Probabistic Forecasting in Renewable Energy

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AMS Renewable Energy Committee

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Outline

- Probabilistic Forecasting
  - What is it?
    - Terminology, Background, Examples
  - What is the state of the RE industry?
    - Are probability forecasts generated/used?
    - What efforts are underway for adoption? (e.g., Vaisala Webinar Excerpt)
  - What help is needed?
    - What does industry need from the other sectors?
    - How can this AMS committee contribute?

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Completing the Forecast

- "Uncertainty is a fundamental characteristic of weather prediction […] and no forecast is complete without a description of its uncertainty."

  Characterizing and Communicating Uncertainty for Better Decisions Using Weather and Climate Forecasts (NRC Report, 2006).

  - A probabilistic forecast gives a *probability* of an event occurring, with a value between 0 and 1 (or 0 and 100%).
  - Context (narrative) helpful to explain the sources of uncertainty and give reasons for them.
  - If not explicit, users will attach their own probabilities to a forecast using past experience as a general guide.

Probability Terminology

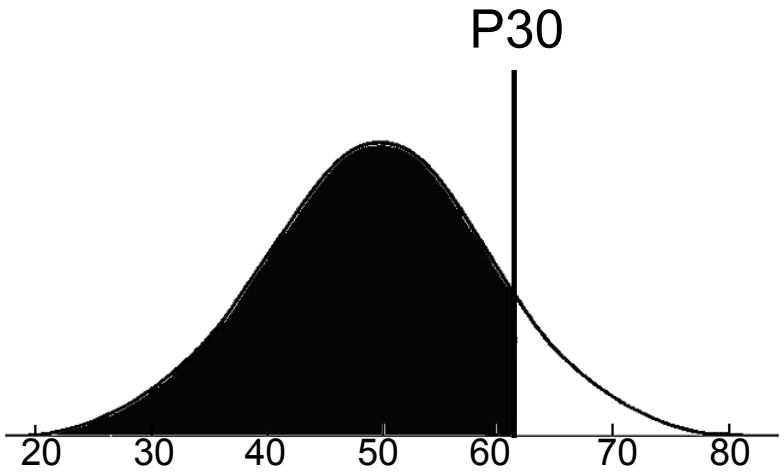
- Prediction Interval: An estimate of an interval in which future observations will fall, with a certain probability, given what has already been observed.

- Definitions:
  - Percentile = Quantile x 100%
    - 10^{th} percentile: the value at which the cumulative probability is 10%
    - 90^{th} percentile: the value at which the cumulative probability is 90%
  - Probability of Exceedance (PoE) = 1 – cumulative probability
    - P90 = 10^{th} percentile
    - P10 = 90^{th} percentile
  - Interval = Segment between two quantiles
    - 80% central prediction interval is the segment between the 10^{th} and 90^{th} percentiles (e.g., [P90, P10])

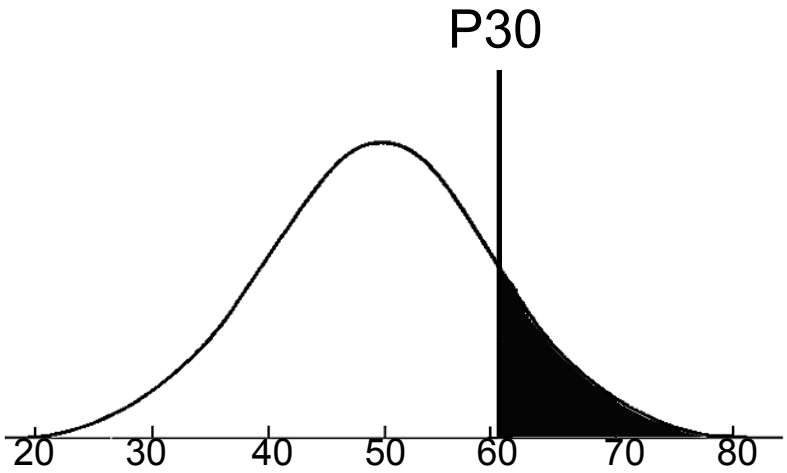
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Probability Forecast Example

There is a 7 in 10 chance that the observation will not exceed 62 MW.



There is a 3 in 10 chance that the observation will exceed 62 MW.



Decision Making Under Uncertainty

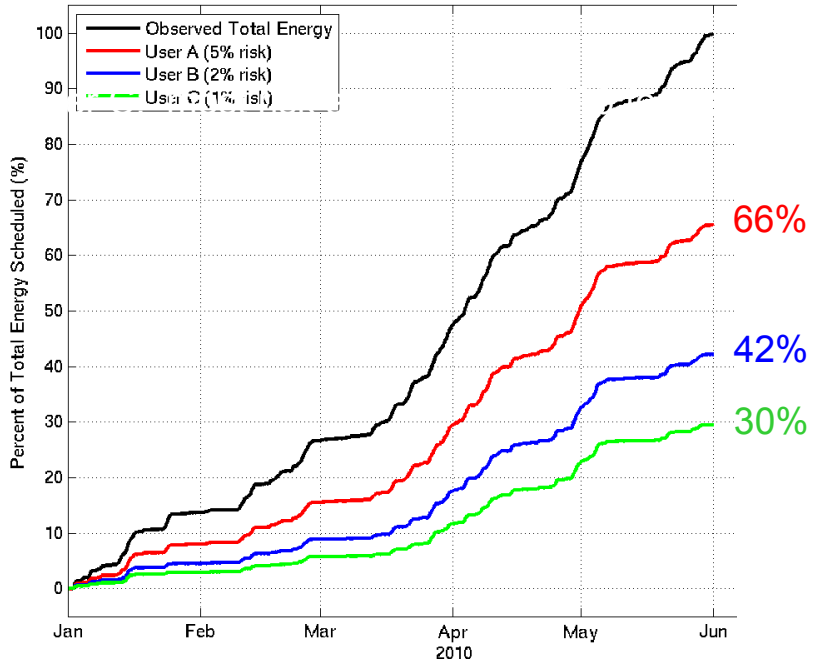
- Burden of decision making shifted to the user
  - A user is presented with too many scenarios and inaction ensues
  - Each decision has unique costs associated with a bad outcome; a user must know and quantify them in order to determine the optimal action
- Expect misinterpretation in communication
  - Use odds notation if possible (e.g., “1 in 10 chance”)
  - Cast in terms of risk management

Example: Hour-Ahead Firm Capacity Scheduling

User A: least risk averse, uses P95 forecast

User B: more risk averse, uses P98 forecast

User C: most risk averse, uses P99 forecast



1% increase in sch. energy > $2K / month *

*for a 100MW wind facility with a 30% c.f. and $10/MWh price premium

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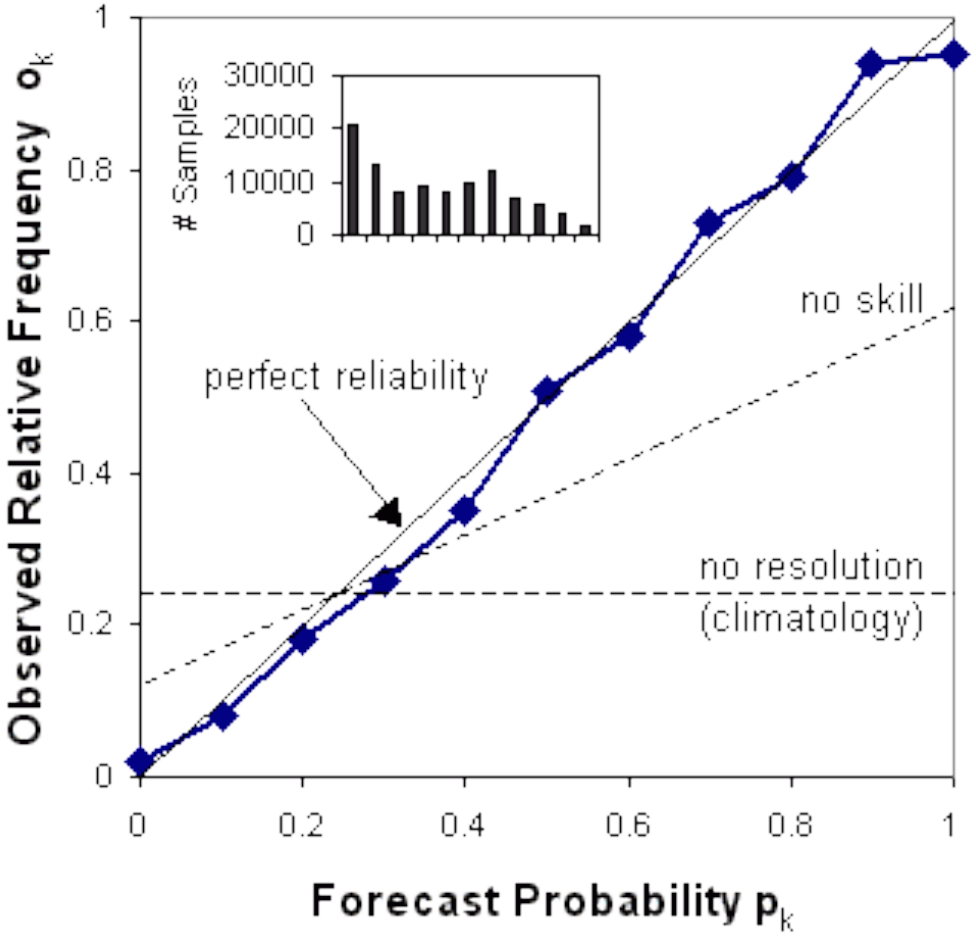
Probability Forecast Verification

- In general, it is difficult to verify a single probabilistic forecast. Instead, a large set of probabilistic forecasts, p_i, is verified using observations that those events either occurred (o_i=1) or did not occur (o_i=0).

- An accurate probability forecast system has:
  - *reliability / calibration* - agreement between forecast probability and the average observed relative frequency
  - *sharpness* - tendency to forecast probabilities near 0 or 1, as opposed to values clustered around the baseline frequency
  - *resolution / discrimination* - ability of the forecast to resolve the set of sample events into subsets with characteristically different outcomes

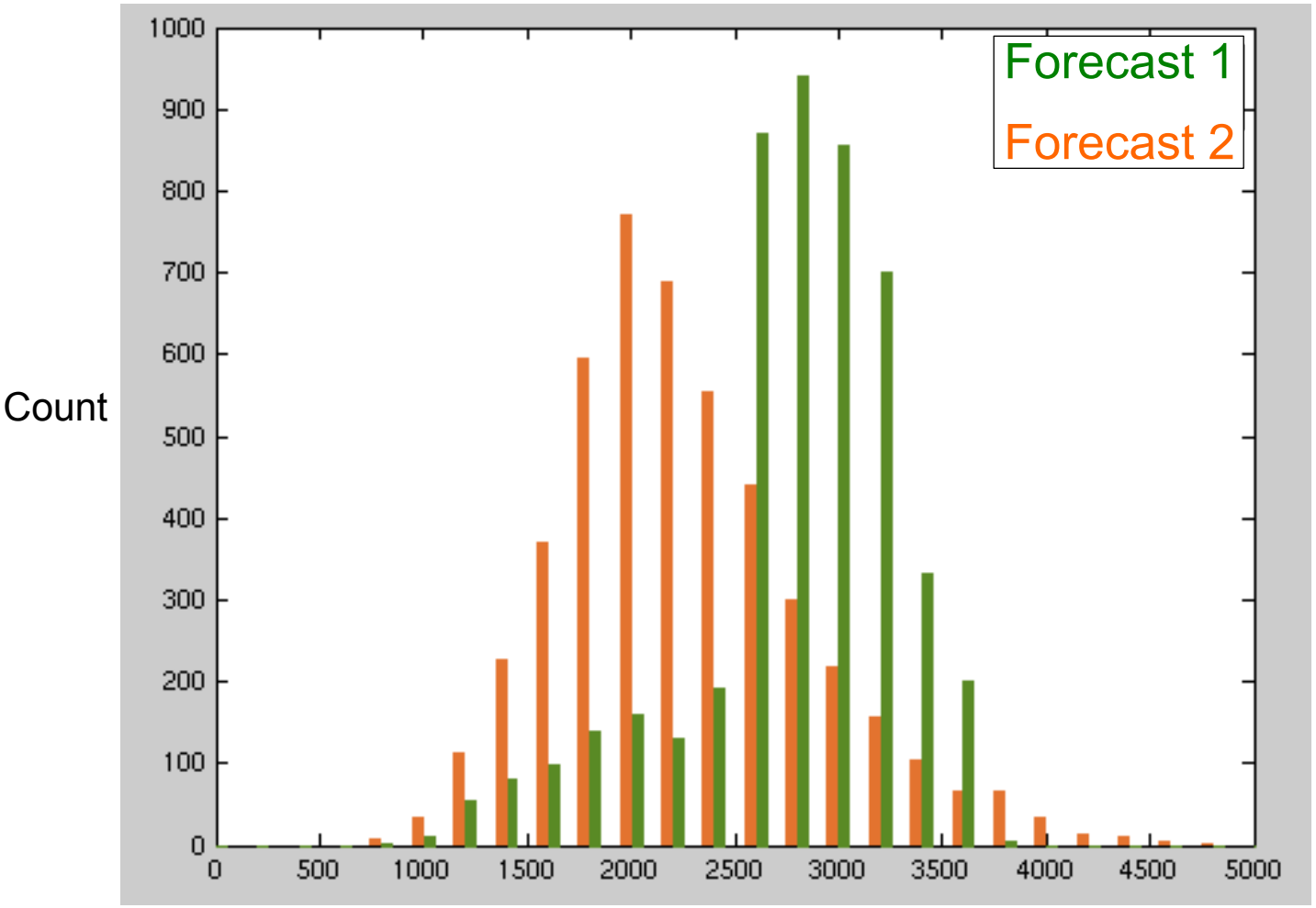
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Reliability Diagram



Variants: Rank Histogram, Probability Integral Transform (PIT) Histogram

Sharpness Histogram



State of the Industry

- Are probabilistic forecasts actively generated?
  - In most cases, yes:
    - forecast service providers have long produced percentiles (usually deciles)
    - other forms/formats (densities, scenarios) less common
    - verification is rare (which providers are calibrated? sharpest?)

- Are probabilistic forecasts actively used?
  - In most cases, no:
    - scheduling entity software often only handles one value for each period
    - deterministic (not stochastic) unit commitment algorithms at the ISOs
    - need transparent markets to incentivize it
  - In a handful of cases, yes:
    - optimizing day-ahead bidding strategy (price expectations)
    - dynamic capacity reserve allocation

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Efforts to Promote Adoption

- Policy
  - Market Rules and Transparency
    - Commentary on predictability of wind/solar, appropriate imbalance charges
    - Advocation for better discoverability of rules, charges, prices, etc.
  - Regulatory Mandates and ISO Practices
    - Commentary on reserve capacity allocation and unit planning/commitment
- Technology Proof of Concept
  - Stochastic UC demonstrations on ISO-size systems
    - Sandia / ISO-NE project under DOE
- Education
  - Conference and Workshop Sessions
    - UVIG Forecasting Workshop
  - Industry Journals and Magazines
    - see Grimit et al. in Jan/Feb 2015 issue of NA Clean Energy
  - Webinars and Interactive Customer Engagements

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Energy Forecasting to Maximize Use of Renewables

When to consider a probabilistic approach

Jeff Lerner, PhD
Manager of Forecast Operations, Vaisala

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Senior Scientist, Vaisala





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Excerpts from Vaisala Webinar: Thursday, January 29, 2015

Webinar Take Home Messages:

- Information contained within a wind power forecast is not fully utilized
- Understanding risk and uncertainty can facilitate the use of probabilistic forecasts
- Use of probabilistic forecasts may prove advantageous to bottom line of operating a wind plant
- Probabilistic forecasts aren't necessarily complicated, as will be shown in the application of a fixed exceedance probability

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Probabilistic Forecasts:
Description and contrast with deterministic forecast

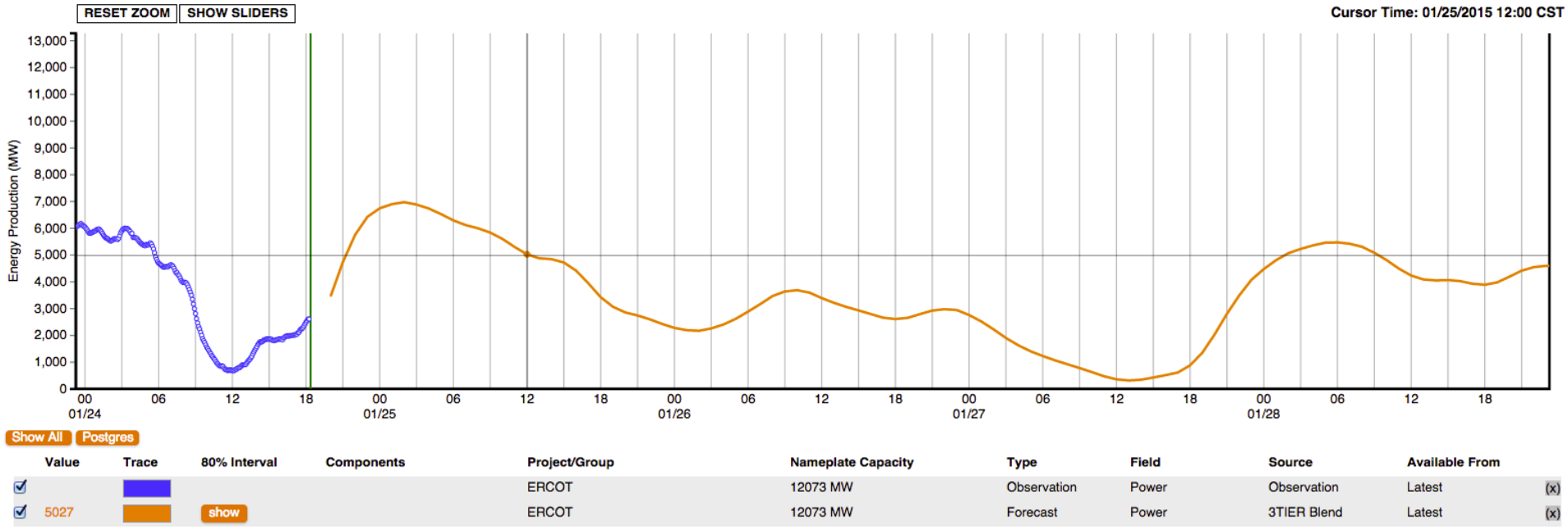
Probabilistic	Deterministic
Rain likely, 70% chance	Tomorrow's high temperature forecast is 48°F
Forecast is for 6–10 inches of snow	PJM's wind forecast is for 1500 MW at 7:00 a.m. tomorrow
There's a 58% likelihood of an El-Nino next year	My tax return will be $528
New England has a 56% probability to win the Super Bowl	Seahawks 24, Patriots 20

Probabilistic forecasts assign a likelihood to each of a number of potential outcomes

Deterministic forecasts are forecasts of a specific magnitude and time. They contain no information on the uncertainty.

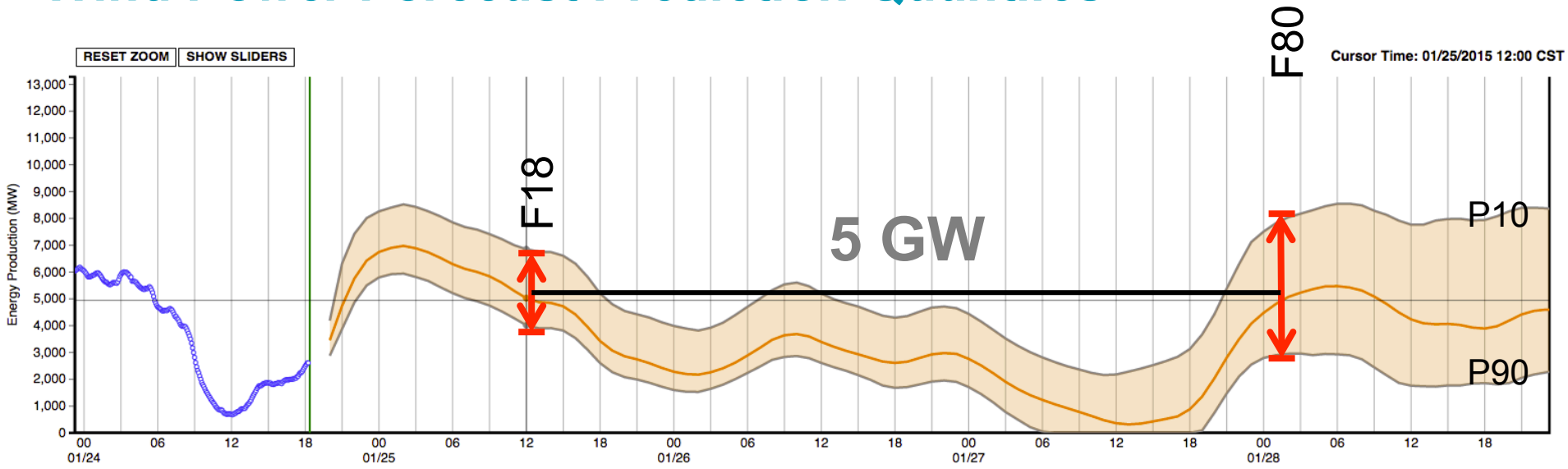
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Understanding risk and uncertainty:
Wind Power Forecast Prediction Quantiles



- Easy to interpret, but no context
- Uncertainty is not contained in this forecast

Understanding risk and uncertainty:
Wind Power Forecast Prediction Quantiles



Show All | Postgres

Value	Trace	80% Interval	Components	Project/Group	Nameplate Capacity	Type	Field	Source	Available From	
☑				ERCOT	12073 MW	Observation	Power	Observation	Latest	(x)
☑	5027		hide	ERCOT	12073 MW	Forecast	Power	3TIER Blend	Latest	(x)
☑	6849			ERCOT	12073 MW	Forecast	P10	3TIER Blend	Latest	(x)
☑	4014			ERCOT	12073 MW	Forecast	P90	3TIER Blend	Latest	(x)

18-hour: 2800 MW prediction interval; 80-hour: 5100 MW prediction interval.

Prediction Interval expresses the probability that the actual production will be observed in this band.

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Statement of the problem:
Common practices for scheduling wind power

- Passing through a deterministic forecast (from ISO or forecast provider)
- “Haircutting” (aka scaling) the deterministic
- Scheduling only what you can cover during high uncertainty periods (e.g., known reserve capacity)

These approaches may help reduce penalties, but lose sight of the “upside potential”

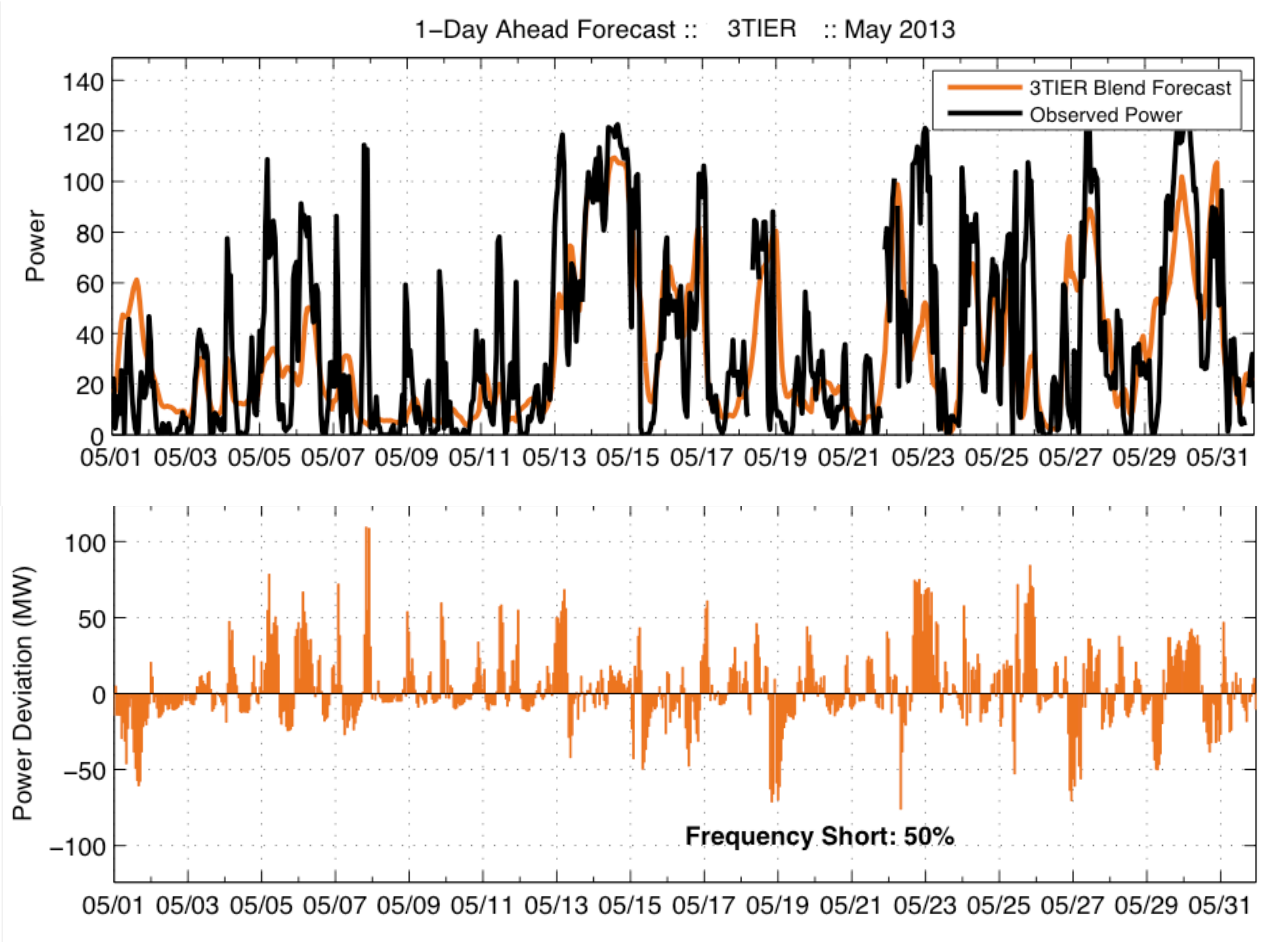
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Considerations From Energy Scheduler's Perspective

- Imbalance Charges
- Transmission:
  hub or node level congestion
- Day-Ahead minus Real-Time (DART) price spread
- Transmission Rights



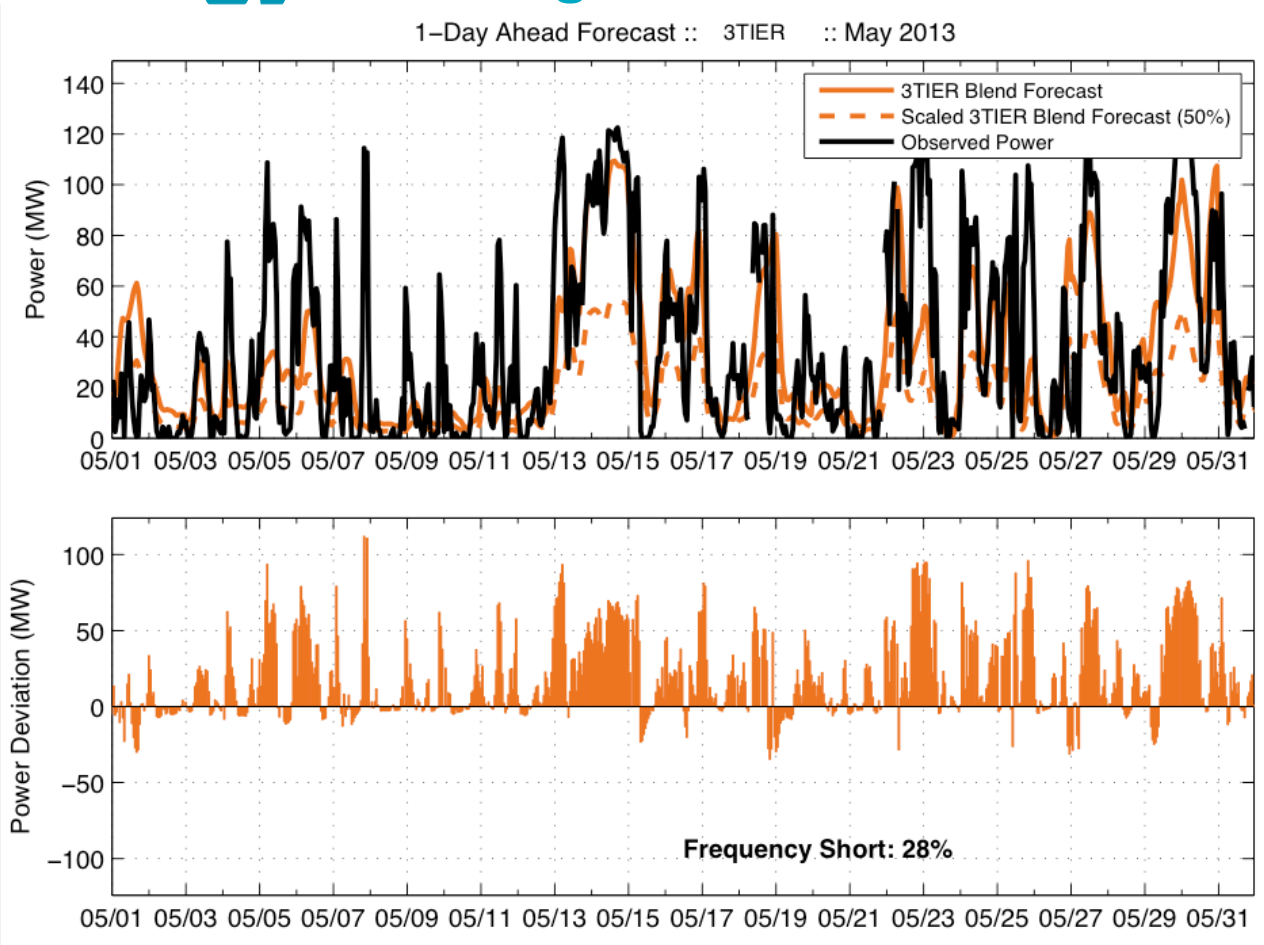
The Problem: *Downside Risk Exposure*



3TIER Blend minimizes bias and MAE; 50% downside risk

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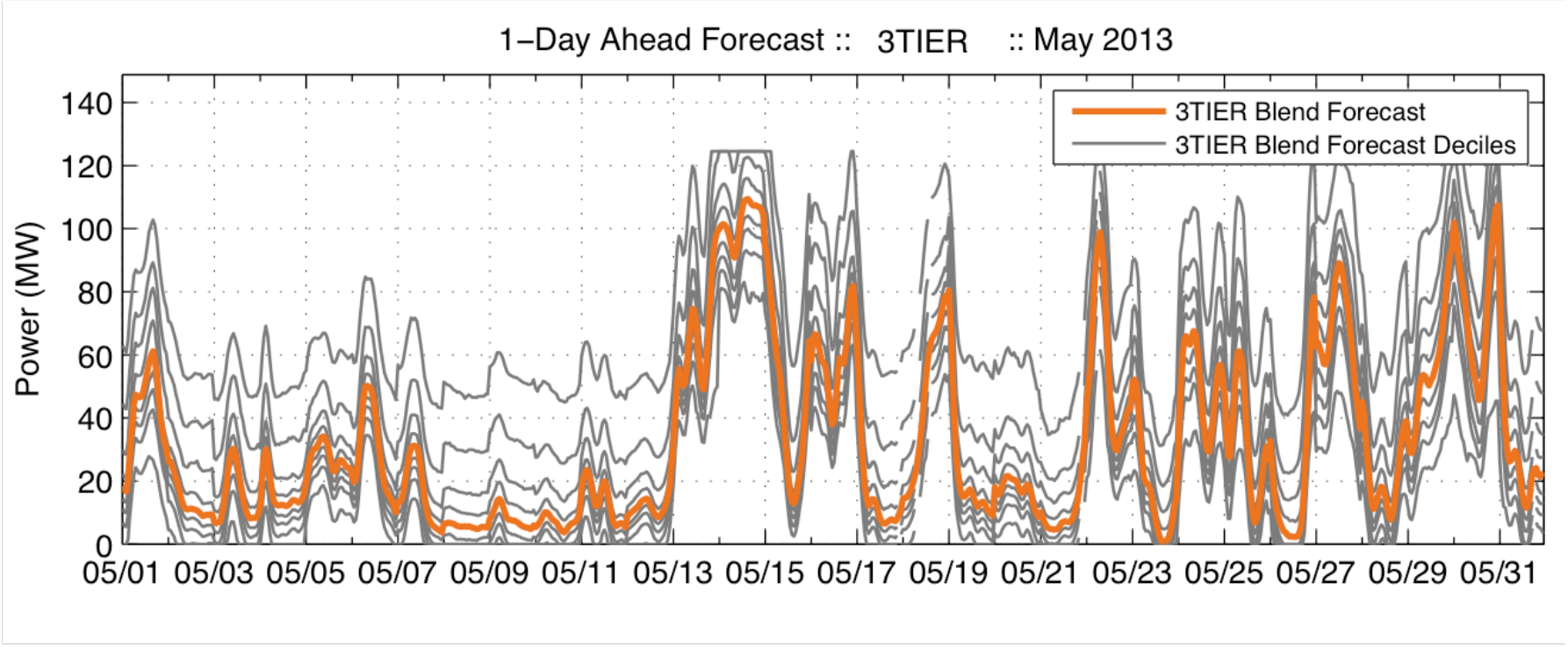
One Strategy: *Scaling the Forecast*



50% scaled 3TIER Blend aka "haircut technique"; 28% downside risk

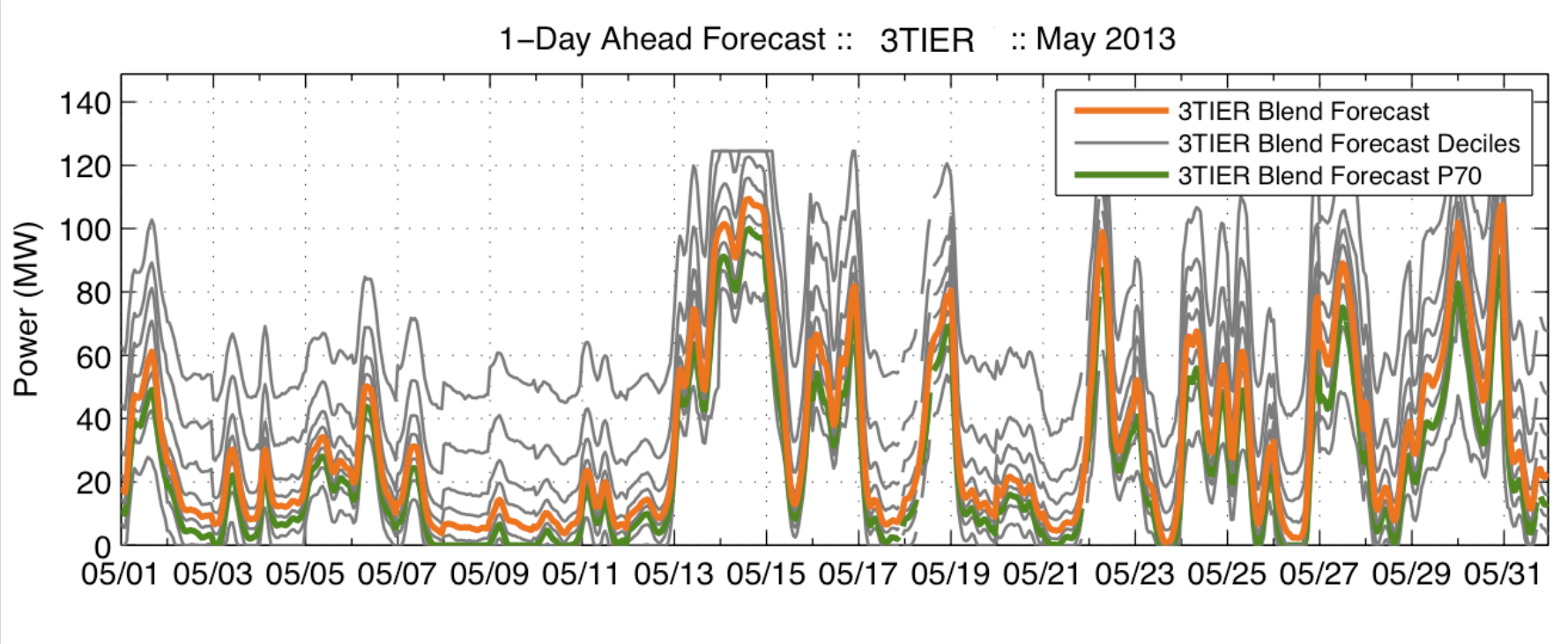
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Vaisala Probabilistic Forecasts



3TIER Blend and prediction deciles:
P10, P20, P30, P40, P60, P70, P80, P90

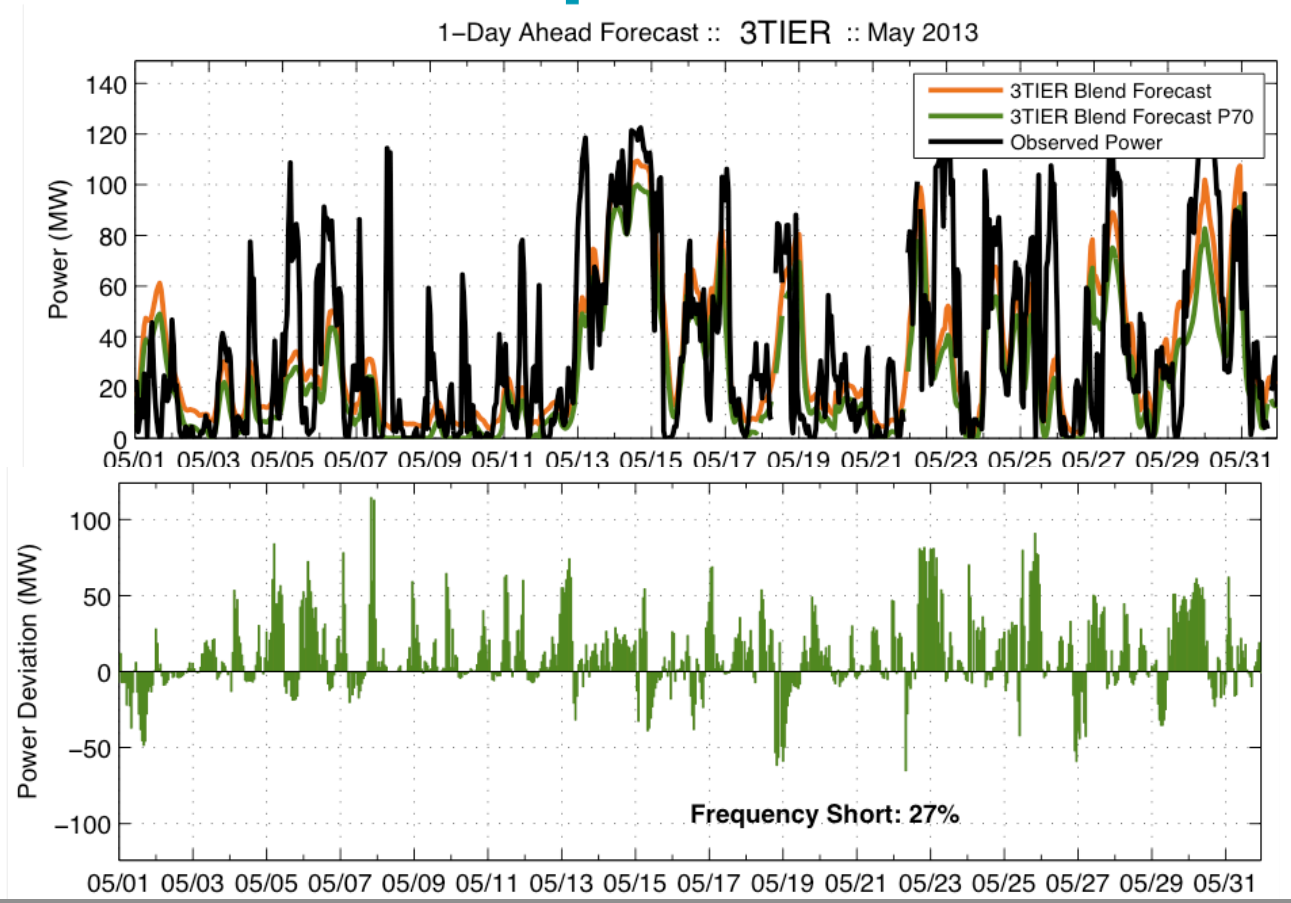
Another Strategy: *Choosing Risk Tolerance*



3TIER Blend and 3TIER 30th percentile or P70;
P70 estimates 30% downside risk

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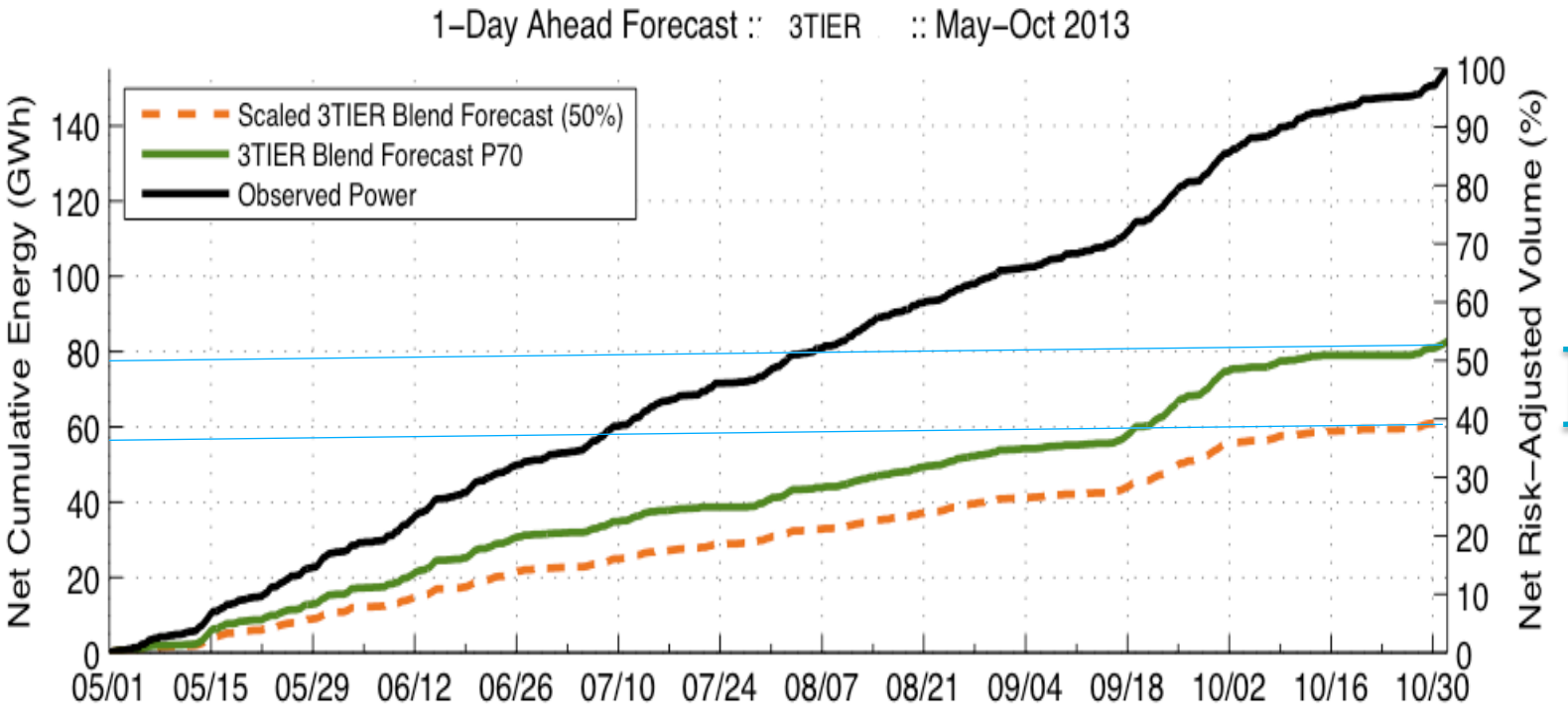
Check the Risk Exposure



3TIER P70 has 27% downside risk;
"Haircut method" was 28% downside, very close to P70

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Compare the Strategies Over Time



Net 20.5 GWh more over a 6-month period!

3TIER P70 and 50% scaled forecast similar risk exposure (27% vs. 28%)

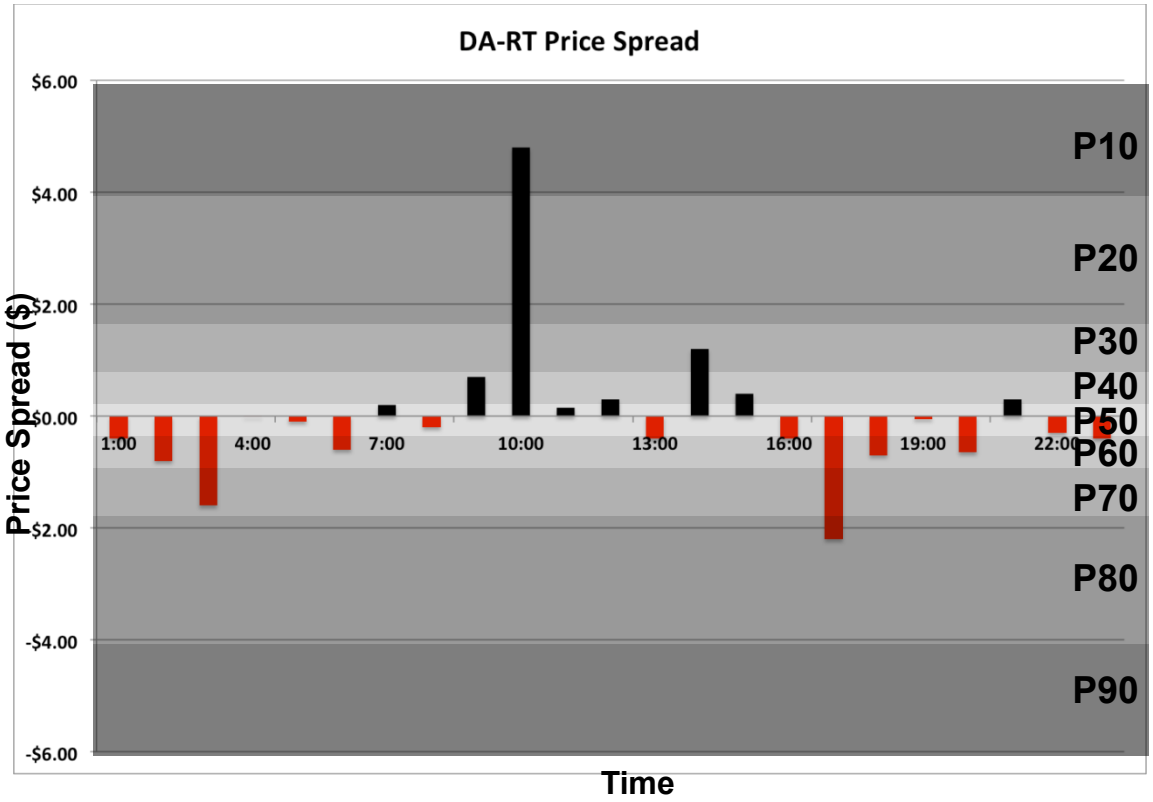
3TIER P70 scheduled 20.5 GWh more energy than scaled forecast!

****Reliable risk and more energy scheduled, day-ahead***

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Advanced Application of Probabilistic Wind Power Forecasts

- Accounting for risk varying with time
  - Energy prices/DA-RT spread
  - Load forecast error
  - Transmission congestion
- Develop rules/algorithm customized to risk profile
  - Choose optimal forecast percentile based on expected risk



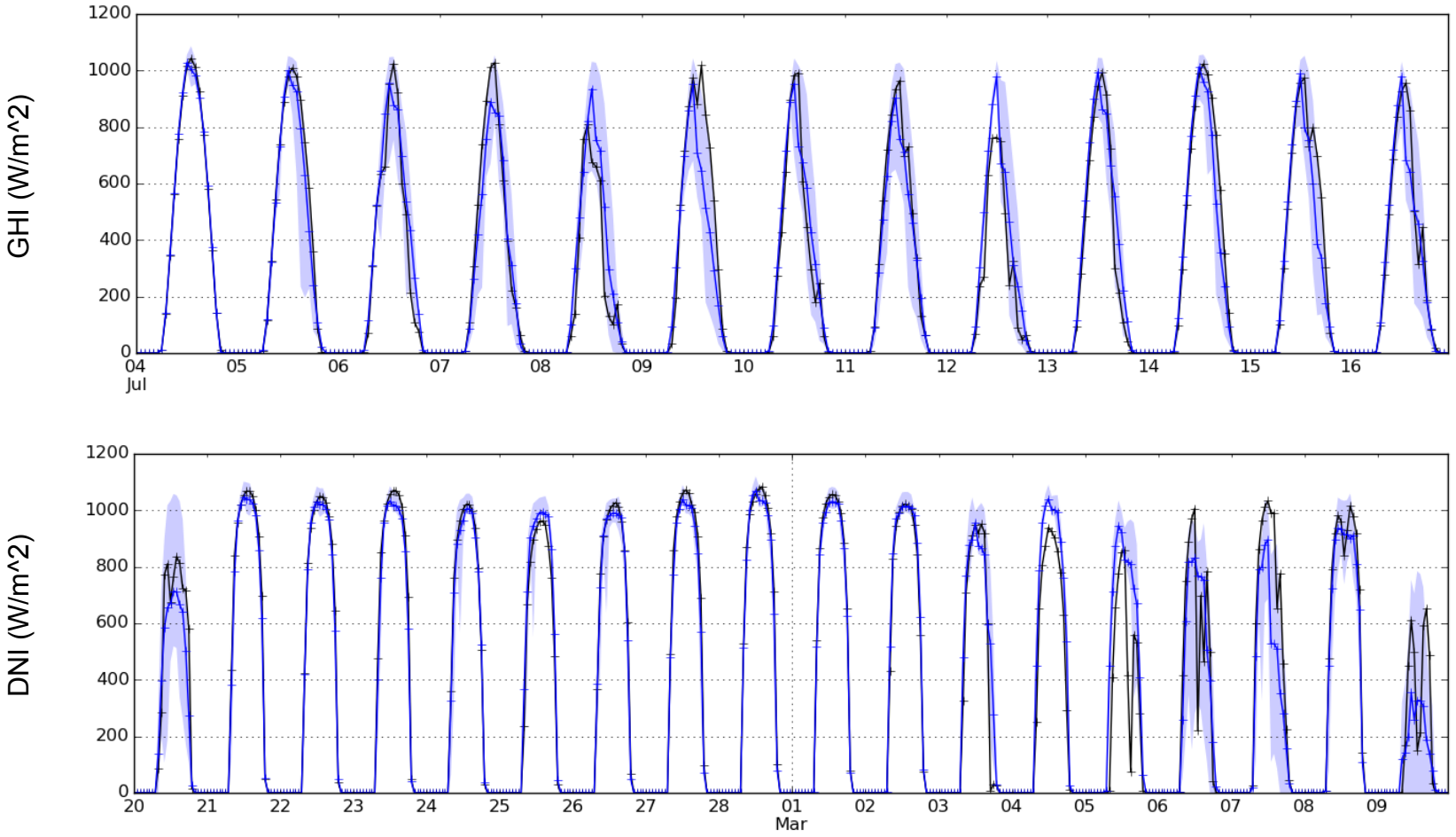
Objective risk assessment takes the emotion out of the forecast.

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More Resources…

- Scheduling More Wind Power: Exploiting Probabilistic Forecasts
  - Grimit et al. 2015: Article, North American Clean Energy, Jan/Feb 2015, pp. 16-17
  - http://www.nacleanenergy.com/magazine/janfeb_2015/index.html#p=16
- Making Energy Balancing Decisions Based on Very Uncertain Wind Power Ramp Forecasts
  - Grimit et al., 2011: Poster 753, 2ENERGY, 91st AMS Annual Meeting, Seattle
- Decision Making Under Uncertainty in Electricity Markets
  - Conejo et al. 2010: Book, Springer US, 539 pp.

New Challenge: Solar Forecasting



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Discussion

- What does private industry need from the other (government, academic) sectors to encourage the use of probability forecasts?

- How can this AMS committee contribute?