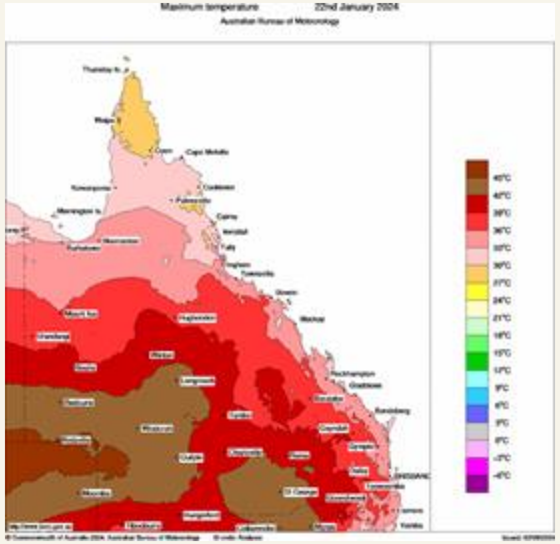


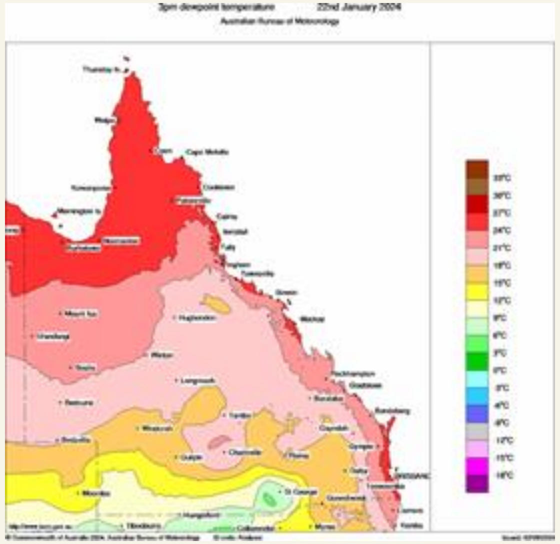


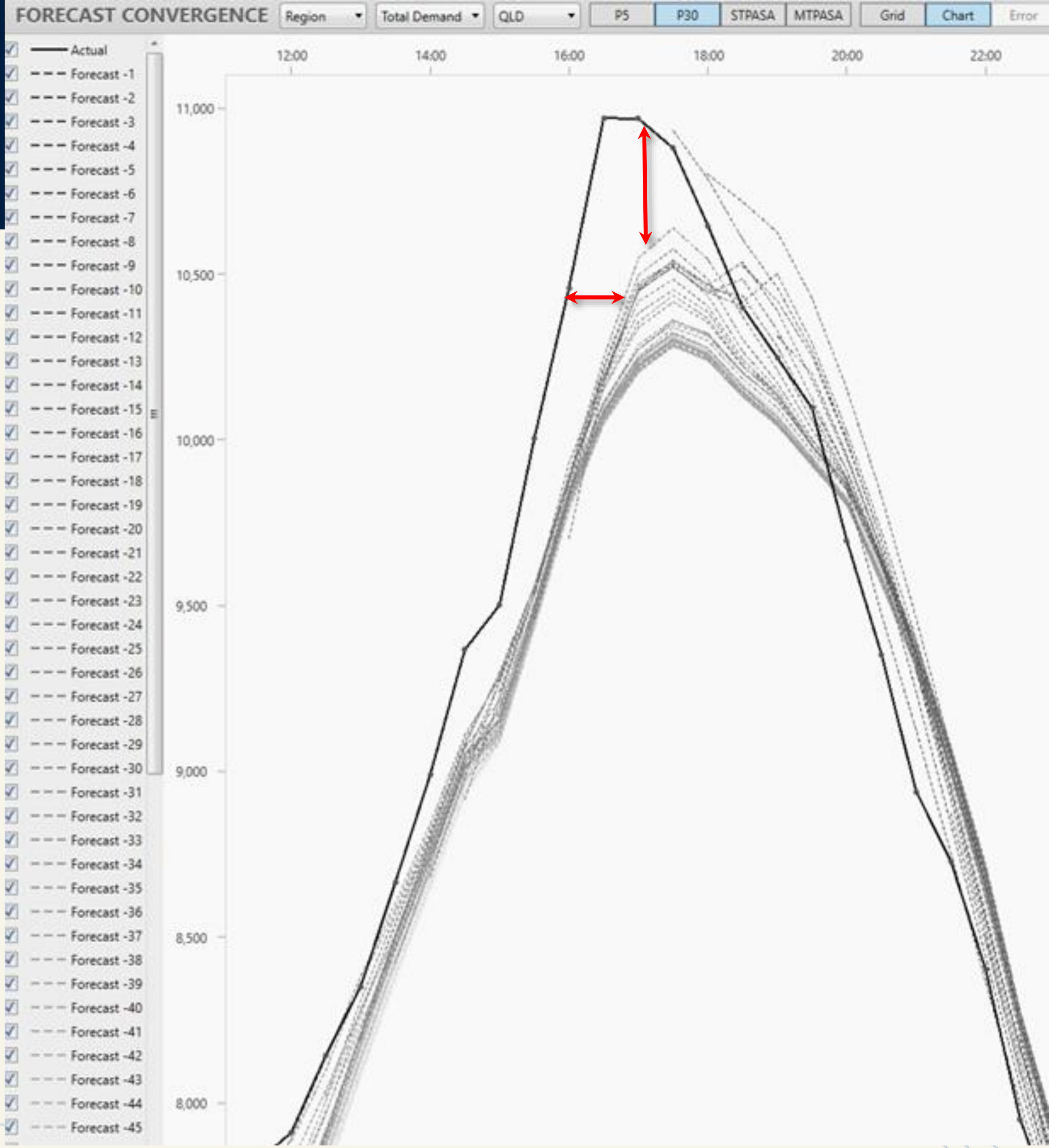


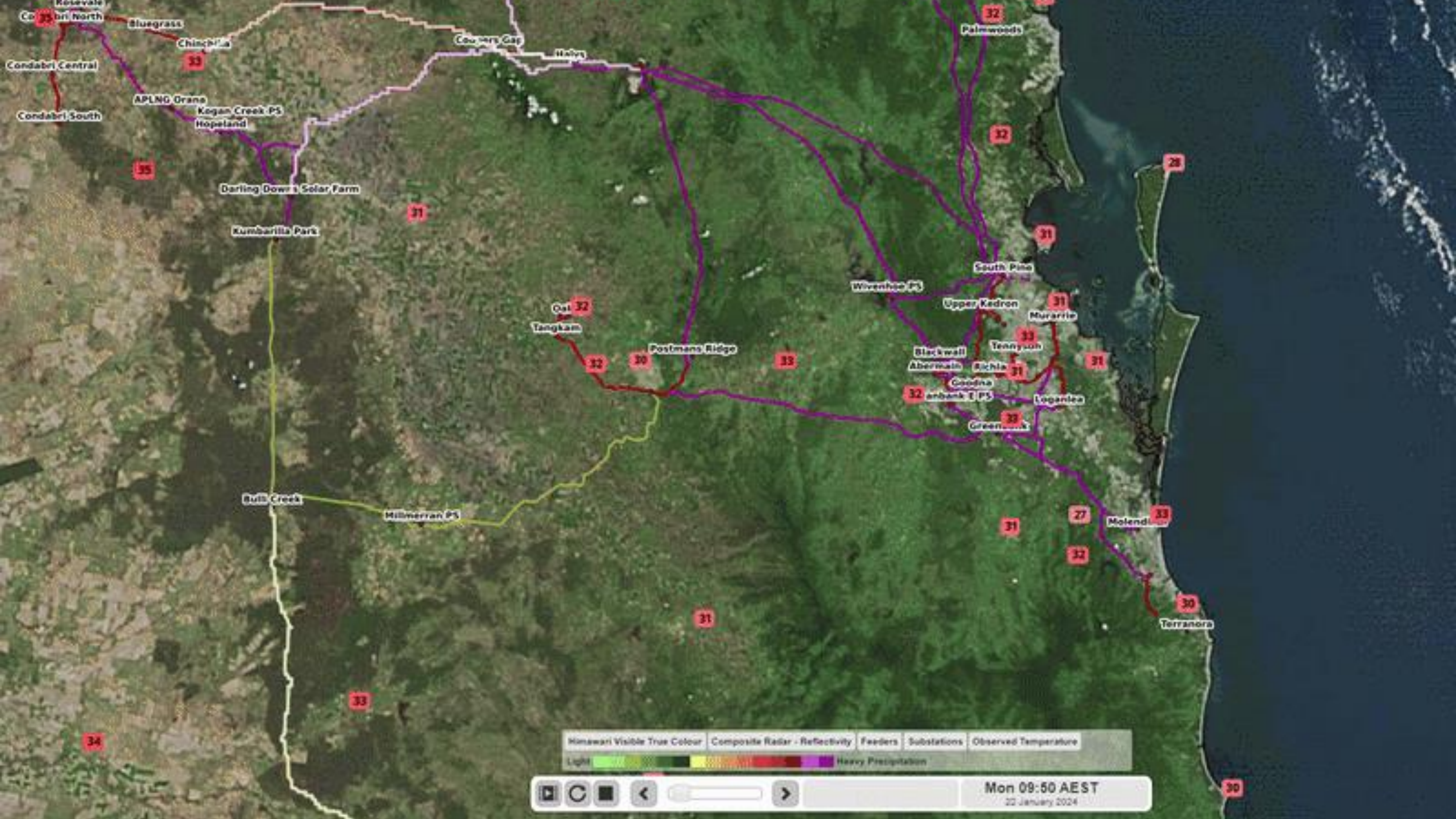
QLD peak demand: Jan 22

- On January 22nd QLD saw its highest ever electricity demand, exceeding the previous record by 875 MW.
- Caused by a combination of extreme heat, high dew point temperatures and a sharp afternoon drop in rooftop solar output.








Rosevale
Bluegrass
Condabri Central
Condabri South
APLNG Orana
Kogan Creek PS
Hopeland
Darling Downs Solar Farm
Kumbarilla Park
Halys
Palmwoods
South Pine
Wivenhoe PS
Upper Kedron
Murarrie
Tennyson
Blackwall
Abermain
Goodna
Loganlea
Tangkam
Postmans Ridge
Bulli Creek
Millmerran PS
Terranora
Himawari Visible True Colour
Composite Radar - Reflectivity
Feeders
Substations
Observed Temperature
Light
Heavy Precipitation
Mon 09:50 AEST
22 January 2024

Summary

- Energy system users typically are interested in a subset of data
  - **Wind forecasting** - wind speed (at heights of 80-250m), air density, temperature
  - **Solar forecasting** - solar irradiance, temperature
  - **Demand forecasting** - temperature, relative humidity, etc
- Hourly intervals makes data more accessible for energy analysts and modellers, and produce more accurate results
- **Probabilistic forecasts are valuable**: capturing uncertainty minimises system cost, and improves reliability
  - What conditions lead to high uncertainty? -> How can network know when to operate conservatively?
- **Reducing forecasting uncertainty would allow storages to operate less conservatively**
- Understanding weather risk will allow us to design and operate a cost-effective system