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Maintaining Reliability in a Near-Zero Carbon Grid

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Supported by Western Interconnection Regional Advisory Body

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Challenges to Grid Reliability

System Stability

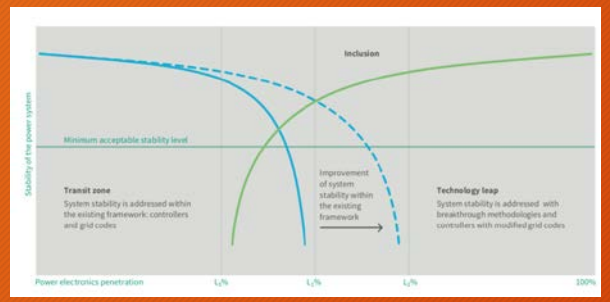
- High penetrations of inverter-based resources (IBR)
- Essential reliability services
- Some transient stability and small signal stability issues still need to be addressed

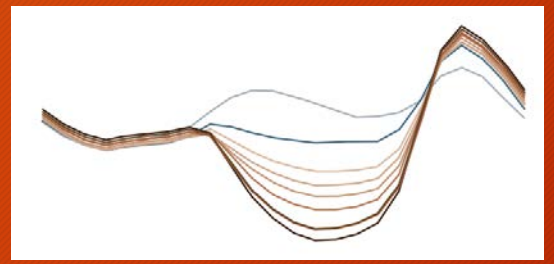
System Balancing

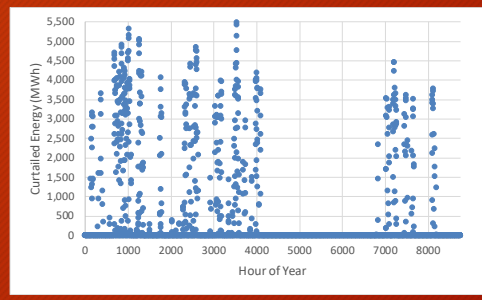
- Wind and solar variability and uncertainty
- Reducing curtailment
- NERC Control Performance Standard 1

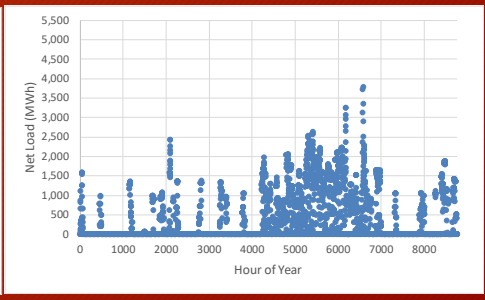
Resource Adequacy

- Seasonal mismatch of supply and demand
- Periods of low wind/solar/hydro
- 1 day in 10 years Loss of Load Expectation







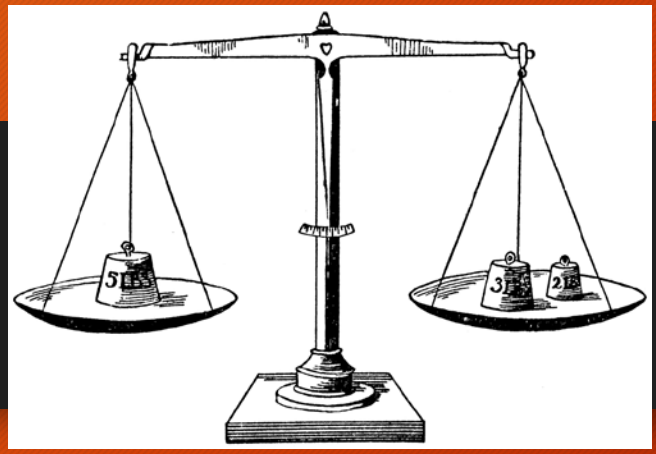


Short-term **Medium-term** **Long-term**

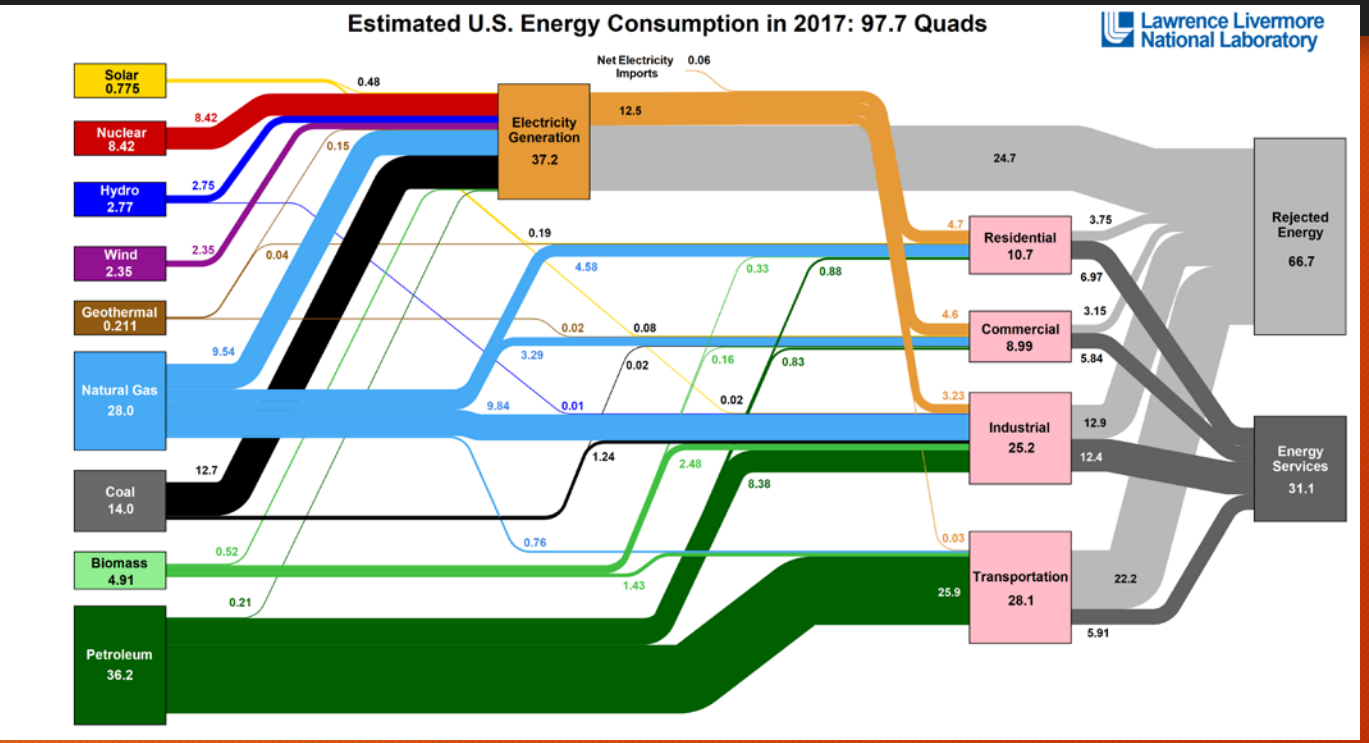
100% Clean Energy is possible with today's technology/know-how.
The question is: Can we do this smarter, cheaper, and by 2045?

Graphics: EU-MIGRATE 2016
CAISO, Fast Facts 2016
A. Bloom, ESIG Planning WG Oct 2018

Resource adequacy



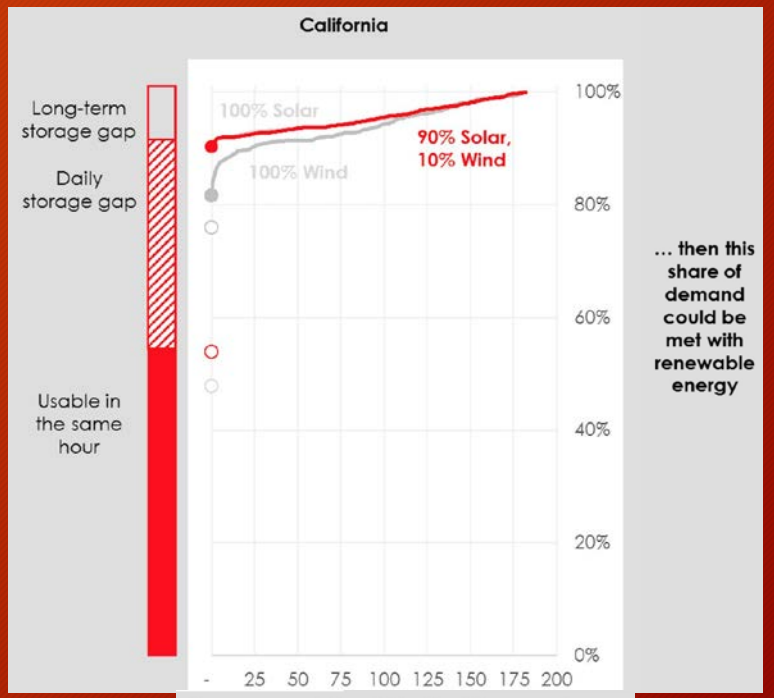
We need to control both sides of the supply/demand balance



Electrification is essential, but need control or price signals. Optimizing and coupling across energy sectors will be challenging.

Lawrence Livermore National Laboratory, 2017 https://flowcharts.llnl.gov/

Seasonal mismatch of supply and demand; long-duration storage and Power-to-X are potential solutions



B. Pierpont et al, "Flexibility: The path to low-carbon, low-cost electricity grids," Climate Policy Initiative Analysis, 2017

Dispatching demand – some thoughts

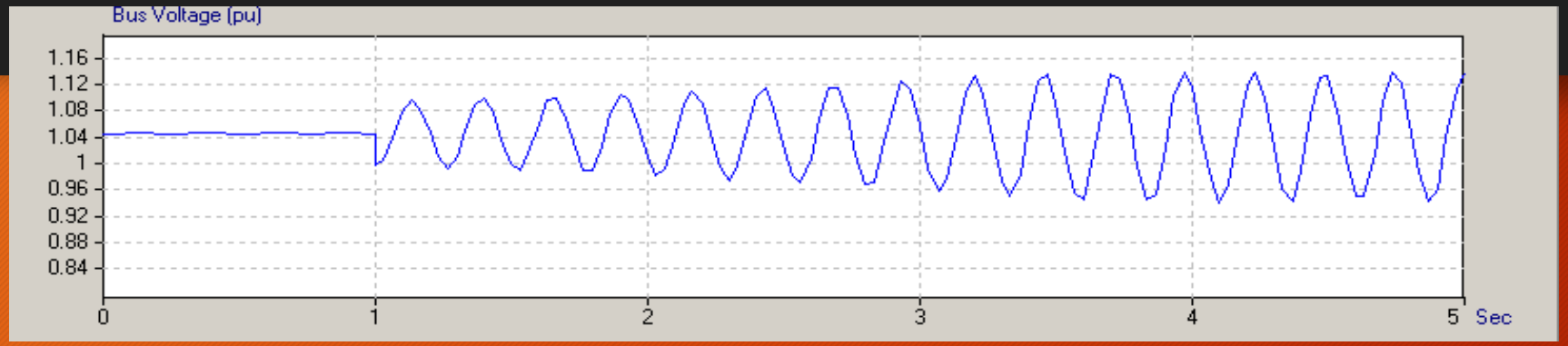
- Prices are a powerful signal! Align rate design with your system operations
  - TOU rates can act like medium-term storage
  - Coincident peak demand charges can act like peaking plants
- Prices alone are not enough information to balance the system; you also need to know quantity.
- The same way a system operator wants to dispatch wind/PV instead of "must-take" wind/PV, we want to move toward dispatching demand instead of "must-give" demand
- Is 1 day in 10 years LOLE necessary for all customers?
- Stop thinking of demand response as a generator and start thinking of demand as demand: "How much do I want to pay for x MWH at that time?"
- Does the LOLE concept still hold with price elasticity of demand?

Lessons learned worldwide

- Markets can incentivize low minimum generation levels on their thermal fleet
  - EirGrid – new system service that incentivizes high inertia and low minimum generation levels
- Cultivate productive uses of cheap electricity
  - Denmark – 620 MW of electric boilers for district heating when prices are negative in Germany
- Use curtailed VER as a resource
  - Curtailed wind/PV can provide reserves, which can help decommit thermal units.
  - Denmark sells down-regulation to other countries, ¼ of which comes from wind.
  - Xcel – up and down regulation from wind, spinning reserves

In a system that will be dominated by weather-driven resources and loads, more dynamic pricing (than TOU) and good forecasting will be essential.

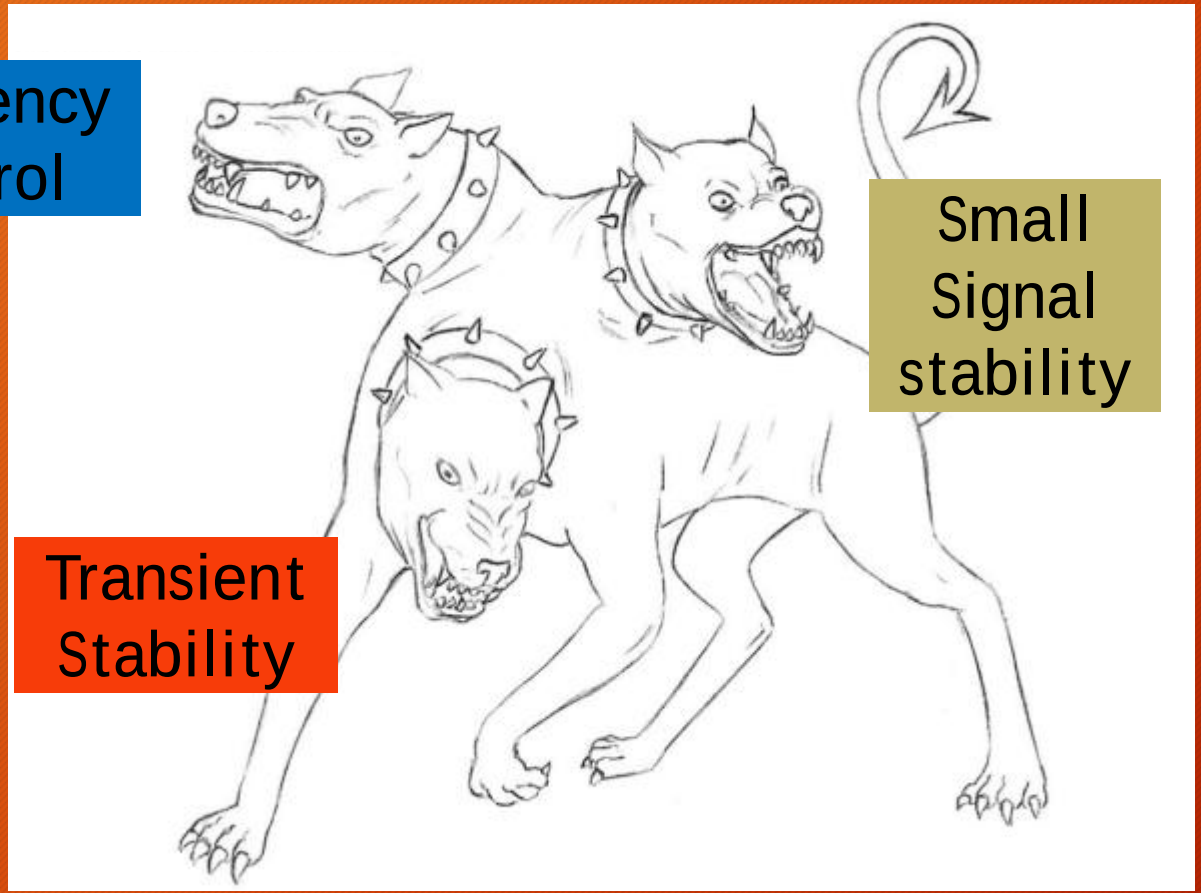
Stability with high penetrations of IBRs



- This is not a “smart inverter”, IEEE-1547, Smart Inverter Working Group, or Rule 21 issue.
- Virtually all of the inverters on the grid are ***grid-following*** inverters. They require system strength to operate reliably and stably. They ‘read’ the system voltage and frequency and inject current appropriately.
- Obviously if all of the electricity in WECC came from IBRs even for a second, it wouldn’t work because the grid-following inverters wouldn’t have a voltage/frequency reference signal to ‘read’.
- We can run into problems before reaching 100% IBR instantaneous penetration. Even a pocket of the system at high IBR penetration can have issues. Note that even moderate annual average VER penetration can translate to high IBR penetration.

Graphic source: ERCOT, Dynamic Stability Assessment of High Penetration of Renewable Generation in the ERCOT Grid Version 1.0, ERCOT, 2018

Stability is a single challenge with different faces

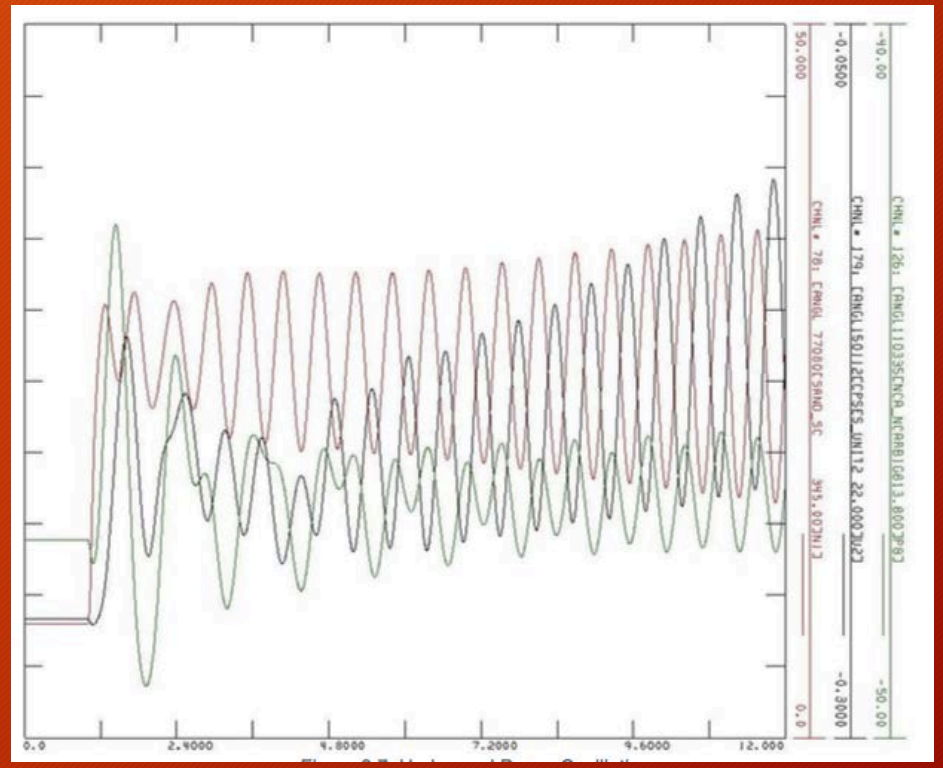


- Systems aren't secure unless they are stable
- All 3 types of stability constraints must be satisfied
- Degree to which each type is constraining varies with each system
- They aren't completely separate

Source: Nick Miller, Hickory Ledge, CREPC, 2019
Dog Image Source: Drawingforall.net

What options can help?

- Reliability-must-run thermal generators can maintain grid strength, but have economic impact and carbon emissions
- Fine-tune controller settings, coordinate controller settings
- Building more transmission to alleviate weak grid issues
- Installation of synchronous condensers to provide grid strength, but this can lead to transient stability issues
- Grid-***Forming*** Inverter technologies, but need to determine how these interact with the grid, and what performance is required



ERCOT, Dynamic Stability Assessment of High Penetration of Renewable Generation in the ERCOT Grid Version 1.0, ERCOT, 2018

Questions?

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We know how to manage variability and uncertainty of wind and solar…

- Commit and dispatch over bigger geographic regions. Interconnect more.
- Faster dispatch
- Faster gate-closing times – make decisions as late as possible
- Incorporate forecasts into commitment and dispatch. Decommit based on forecasts
- Increase flexibility of thermal units – low turndown, shorter downtimes, shorter startup
- Operate all assets as flexibly as possible
- Wind and solar provide essential reliability services (reserves, voltage support, etc)
- Demand response
- Energy storage

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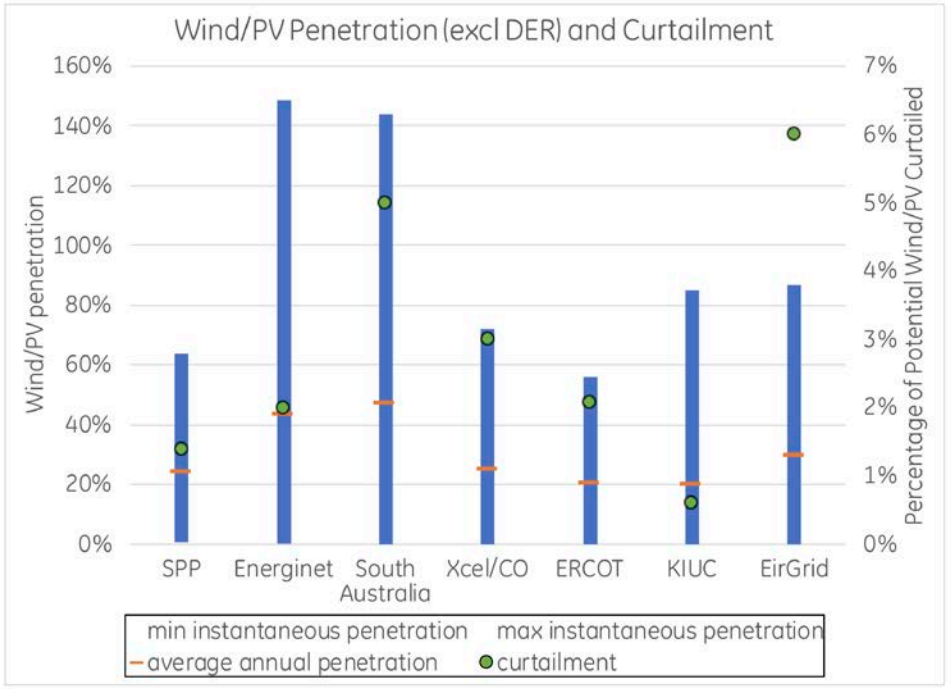
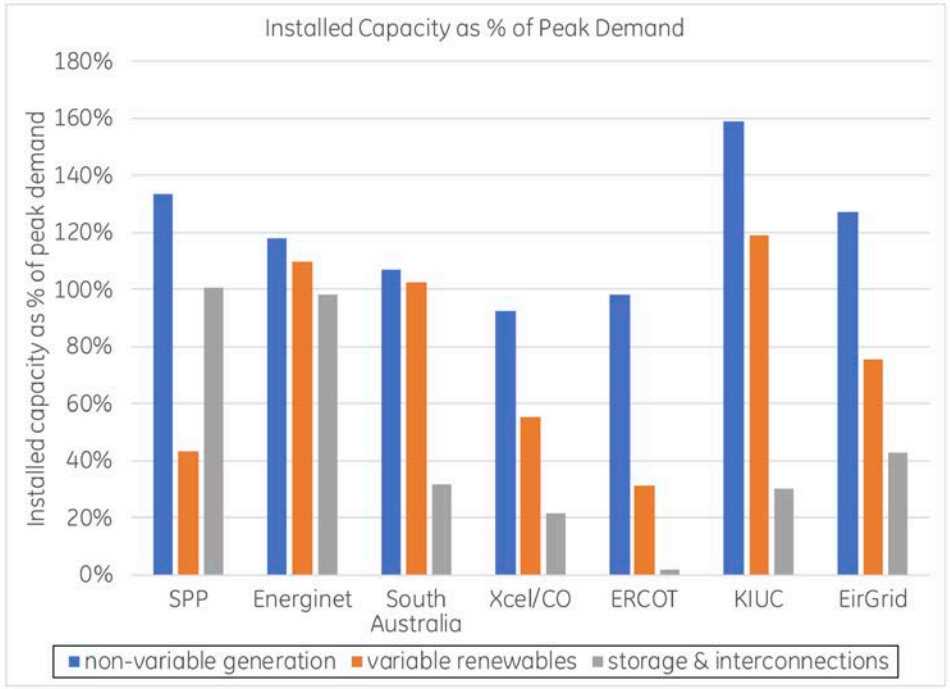
At some point you exhaust the flexibility potential in these options

Do you want to keep your thermal generators around?

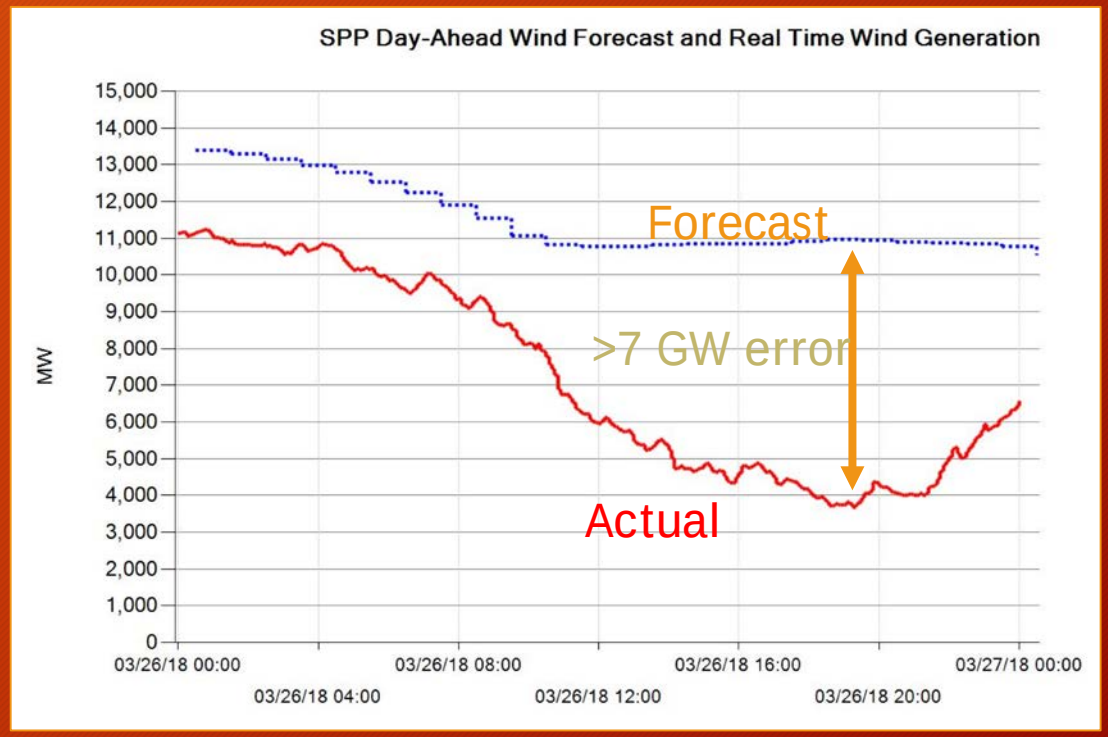




- No-regrets actions
- Biogas, syngas, hydrogen production; using existing gas infrastructure

Forecasting and storage

- Even with commercial, cost-effective long-duration storage, operations will be challenging.
- When do you charge and discharge storage resources? This depends on forecasts, optimization, and decisions in the various timeframes associated with storage resources.
- Very high VER penetrations are dependent on how well you can forecast. Managing tail events of forecast error distributions will be challenging.



Source: Bruce Rew, Southwest Power Pool, 2019