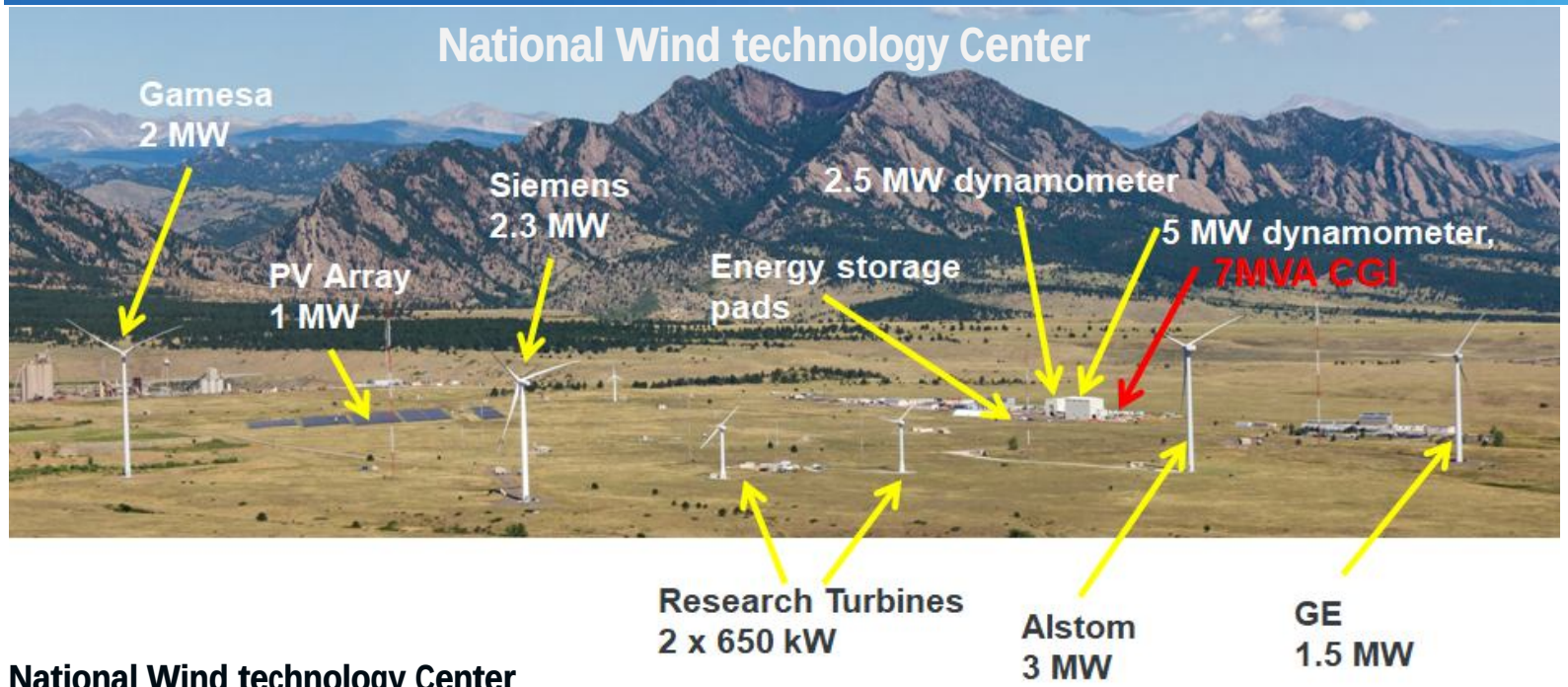
NREL
NATIONAL RENEWABLE ENERGY LABORATORY
40
1977 – 2017

Overview of Wind and Solar Power Forecasting

Vahan Gevorgian , NREL

Workshop on Current practices in Wind and Solar forecasting
January 22-23, 2018
Chennai, India

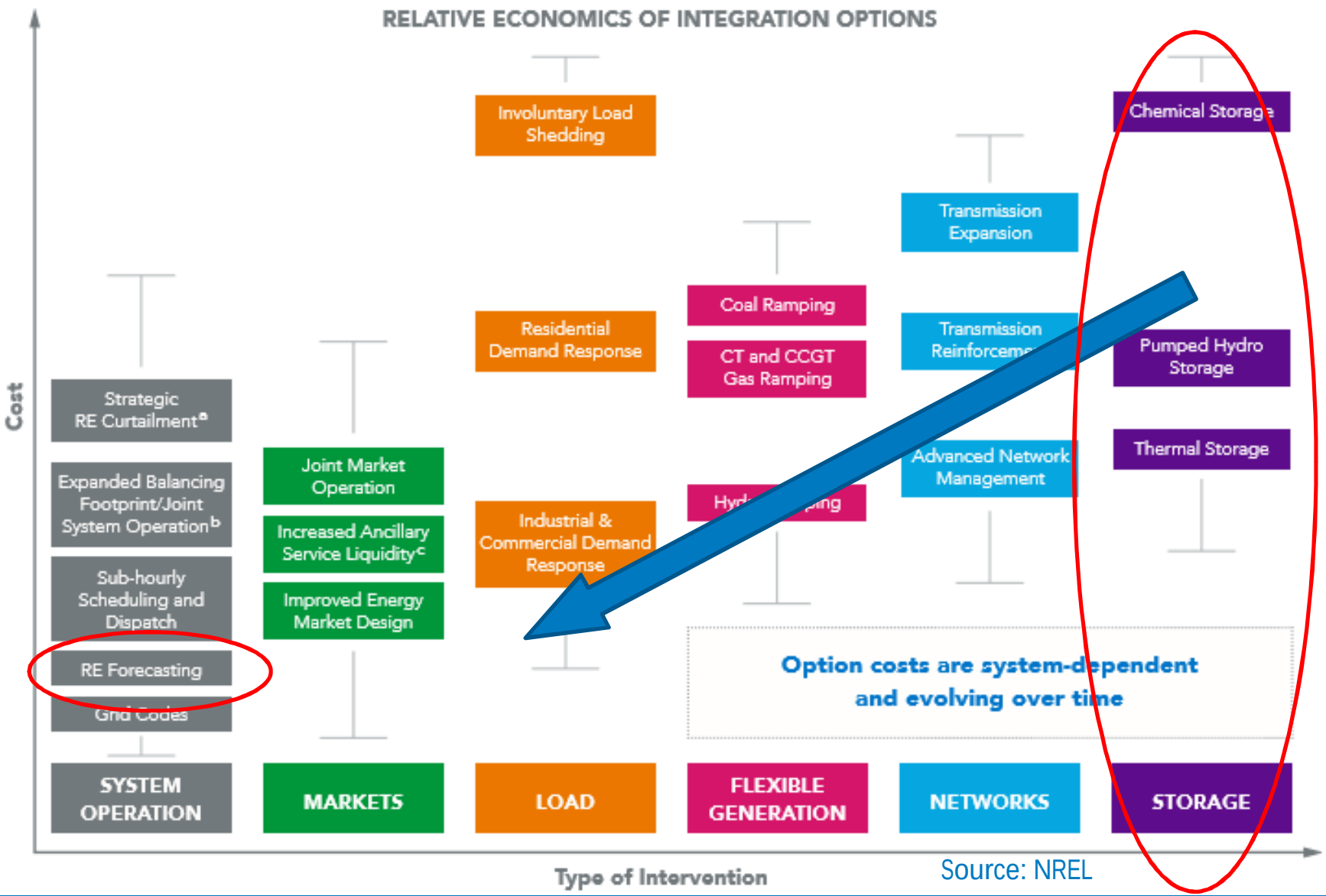
National Renewable Energy Laboratory (NREL)



National Wind technology Center

Main NREL Campus

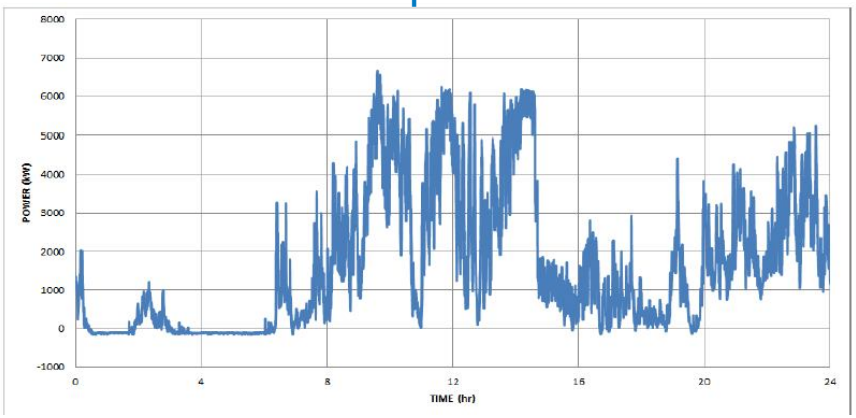
Changing Flexibility Resources Landscape



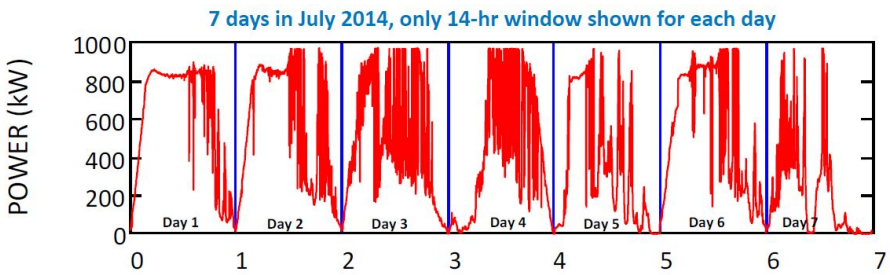
Source: NREL

Challenges of Forecasting Variable and Uncertain Generation

Wind power



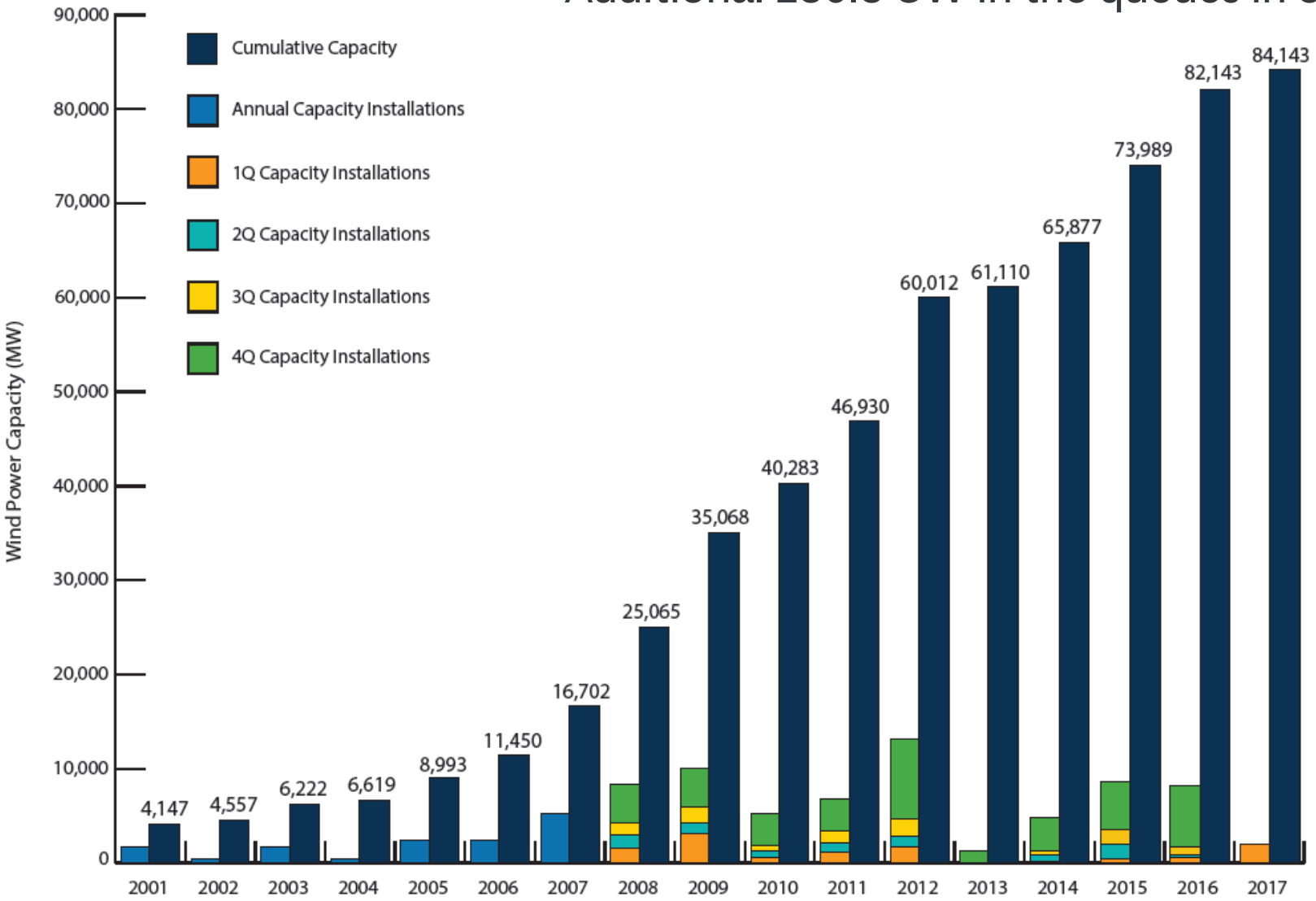
Solar PV Power



- How can wind and solar forecasting improve power system operation by reducing integration cost of renewables?
- How to produce reliable and accurate forecasts at different time horizons?
- How to integrate resource forecasting system into power system operation and decision making?

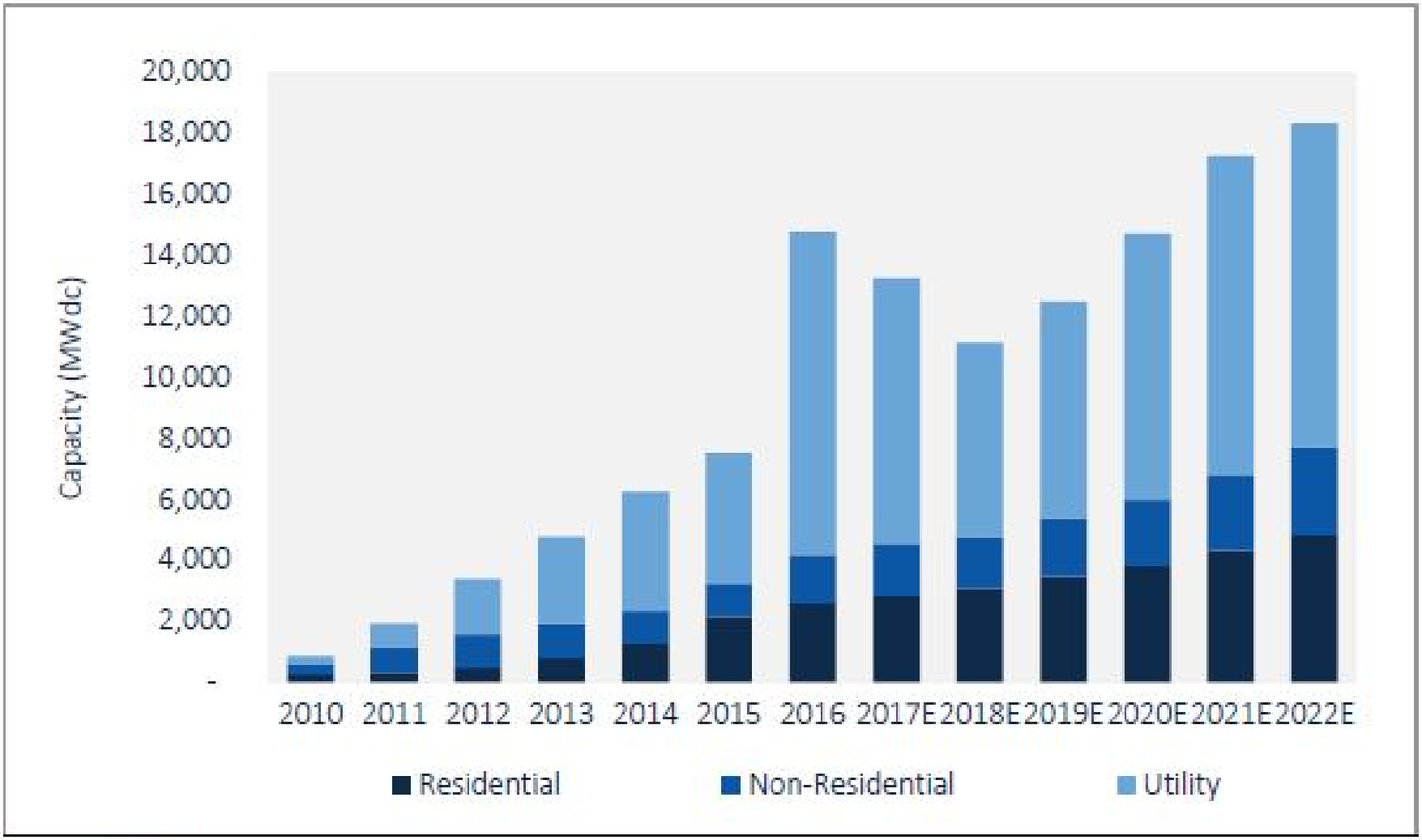
U.S. Annual and Cumulative Wind Power Capacity Growth

Additional 136.8 GW in the queues in 5 years



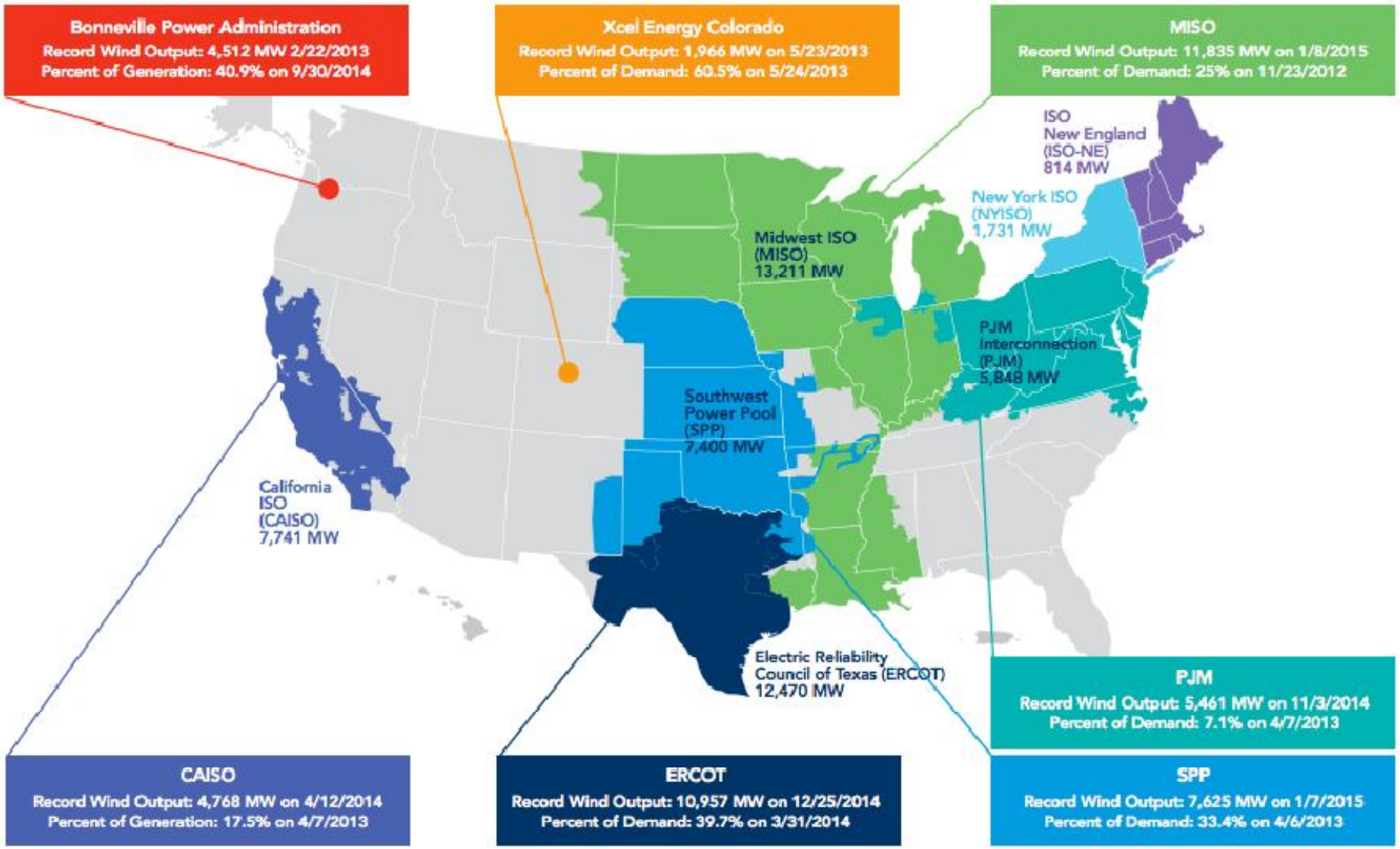
American Wind Energy Association | U.S. Wind Industry First Quarter 2017 Market Report | AWEA Public Version

U.S. PV Installation Forecast, 2010-2022



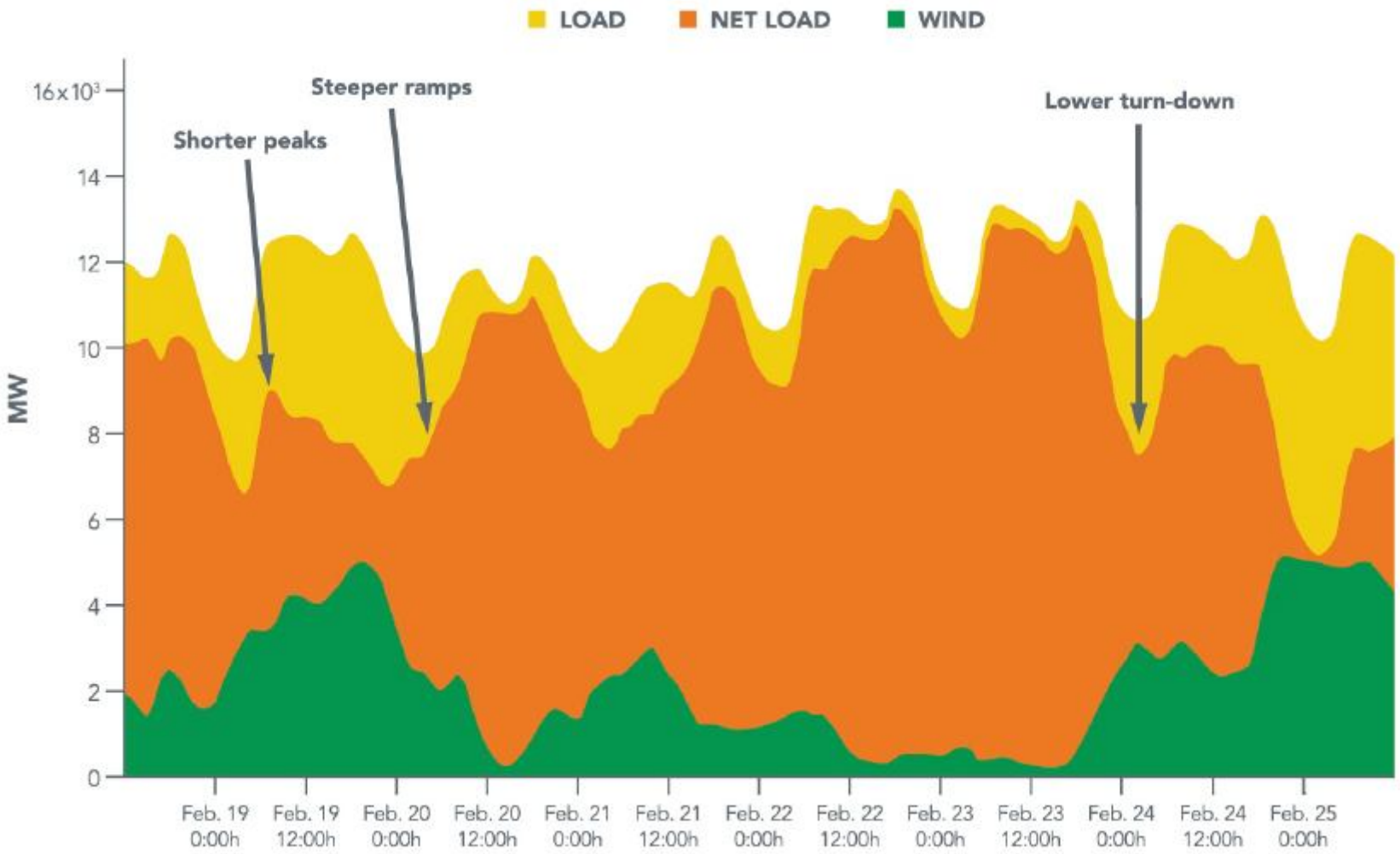
Source: GTM Research

U.S. Wind Installation and Generation by ISO



Source: AWEA

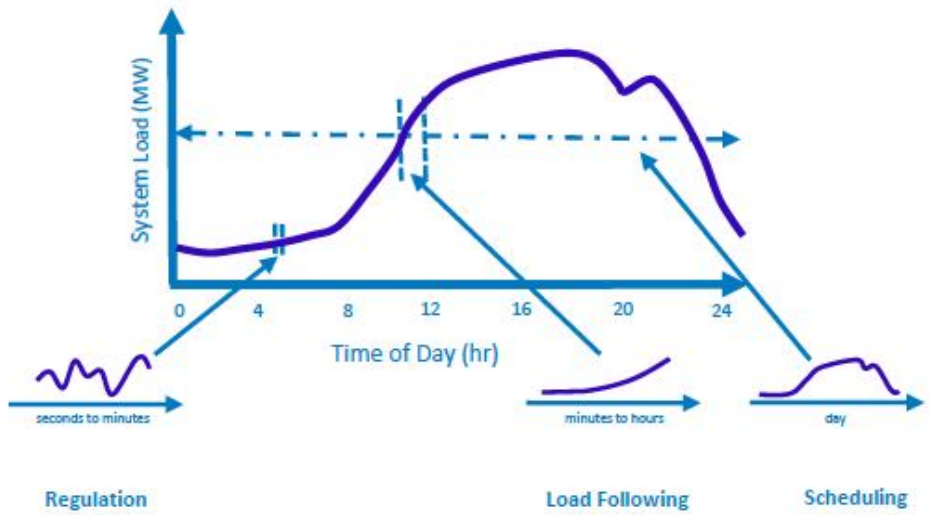
“Flexibility” Can Help Address the Grid Integration Challenges



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:



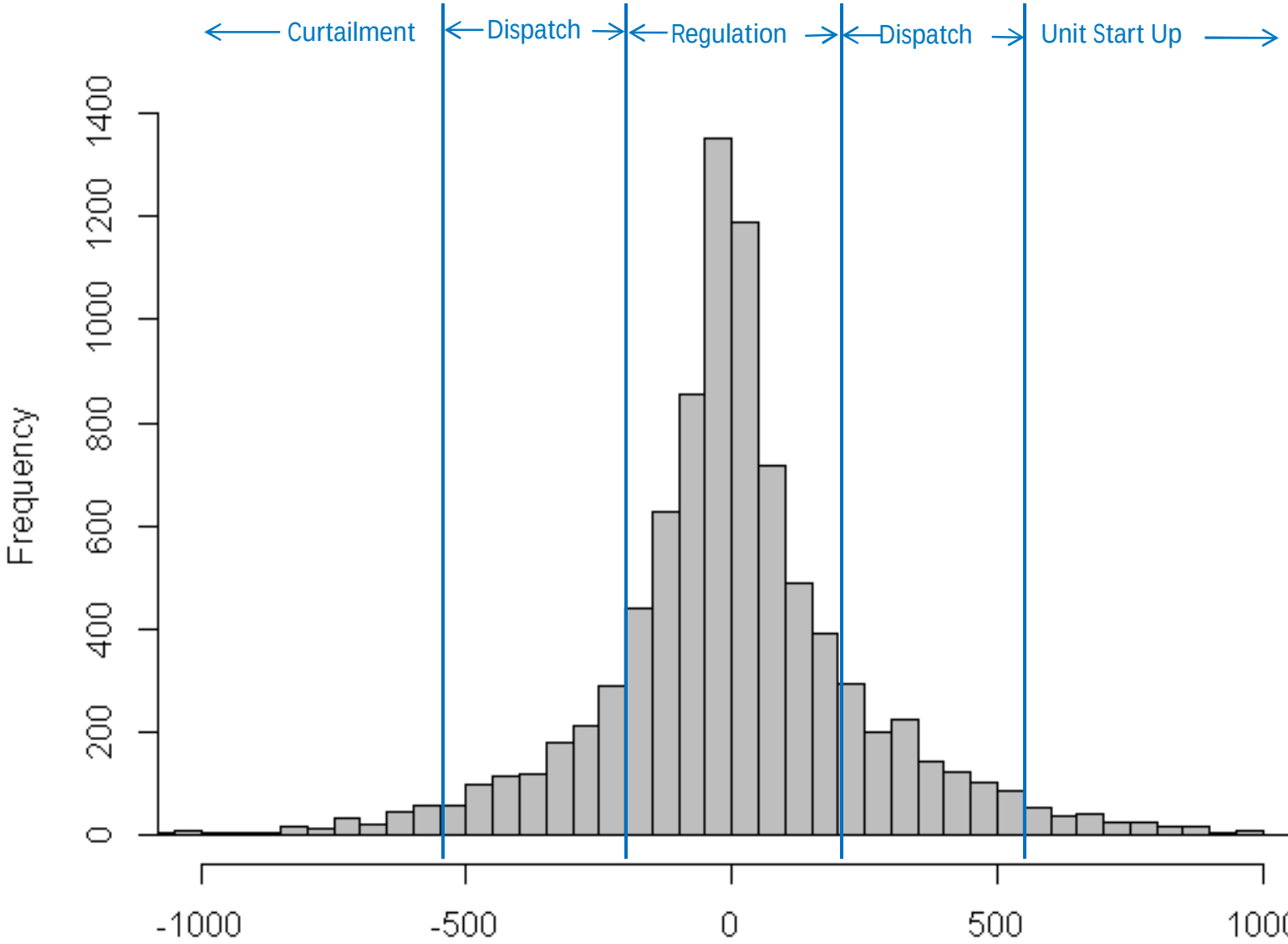
What Impacts the Magnitude of Forecast Errors

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

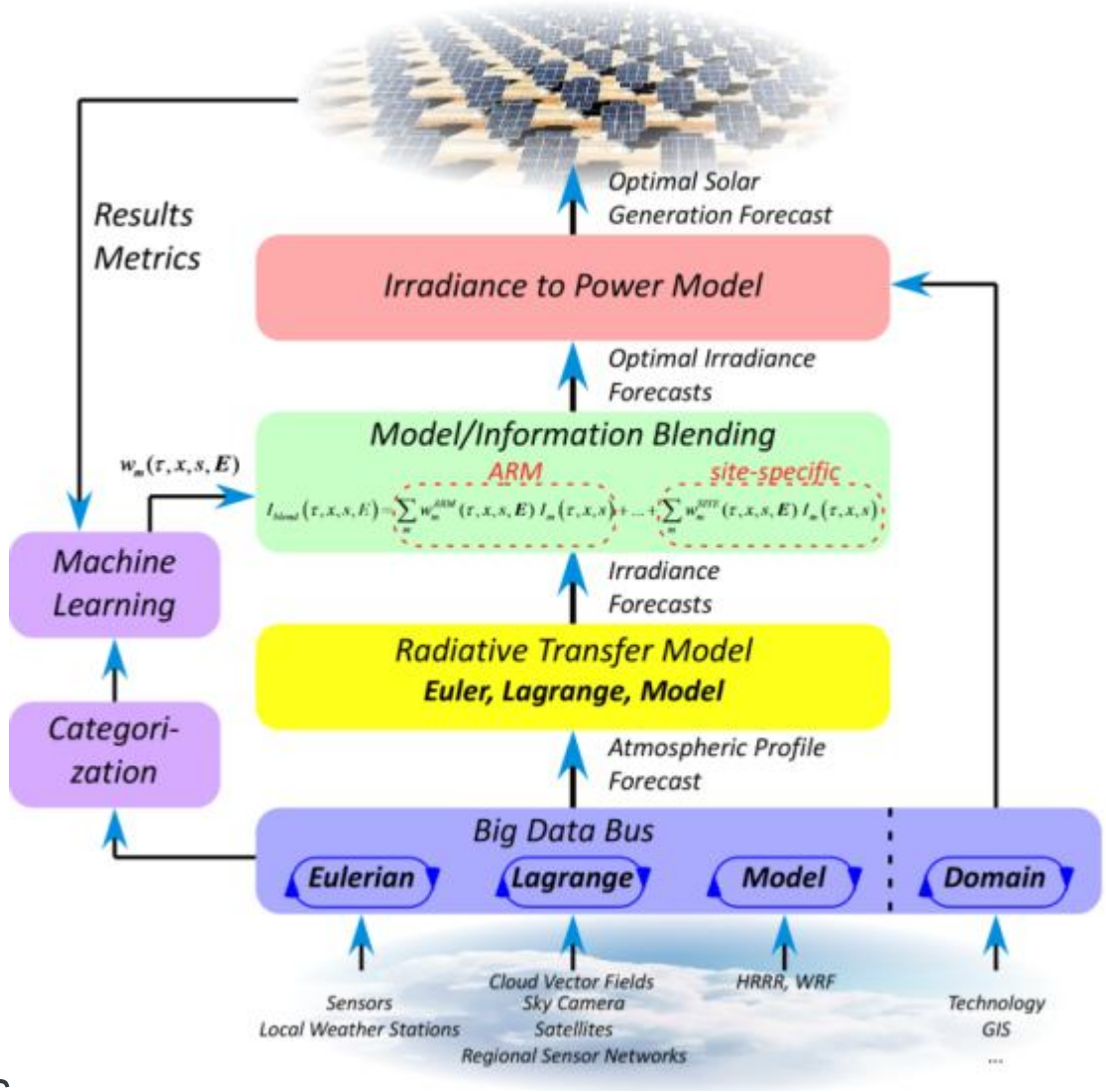
Courtesy B. O'Neill, NREL

Why are Forecast Errors Important?

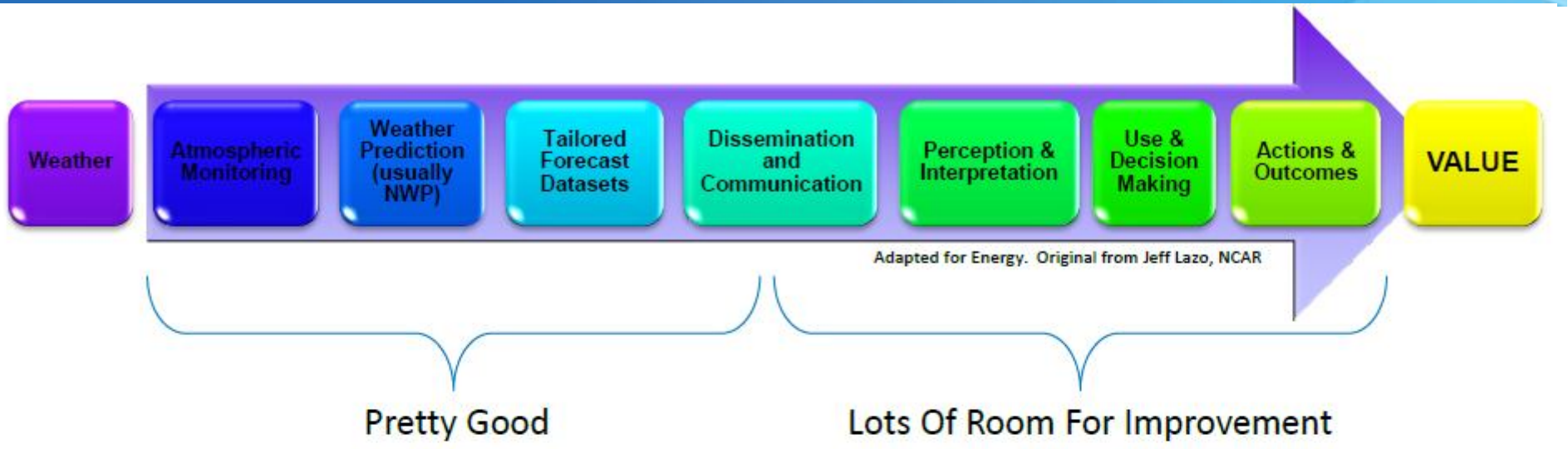


Solar Power Forecasting

- Solar forecasting is about 10 years behind wind forecasting
- Distributed solar power forecasting
- U.S. DOE Solar Forecasting Projects:
  - IBM Team
    - Machine Learning Approach
  - NCAR Team
    - Numerical Weather Prediction (NWP) and Satellite Improvements



Resource 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***

Courtesy B. O'Neill, NREL

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

Statistical methods include:

- Persistence
- Neural networks
- Dynamic neural networks
- Analog ensembles
- Spatial correlation

Courtesy B. O'Neill, NREL

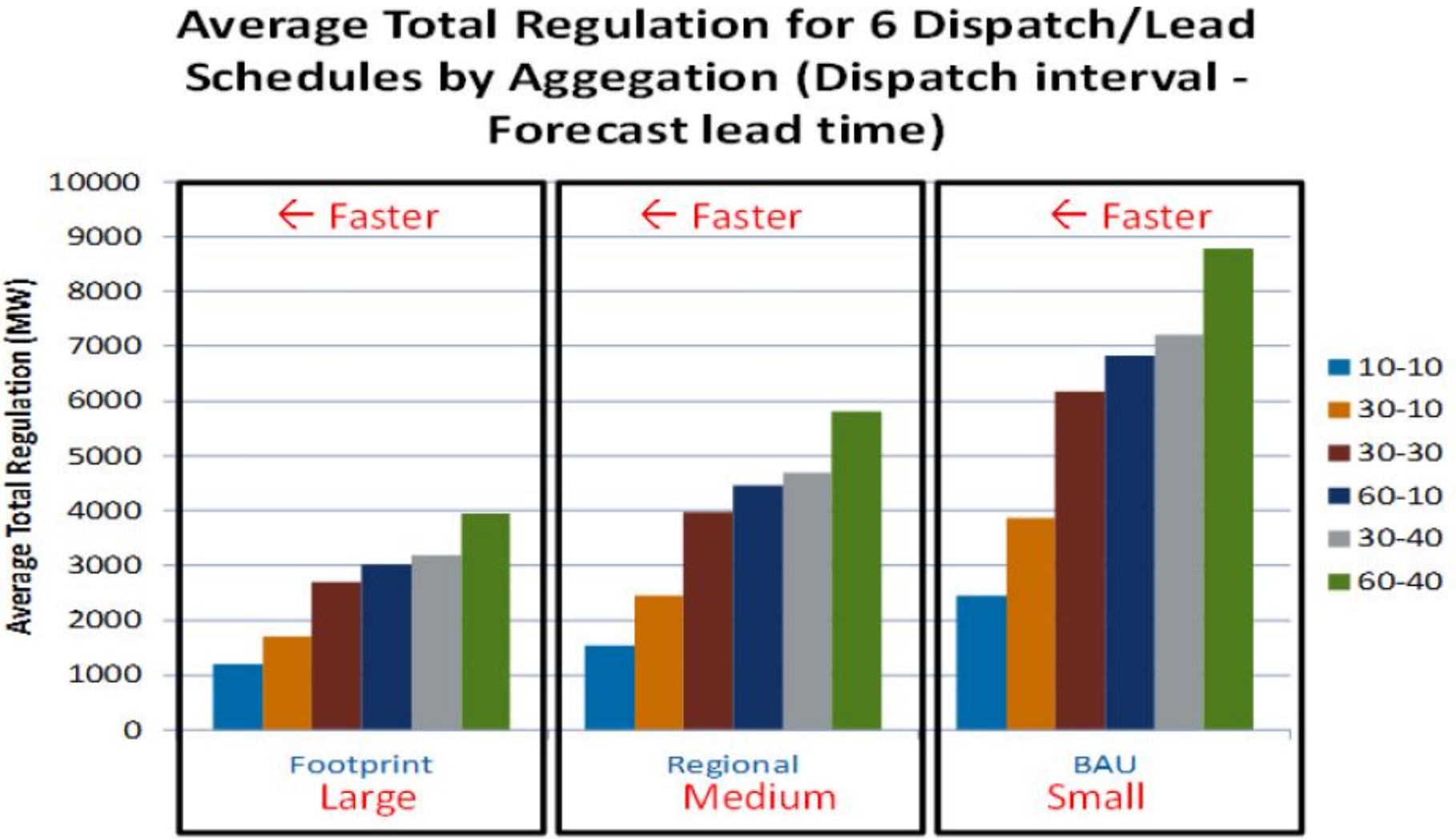
How are Wind and Solar Forecasts used in Operation?

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

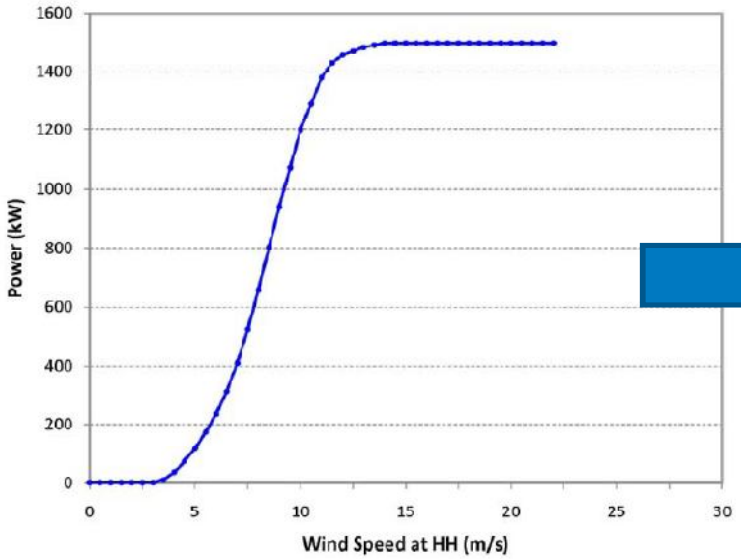
Faster Markets and Larger Footprints → Less Reserves



Courtesy M. Milligan, NREL

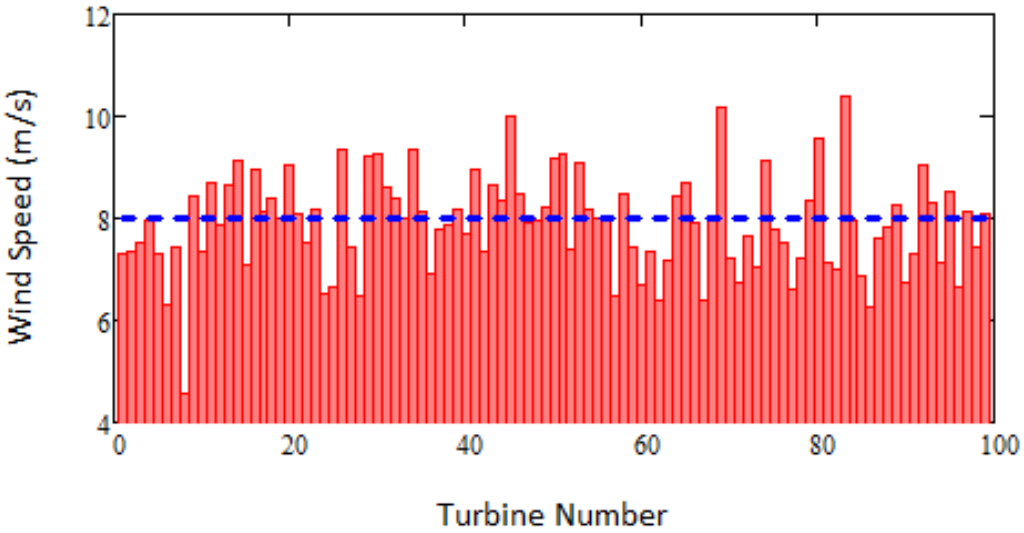
Equivalent Wind Plant Power Curve

Example of certified power curve for a single wind turbine generator



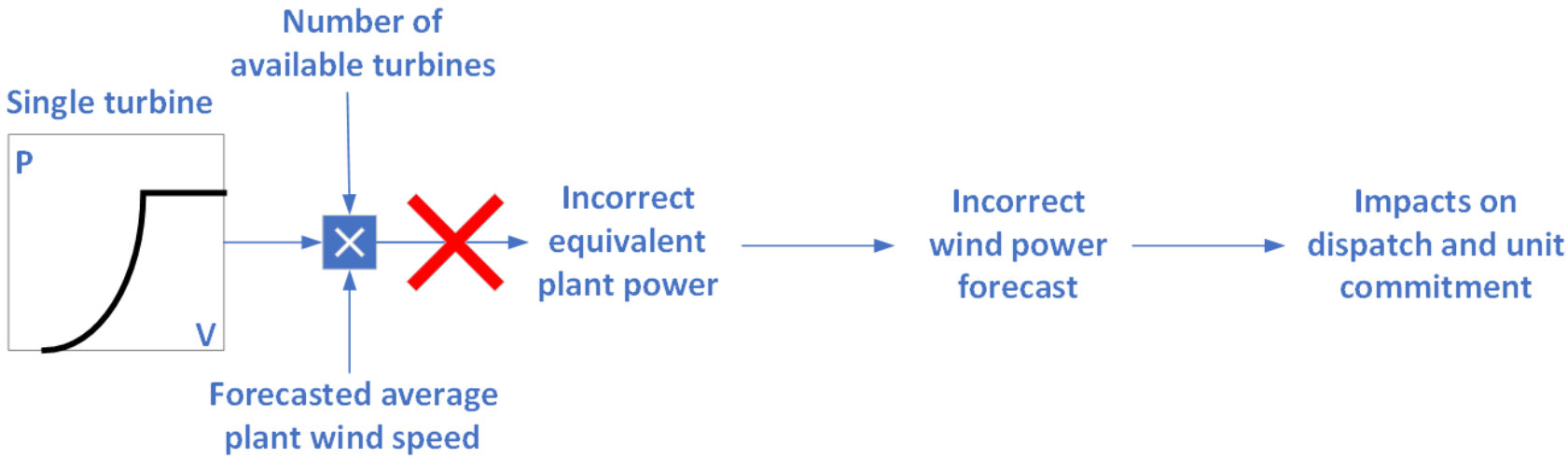
Accurate equivalent plant power curve is extremely important for calculating power output from wind speed forecasts

- Diversities of wind speeds exist in large wind power plats
- Many wind generators spread over plant footprint (sometimes at different elevation)
- Equivalent output of the plant is influenced by many parameters



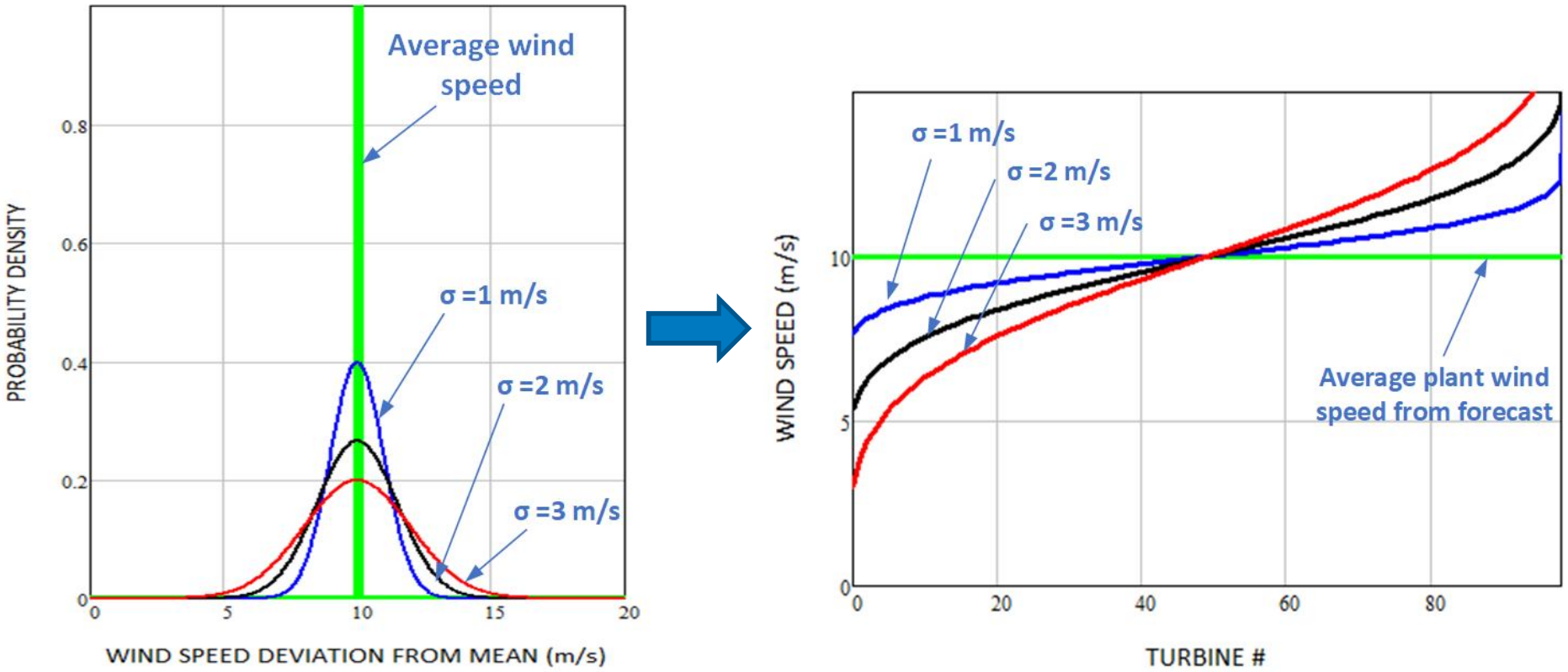
Incorrect Equivalencing Results in Power Forecast Errors

- No single wind speed can adequately represent the wind conditions across the entire wind plant
- Many wind speed values are required to characterize the plant operation.
- Depending on how the wind speed values are obtained, using them to characterize the plant operation can result in large uncertainty.



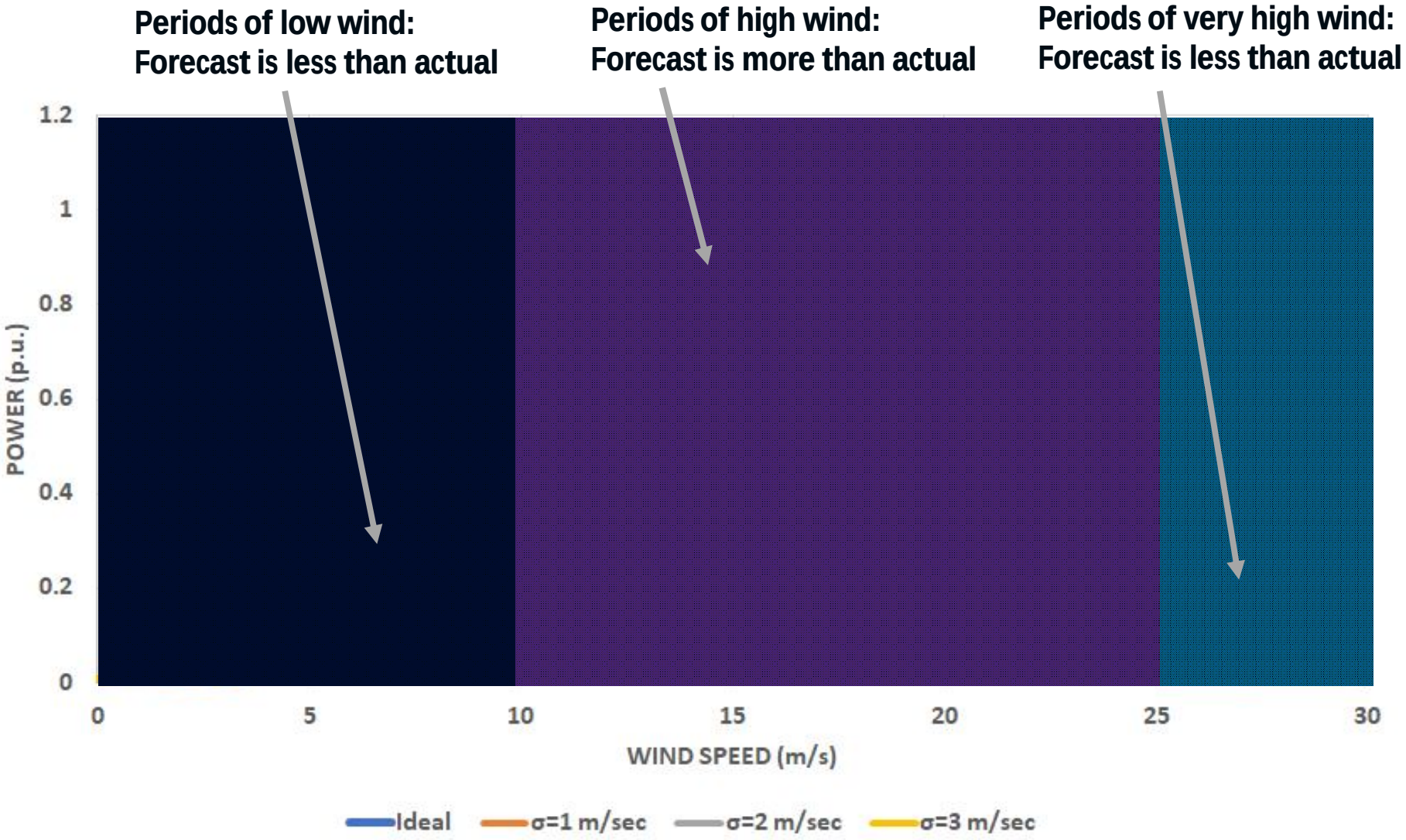
Example: 300 MW plant

- 100 x Vestas V90 3 MW wind turbines



Equivalent Wind Plant Power Curve

- Example – 300 MW plant, 100 x V903 MW wind turbines



Thank you!

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