Forecasting Wind

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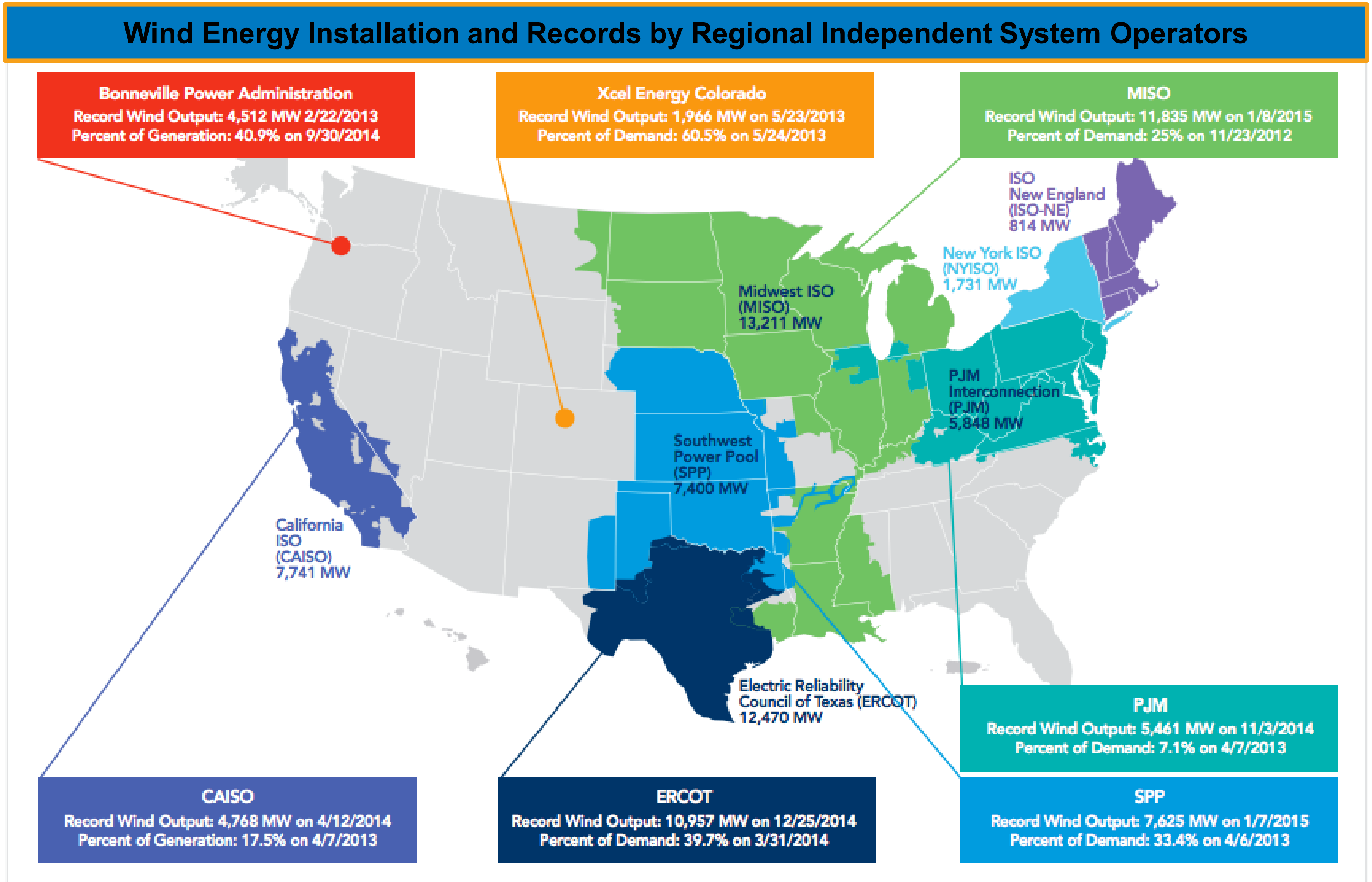
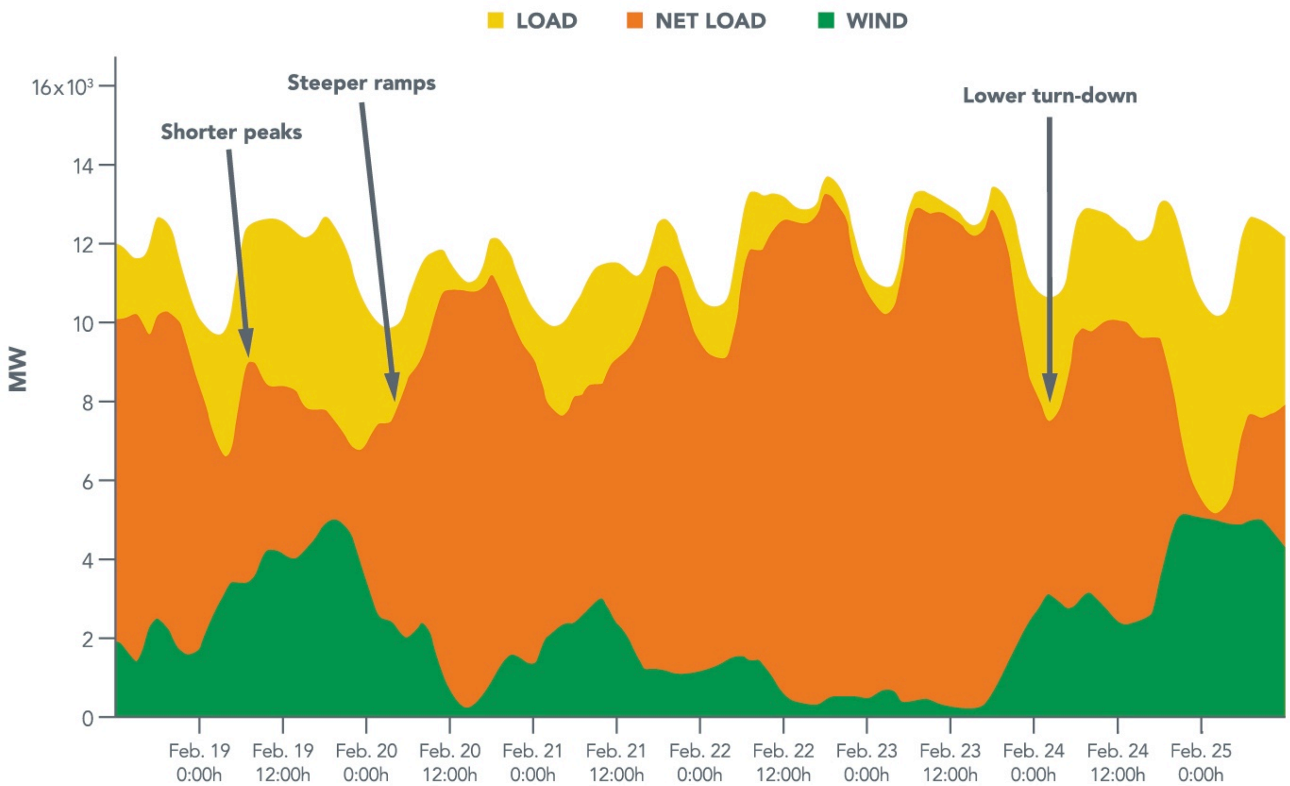
U.S. Wind Installation and Generation by ISO



Source: AWEA 2014 Year-End Market Report

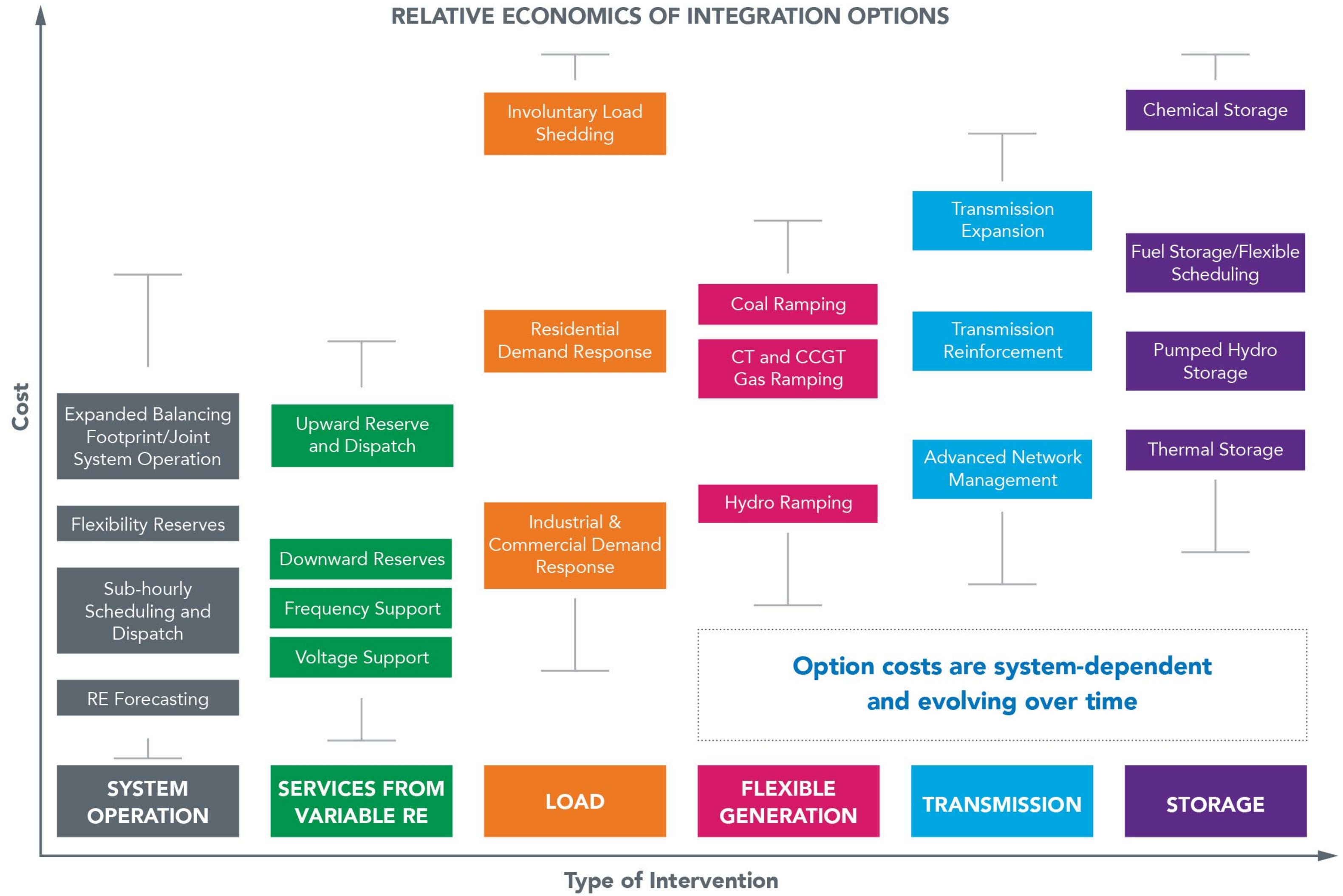
“Flexibility” Can Help Address the Grid Integration Challenges

***Flexibility**: The ability of a power system to respond to change in demand and supply*

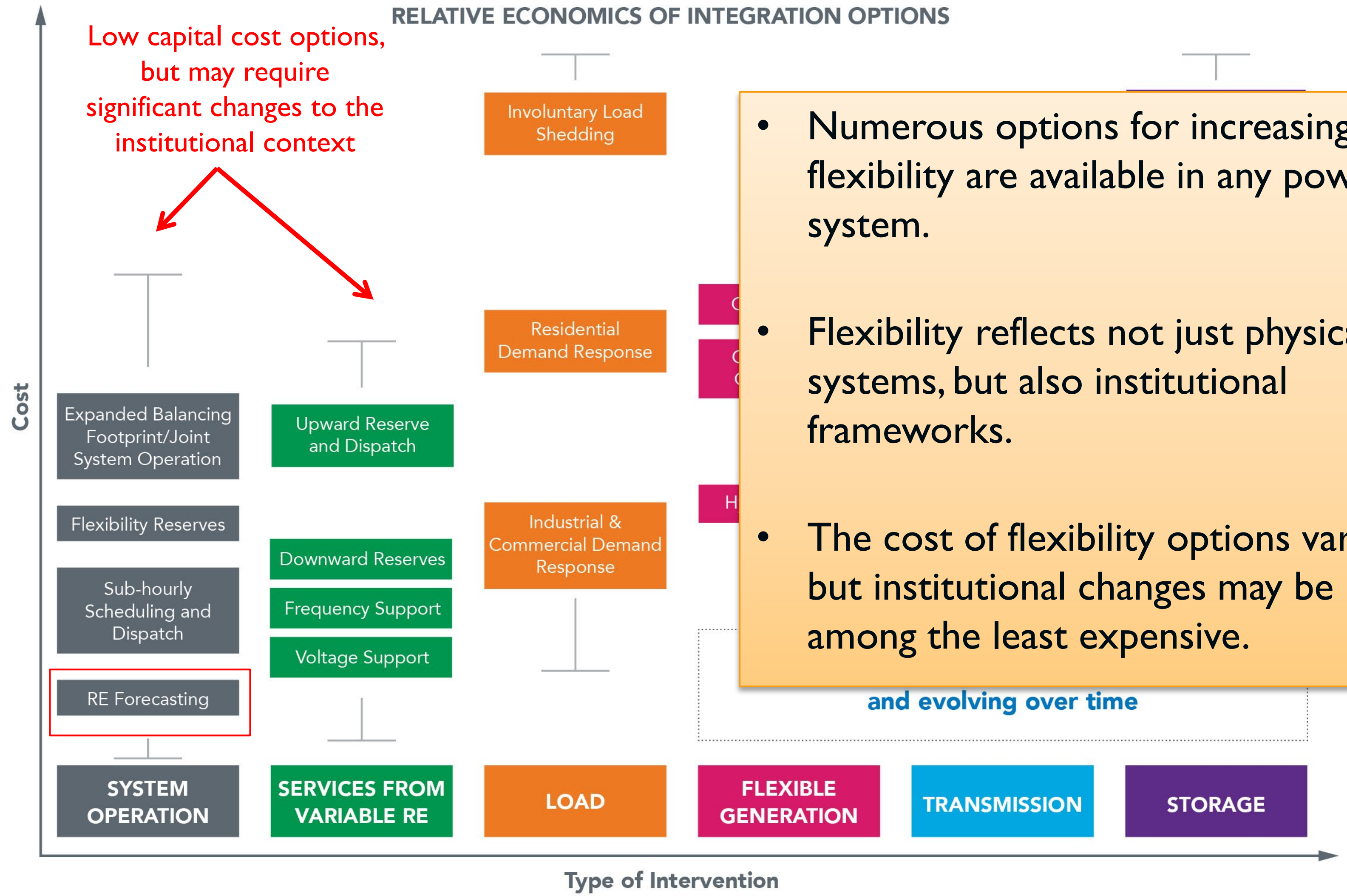


- Increases in variable generation on a system increase the variability of the ‘net load’
  - ‘Net load’ is the demand that must be supplied by conventional generation unless RE is deployed to provide flexibility
- High flexibility implies the system can respond quickly to changes in net load.

Frequently Used Options to Increase Flexibility

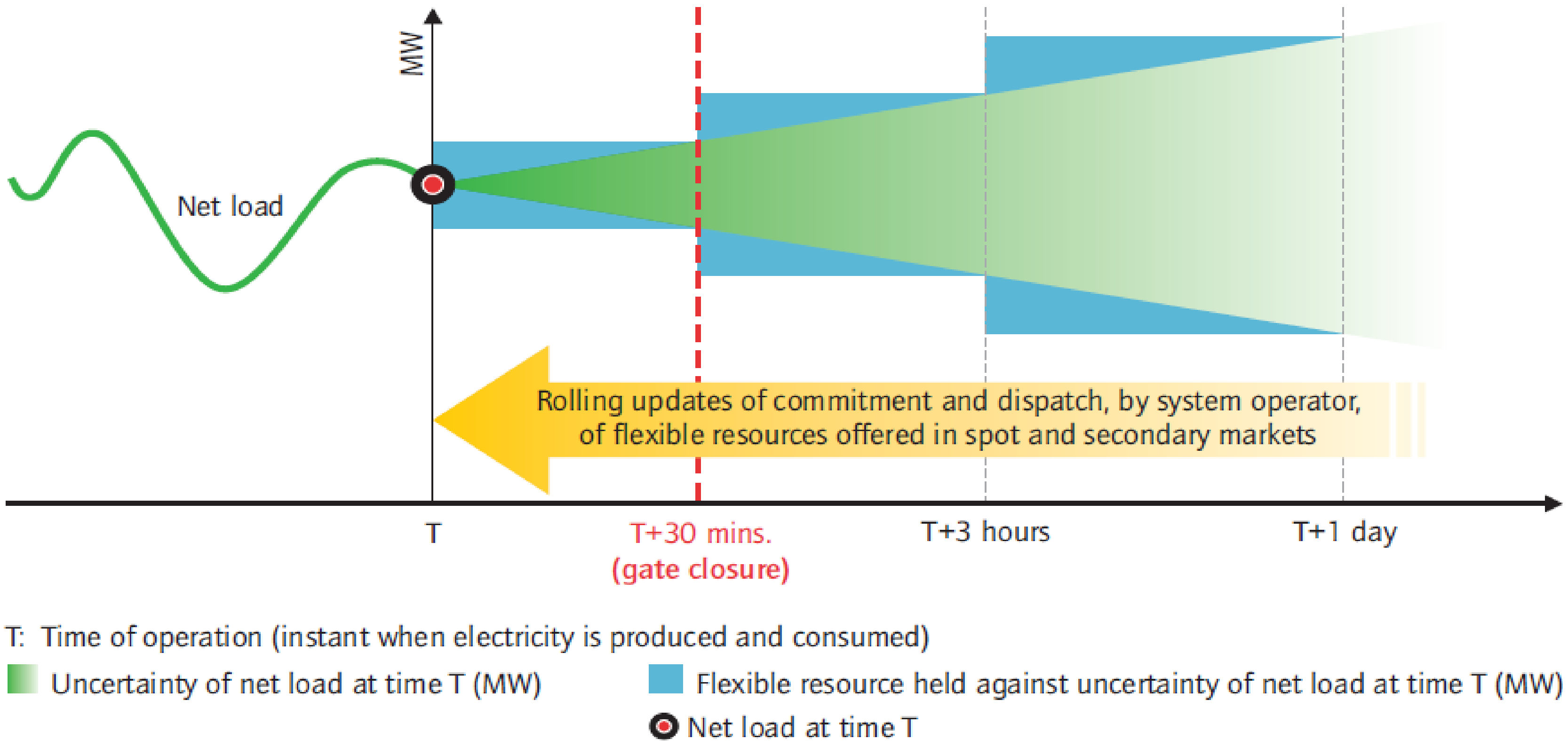


Frequently Used Options to Increase Flexibility



- Numerous options for increasing flexibility are available in any power system.
- Flexibility reflects not just physical systems, but also institutional frameworks.
- The cost of flexibility options varies, but institutional changes may be among the least expensive.

More Frequent Decisions Reduce Uncertainty

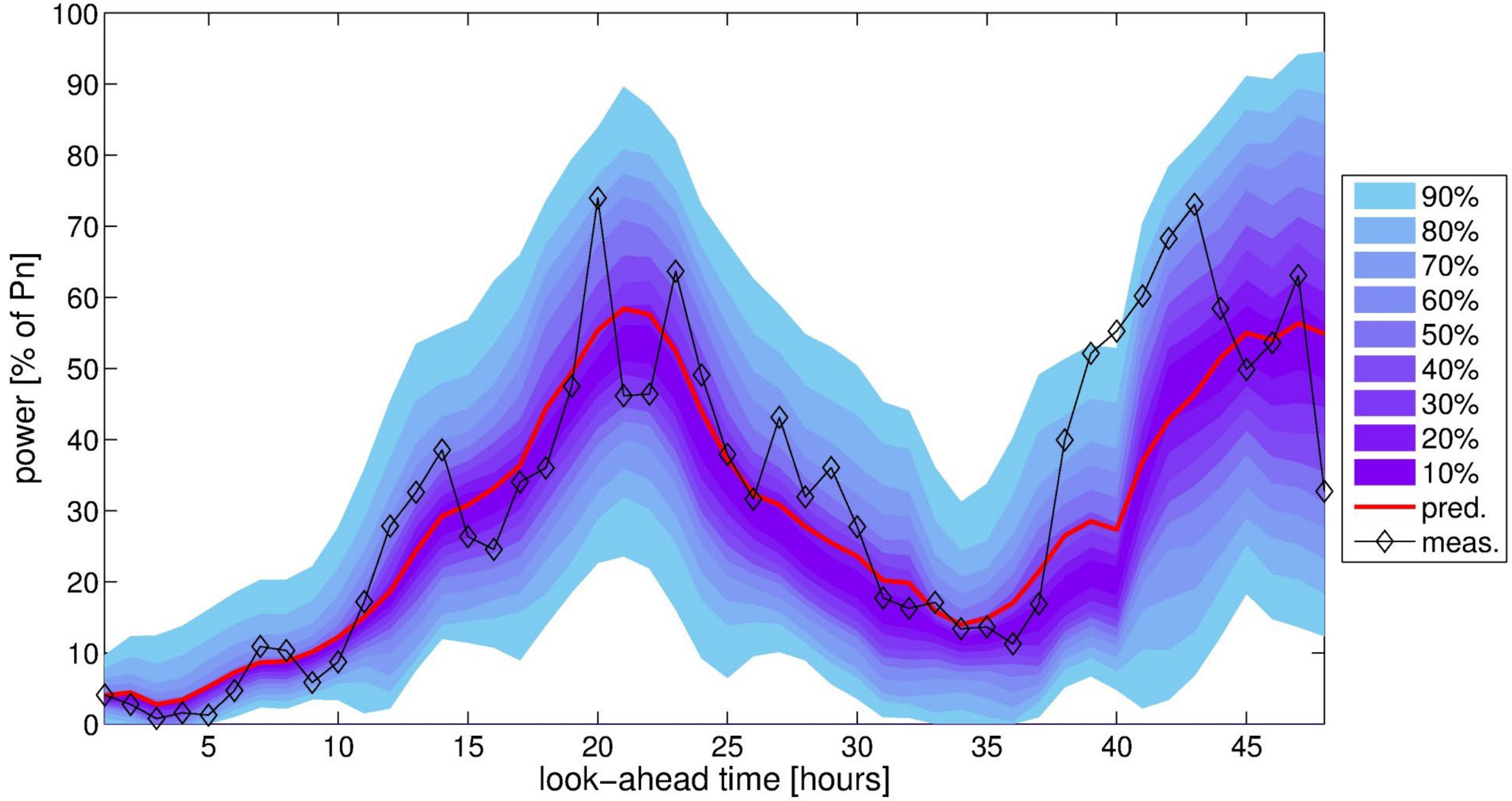


Givar_Fig24

Source: Harnessing Variable Renewables – A Guide to the Balancing Challenge, International Energy Agency, 2011

Why Is Forecasting Crucial to Integrating Variable RE to the Grid?

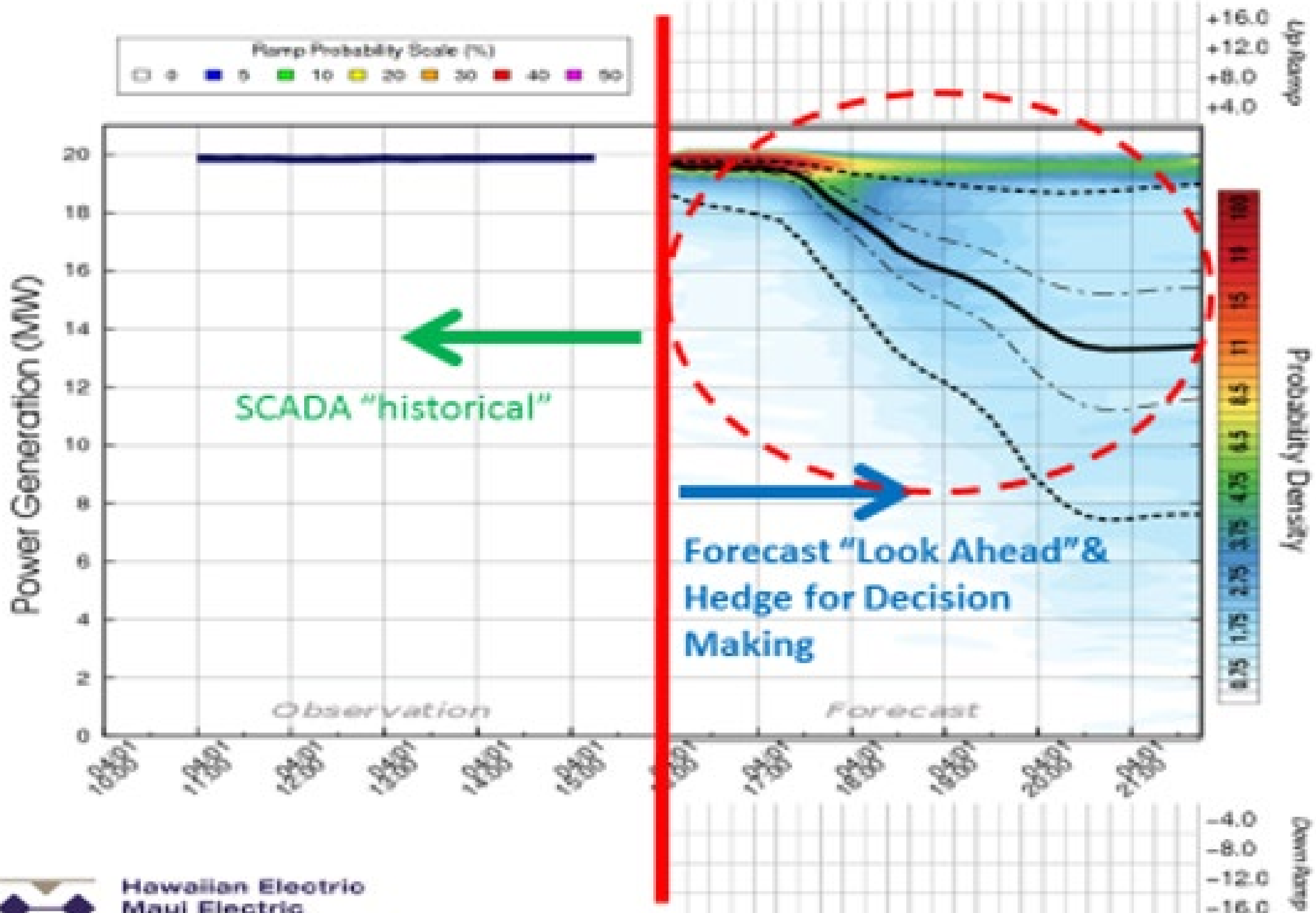
Operating with increased uncertainty…



Average day ahead error: 8%-10% for wind farm, 4% for system
Ramp error: Over 50% for large ramps

Source: Pierre Pinson, DTU, Denmark

Forecasting Can Provide Situational Awareness



Hawaiian Electric
Maui Electric
Hawai'i Electric Light

Source: "Building Operational Confidence in Using Probabilistic Wind and Solar Forecasts for Managing Variable Renewables", A. Brightbill, AWEA Windpower 2014

What Services Can a Forecast Provide?

- Economic benefits through:

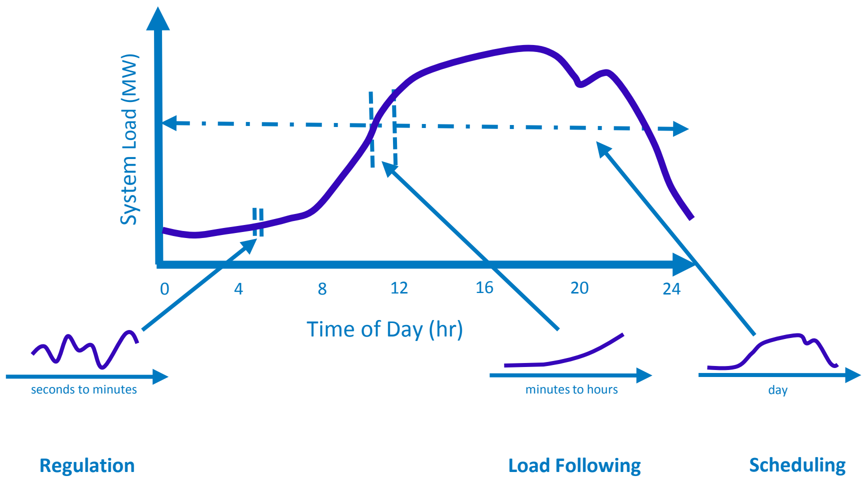
- Improved unit commitment
  - Day-ahead forecasts for most thermal units
  - 4-hour-ahead forecasts for combined cycle natural gas plants

- Reduced re-dispatch costs
  - Less “mileage” on operating units
  - Less starting of gas turbines and other fast acting units

- Reduced reserve levels
  - Regulation reserve
  - Flexible/load following reserve

- Decreased curtailment of RE generation

- Potentially impacting all timescales:



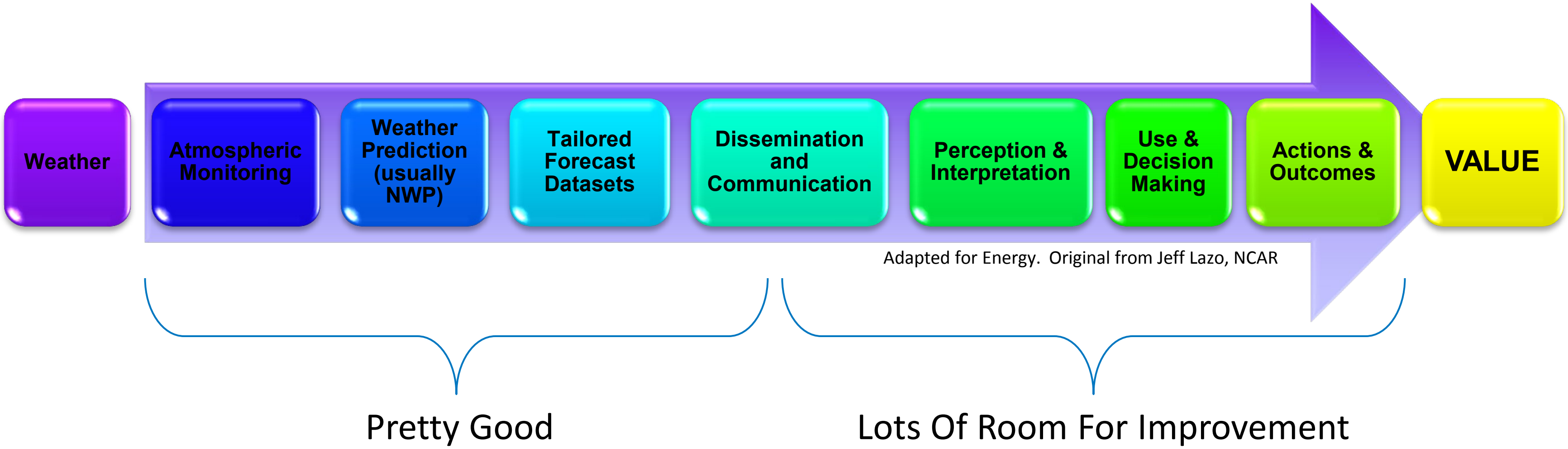
How Are Wind and Forecasts Used in System Operations? Examples from the United States

Balancing Authority	Type of variable RE forecasted	Forward Unit Commitment (Day-ahead, week-ahead, etc.)	Intra-day Unit Commitment	Transmission Congestion Management	Reserves	Management of Hydro or Gas Storage	Generation/ Transmission Outage Planning
Alberta Electric System Operator	Wind		X		X		
Arizona Public Service	Wind	X	X			X	
Bonneville Power Administration (BPA)	Wind			X	X	X	
California Independent System Operator (CAISO)	Wind and solar		X				
Glacier Wind	Wind				X		X
Idaho Power	Wind	X	X		X	X	
Northwestern Energy	Wind	X	X		X		
Sacramento Municipal Utility District*	Solar		X				
Southern California Edison*	Wind* and solar		X	X		X**	
Turlock***	Wind						
Xcel Energy	Wind and solar	X	X	X	X	X	

* *Also participants in the CAISO's Participating Intermittent Resource Program*
** *For hydro only, not natural gas*
*** *Uses forecast for trading, optimization, marketing, and compliance with BPA scheduling directives*

Source: Porter and Rogers, 2012. *Survey of Variable Generation Forecasting in the West.*

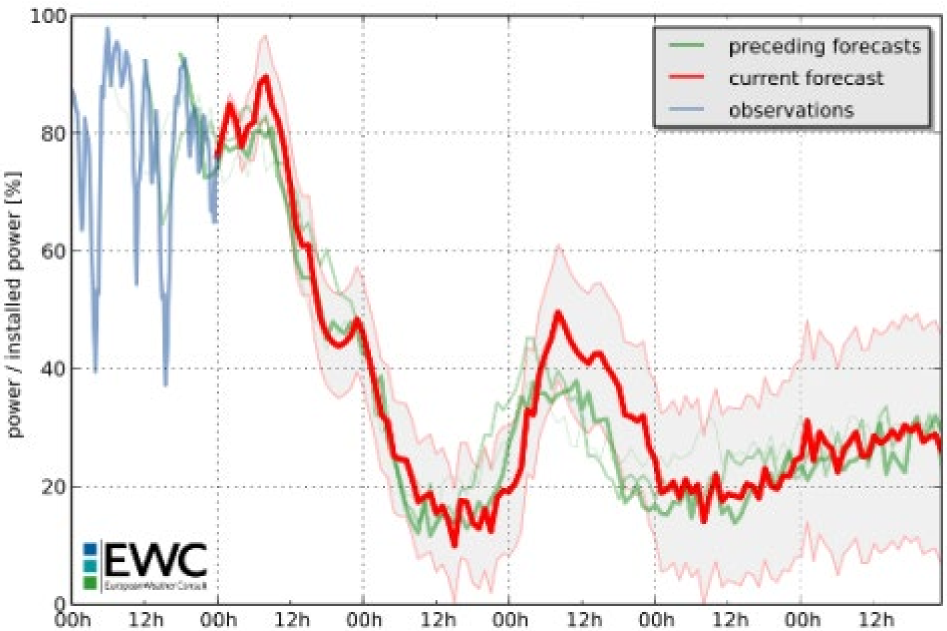
The Weather Forecast Value Chain



- Variable RE and load forecasts provide enormous return on investment
- But value chain is not being fully utilized, especially for variable RE
- More value can be extracted if there is more focus on the elements to the right
  - *These convert data into actions and outcomes*

Why Are Forecast Errors Important?

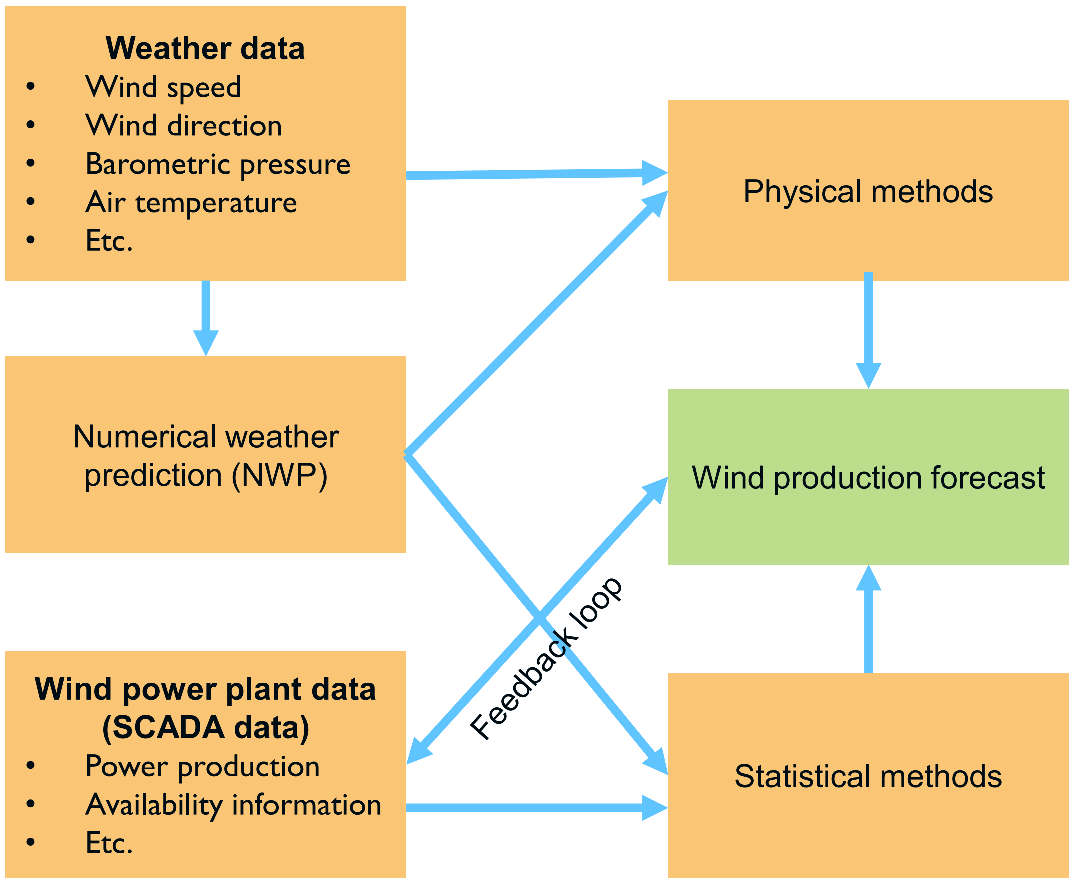
- **Forecast error** is the difference between predicted and real-time generation from VRE resources (MBE, MAE, RMSE)
- More accurate forecasts (i.e., lower forecast errors) lead to higher efficiency in the unit commitment and dispatch process
  - Reduced curtailment
  - Lower reserve requirements



Historic forecast errors are used to benchmark different forecasting methods

- Persistence forecasts
- Numerical Weather Prediction (NWP) models
- Statistical corrections (autoregressive, machine learning)
- Ensemble methods

Wind Forecast Data Requirements and Methods



Wind Forecasting Role in Market Operations

	Type of Forecast	Time Horizon	Key Applications	Methods
Generation	Intra-hour	5-60 min	Regulation, real-time dispatch market clearing	Statistical, persistence.
	Short term	1-6 hours ahead	Scheduling, load-following, congestion management	Blend of statistical and NWP models
	Medium term	Day(s) ahead	Scheduling, reserve requirement, market trading, congestion management	Mainly NWP with corrections for systematic biases
	Long term	Week(s), Seasonal, 1 year or more ahead	Resource planning, contingency analysis, maintenance planning, operation management	Climatological forecasts, NWP
Decision support	Ramp forecasting	Continuous	Situational awareness, Curtailment	NWP and statistical
	Load forecasting	Day ahead, hour-ahead, intra-hour	Congestion management, demand side management	Statistical

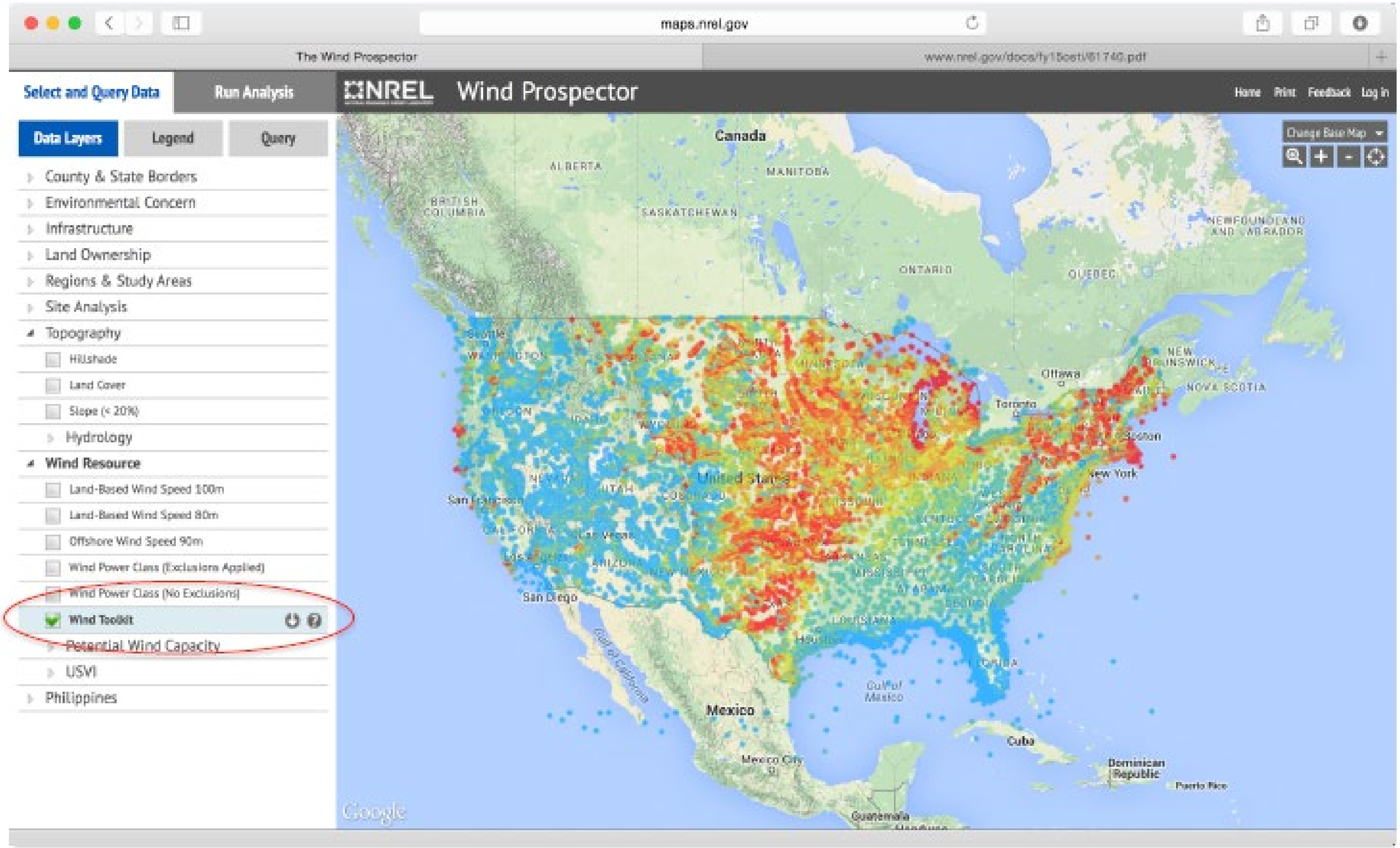
What Impacts the Magnitude of Forecast Errors?

Forecast errors are affected by the forecast time-horizon, local geographic conditions, geographic diversity and data quality

- Forecasts become less accurate for longer look-ahead time horizons
- Local conditions affect RE forecasts differently
  - **Wind**: Hills and trees reshape wind speeds and directions
    - – Complex topography increases wind forecast errors
  - **Solar:** Clouds cause variability and uncertainty in real-time solar irradiance
    - – Cloudless areas typically have lower forecast errors
- **Geographic diversity** of RE resources reduces errors
- **Data quality** can greatly improve forecast accuracy

WIND Toolkit

Data Access Via https://maps.nrel.gov/wind-prospector/



The WIND Toolkit is a grid integration dataset

RE integration datasets

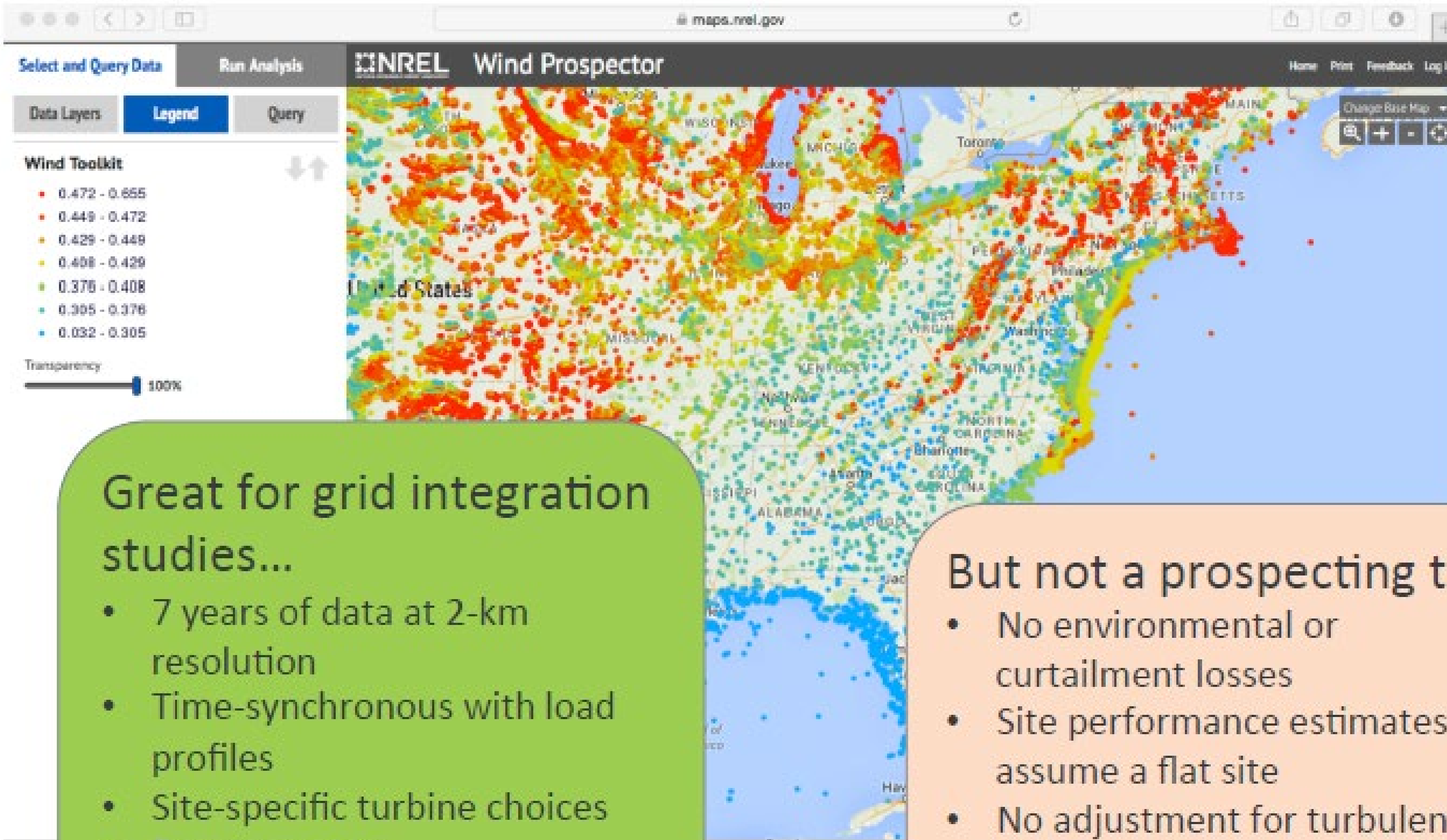
- High resolution (temporal and spatial)
- Long duration (multiple years)
- Realistic energy generation characteristics
- Generation data covering one or more Electric Reliability Council

What's new in the WIND Toolkit?

- Seamless in time and space
- Covers CONUS
- Uses WRF
- Validated against multiple data sources
- Site-specific WTG power curves
- Data are available online

The WIND Toolkit is a collaboration between NREL and 3Tier, run on supercomputers at Sandia and NREL, with input from a board of SMEs

Ways to use the WIND Toolkit data



Great for grid integration studies…

- 7 years of data at 2-km resolution
- Time-synchronous with load profiles
- Site-specific turbine choices
- Easy to access
- Can be duplicated and refined

But not a prospecting tool

- No environmental or curtailment losses
- Site performance estimates assume a flat site
- No adjustment for turbulence
- Wake model doesn't take into account turbine layout

Key Takeaways

- Wind and solar generation increase variability and uncertainty; however, actual operating experiences from around the world have shown up to 43% annual penetrations are possible.

- Forecasts, along with other complementary sources of flexibility, become increasingly important as wind and solar penetration increases in a system.

- Forecasting provides economic and other benefits to stakeholders across the power system.
    - At the system level, forecasts increase operational efficiency, reduce overall costs, and allow more renewable energy to be economically integrated.
    - At the plant level, forecasts increase the value of an owner's generation capacity and ensure that it is utilized to the greatest extent possible.

- The economic value of forecasting varies based on a variety of factors (including the extent to which forecast timeframes are aligned with system operation and market timeframes); however, improved forecasting is likely to benefit nearly all systems integrating wind and solar.

- There are a variety of approaches to and sources of forecasting. Regardless of approach, procuring a forecast is the most important first step!

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