

Determining the Value of More Accurate Wind Power Forecasting in Global Electricity Markets

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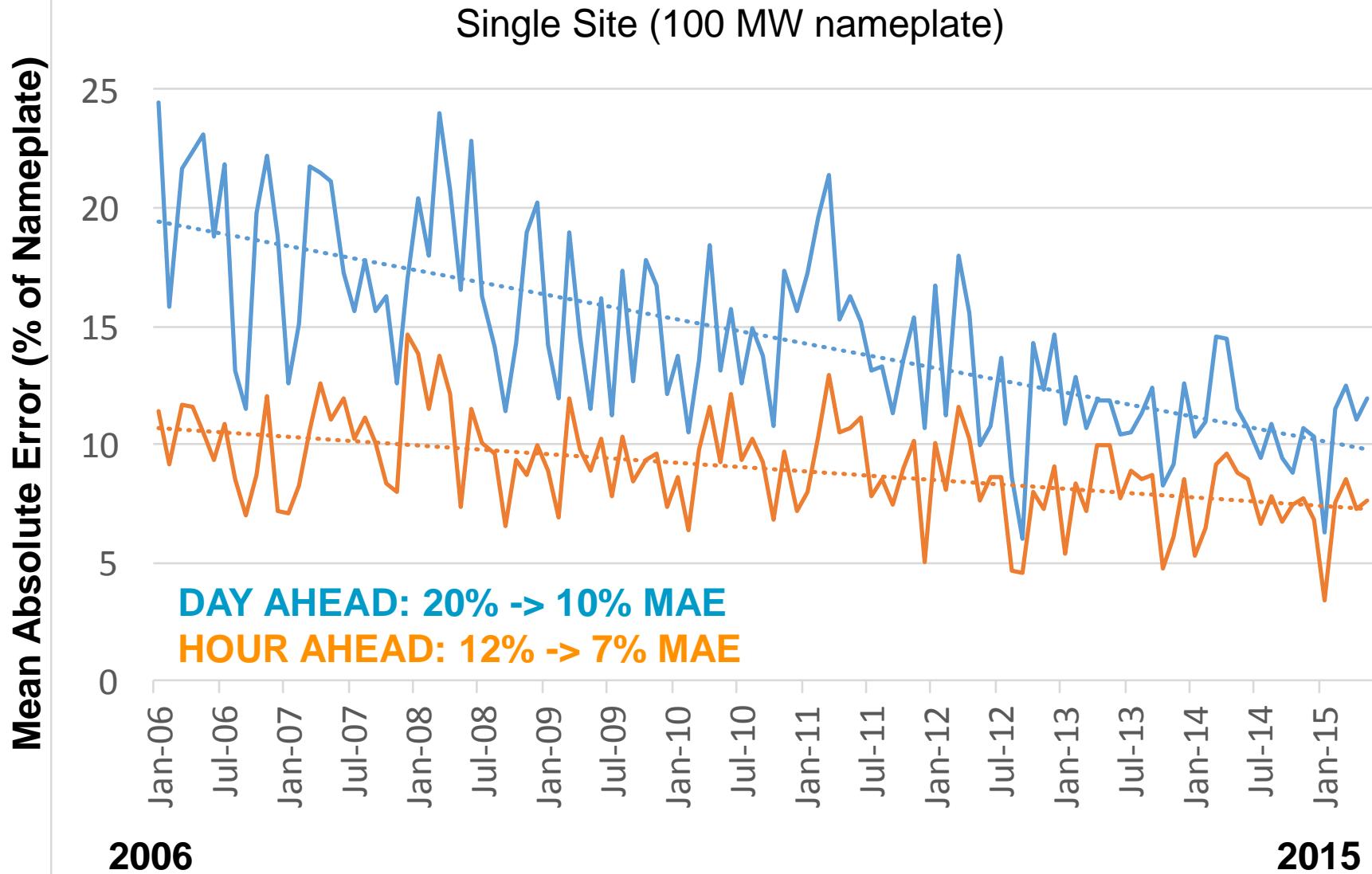
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- More Global Markets
- Market Comparison Summary
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- We may be right/wrong/crazy – but we need to start quantifying incremental value

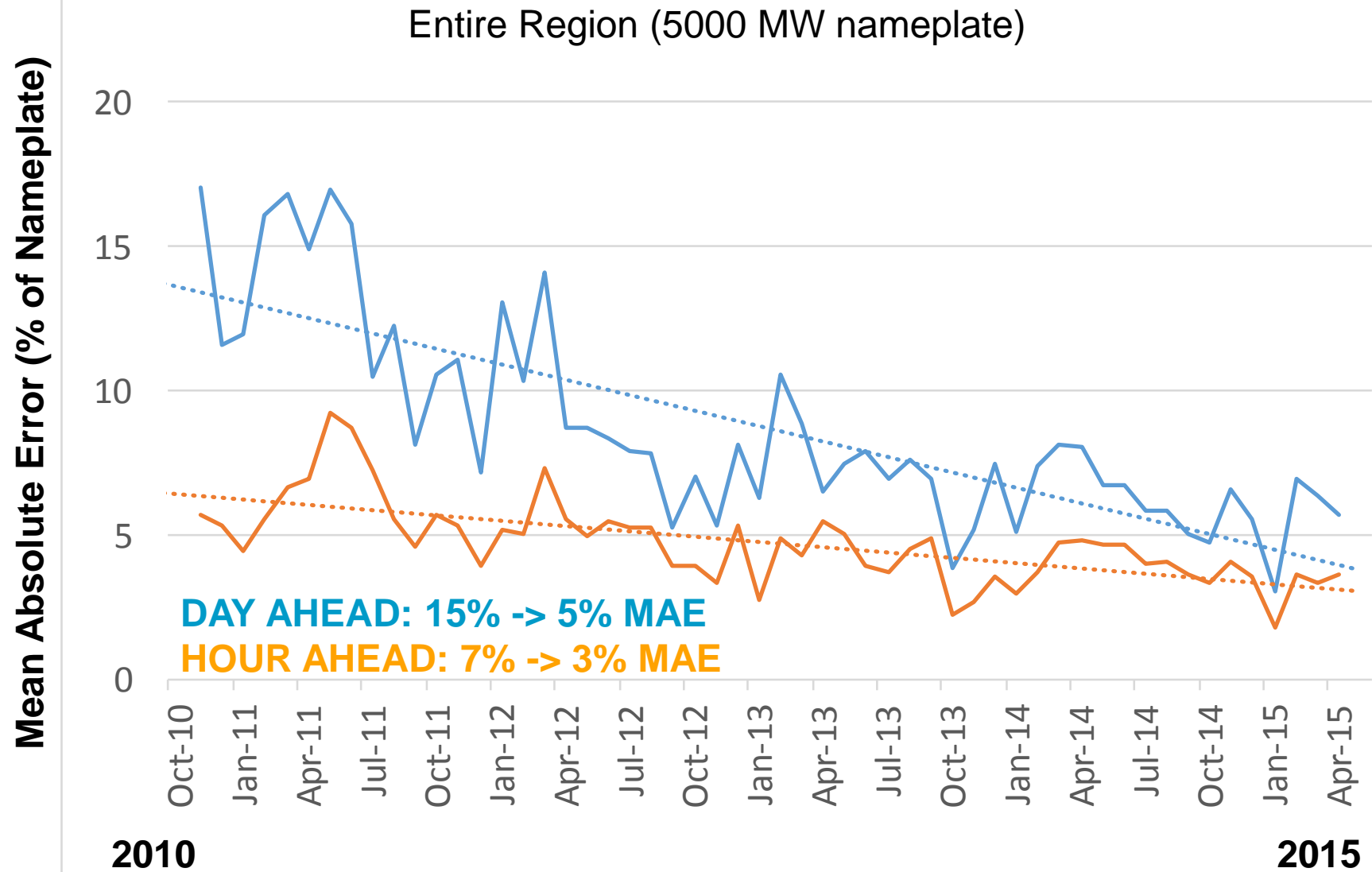


We've come a long way

Forecast Improvement Over Time



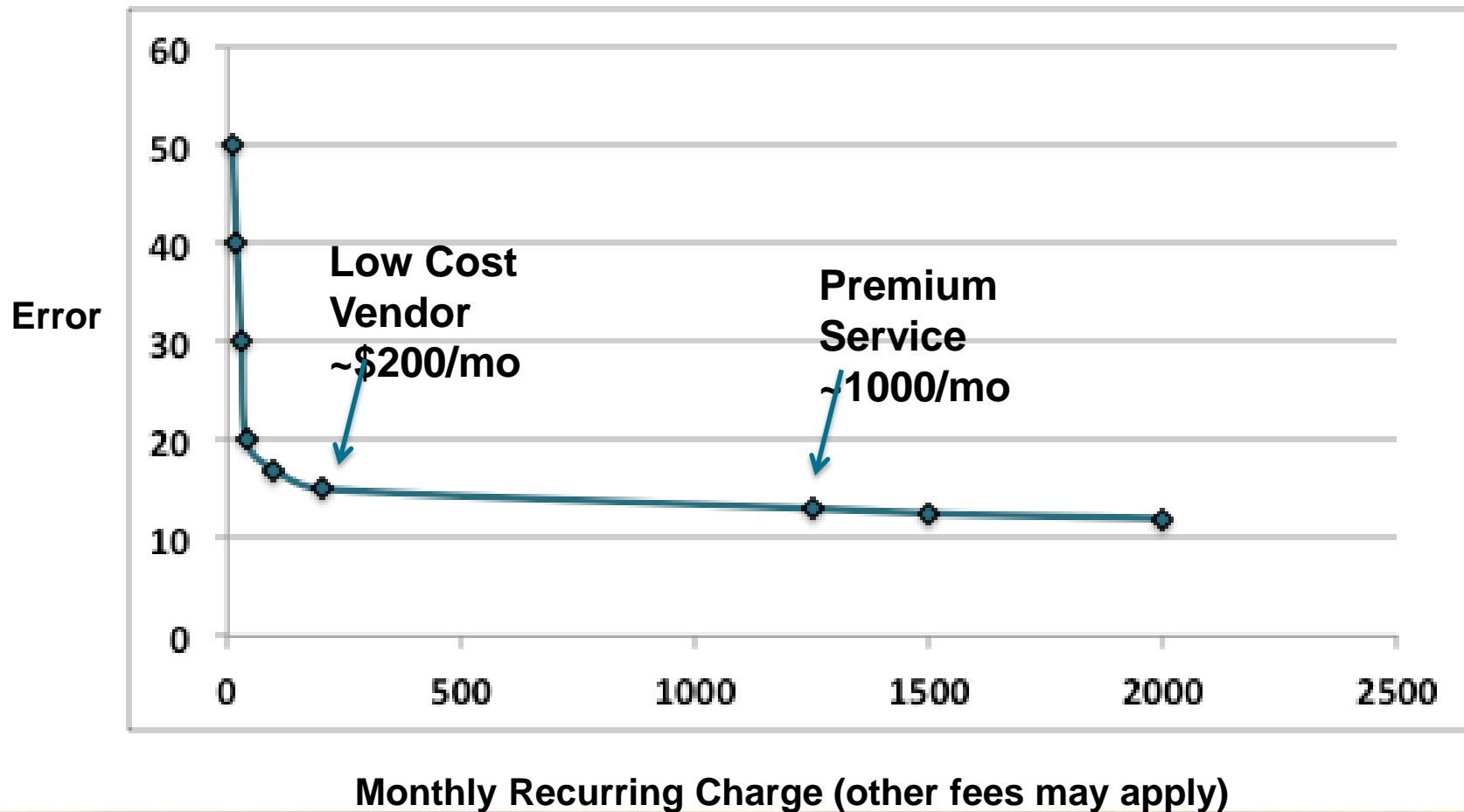
Forecast Improvement Over Time



Where do we go from here and how?

Accuracy versus Cost Curve

Cost is easy – what's the value?!



Motivation and Project Description

- The incremental value of more accurate wind power forecasts depends on the market rules that control energy scheduling and imbalances.
 - Some markets penalize large deviations, driving down the profits of the wind producer in favor of better grid reliability.
 - Other markets issue low imbalance charges to attract more renewable resources onto the grid.
- We examined the market rules for a representative set of global electricity markets (Europe, N. America, Asia)
 - Used Vaisala forecasts and customer-supplied actual generation at real wind facilities, physically located in each market
 - Collected appropriate prices/imbalance charges and applied them

Methodology (Let's keep it simple to start)

- Model all rules that directly impact wind power producers' revenue
- Ignore:
 - Capacity markets
 - Transmission rights
 - Curtailment / Set Points (and make whole payments)
- Use explicit time series of:
 - Actual wind generation (1 hr, 15 min, or 5 min)
 - Real Vaisala forecasts and synthetic forecast improvements
 - Real price/charge data (DA, RT, imbalance)
- Assume that market participants cannot skillfully forecast DA – RT price spreads
- Assume participation in the market closest to real-time
 - In some cases, that is the day-ahead market (e.g., PJM)
 - In others, that is the intra-hour market (e.g., MISO: 5-min)

Electricity Market Overview

	Bilateral Trading	Day Ahead Market	Real Time Market	Imbalance Charges/Credits
India	X		✓	X
China		X	X	
Nord Pool		✓	X	X
Germany		X	✓	X
MISO	X	X	✓	X
PJM	X	✓		X
BPA	X			X
ERCOT		X	X	

X = market type exists

✓ = market studied (most liquid market closest to real-time)

We looked at Pay and Value

- $\text{Value} = \text{Real-Time Price} * \text{Actual Wind Generation}$
- $\text{Pay} = \text{Actual revenue to producer including imbalance charges/credits}$
- $\text{Pay} / \text{Value}$
 - Ratio used to determine economic impact of imbalance charges
- $\text{Incremental Value Metric} = (\$ / 100 \text{ MW} / -1.0 \% \text{pt MAE} / \text{yr})$

So what do we think the answer is?

What would we like it to be as forecasters?

What would we like it to be as wind farm owner/operators?

What would we like it to be as system operators?

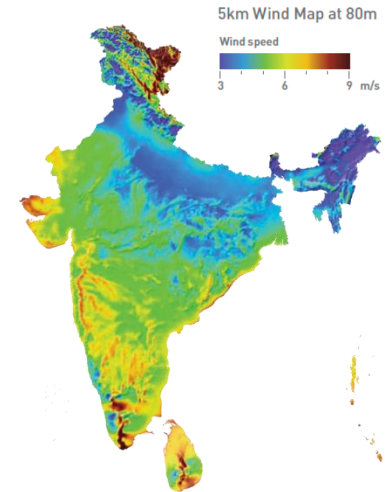
Lets say we can improve the forecast by 1 whole %pt! at a cost of \$10k, what is Benefit Cost Ratio

- \$100,000 per 100 MW per 1.0 %pt per year = \$1,000,000 or **100:1**
- \$10,000 per 100 MW per 1.0 %pt per year = \$100,000 or **10:1**
- \$1,000 per 100 MW per 1.0 %pt per year = \$10,000 or **1:1**
- \$100 per 100 MW per 1.0 %pt per year = \$1,000 or **0.1:1**

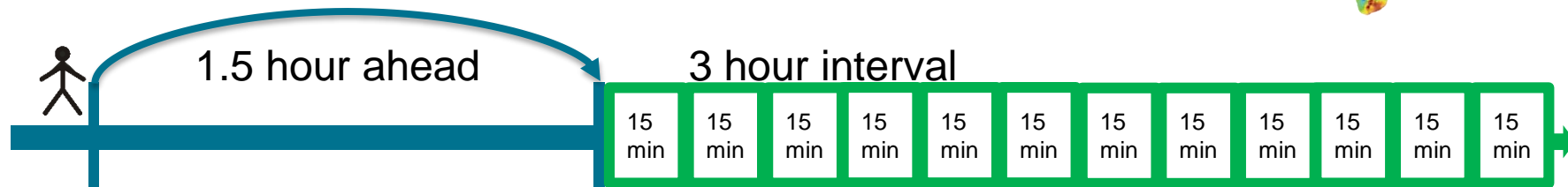
Let's first look at a market that is struggling, just now, with imbalance issues?

Market Example: India

Old Rules



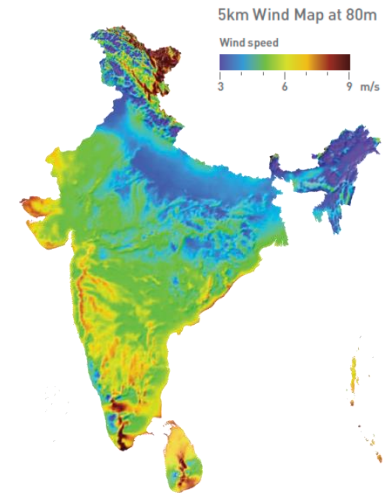
- Forecast requirement:



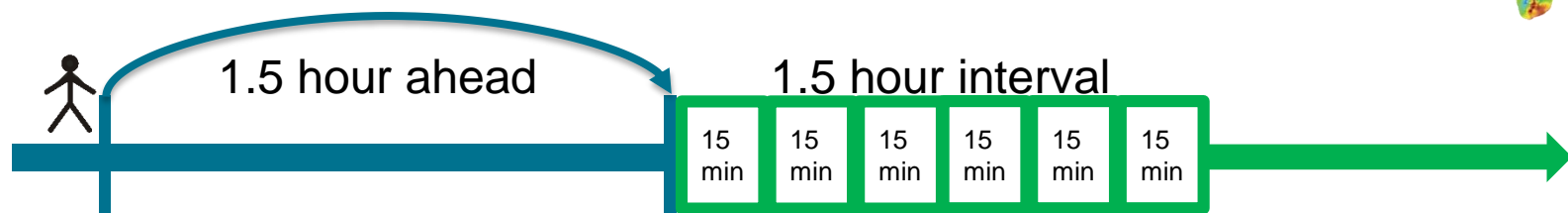
- Imbalance charges based on:
 - deviation from forecast
 - grid frequency – direction of the imbalances
- Incentives:
 - toward high-biased schedule (over prediction is rewarded A LOT)
 - toward unfair cost allocation

Market Example: India

Proposed Rules 03/2015

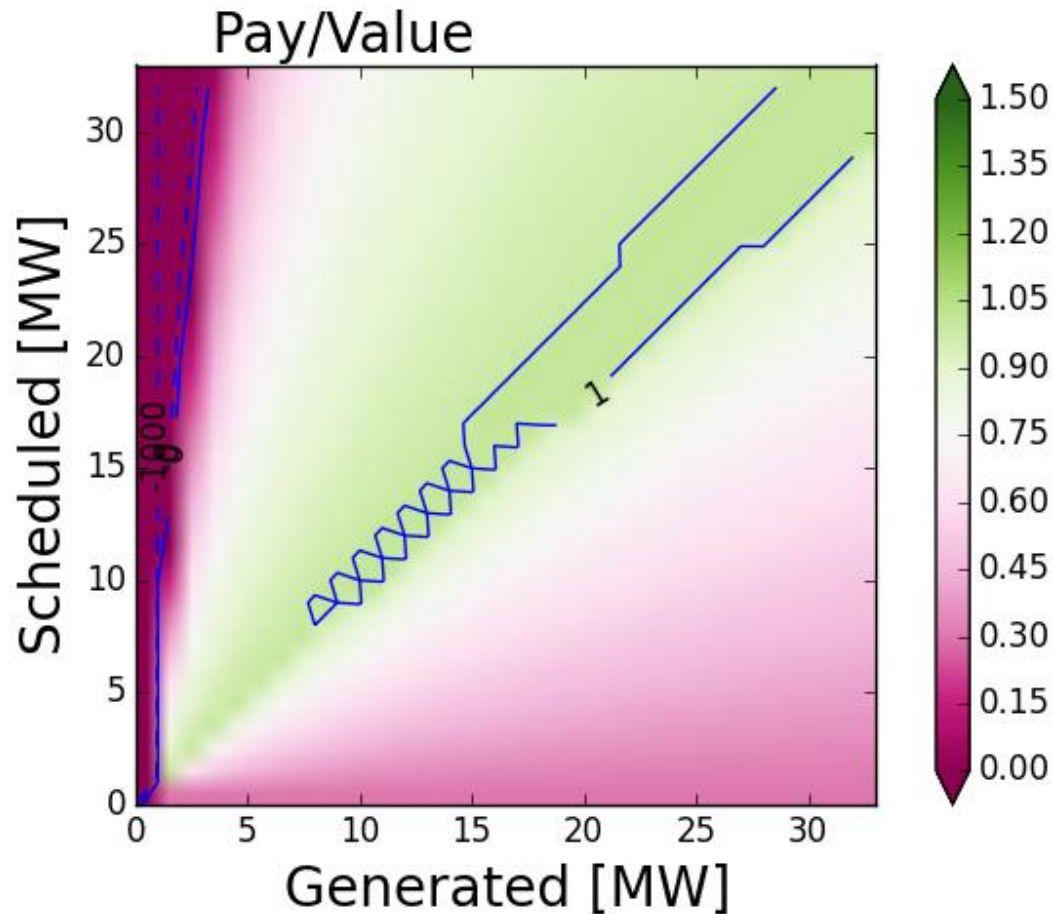


- Forecast requirement:



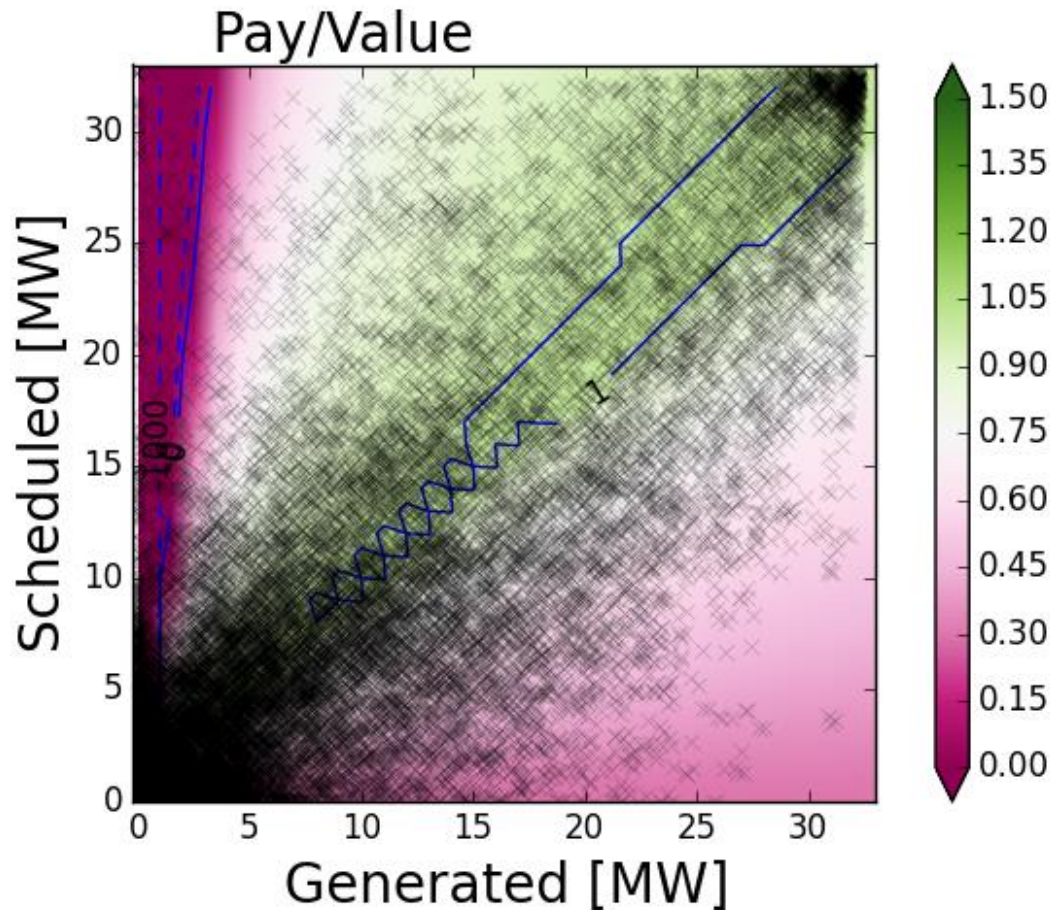
- Incentive to maintain low absolute error
 - Tolerance band: errors within 12% of generation
- Reduced incentive toward high-biased schedule

India Proposed Market Rules



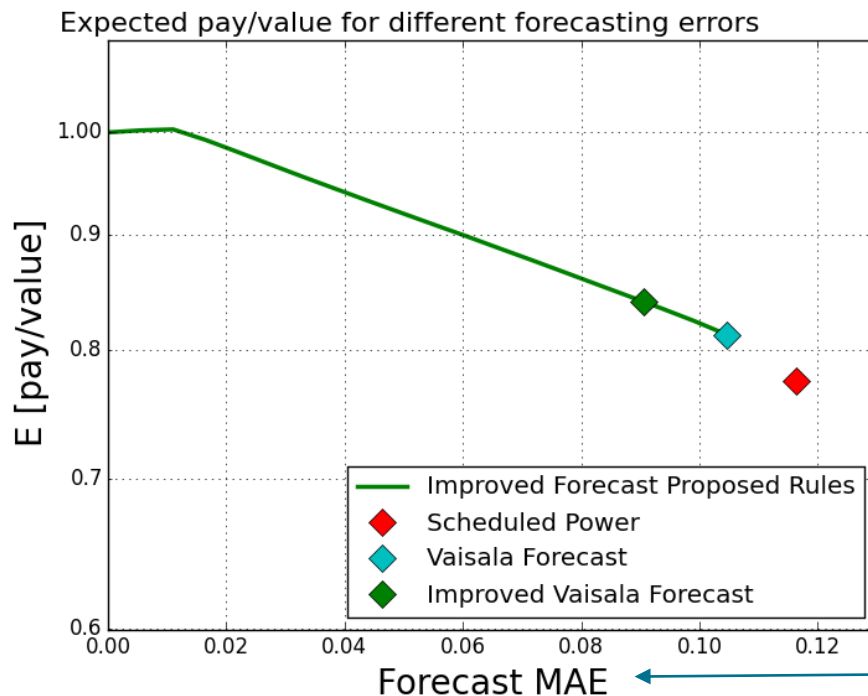
- Full Decision Surface of Pay/Value for any possible combination of Schedule and Generation. Terminology.
- Strong incentive to get it right, over schedule is better than under – but Pay/Value never greater than 1.0. Old Rules P/V >2.0 in some cases

India Proposed Market Rules



- One year of forecast values plotted on same surface. Market prices and structure fixed, so can easily calculate annual changes to P/V based on incremental improvements in forecast accuracy.
- Huge Scatter due mostly to poor timeliness of data for scheduling into RT market.

Value of Improved Forecast



Wow!

\$400k in savings with an extra \$10k in spend.

40:1 Benefit/Cost Ratio

India – Proposed Rules	Incremental Profit (100 MW)
Manual schedule through client	-\$558,788 / yr
Improved Vaisala forecast	\$421,212 / yr

Market Example: India

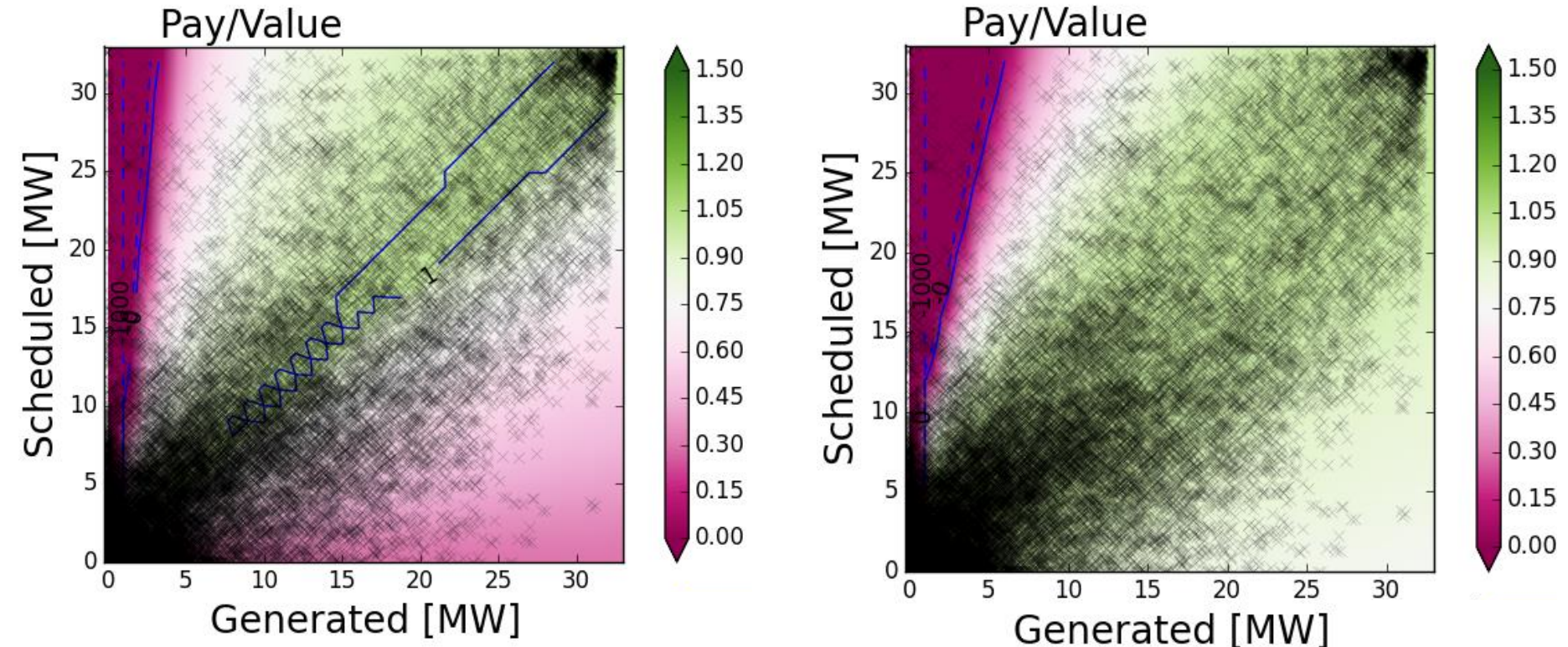
New Rules 11/2015

- Proposed market rules subject to comments
- Proposed improvements
 - Shorter lead time (90 min lead to 60 min lead)
 - Basing error metric on nameplate capacity rather than generation
 - Loosening the error band (from 12% to 15%)
 - Lowering the charges to 10%-30% of contract (PPA) rate

India Market Rule Comparison

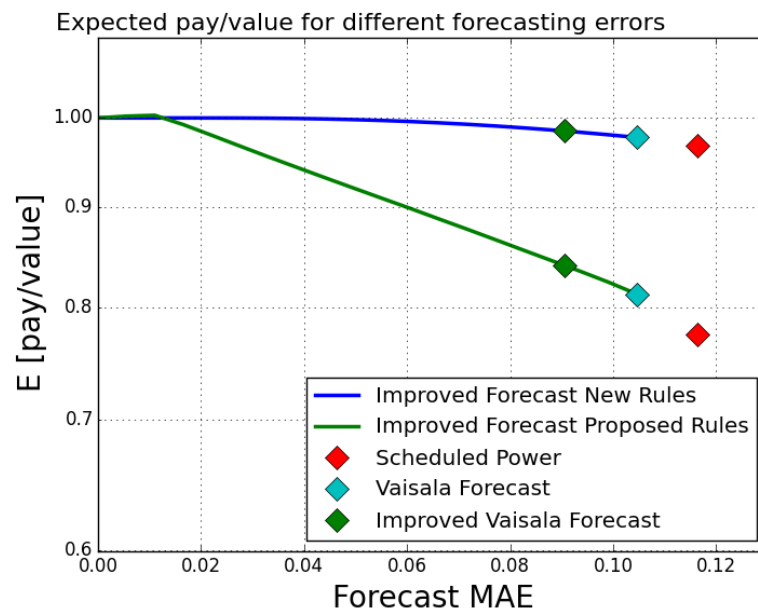
Proposed

New



What's the difference: There's a lot more green on the right!

India Market Summary



Darn!

**Proposed 40:1
Benefit/Cost Ratio**

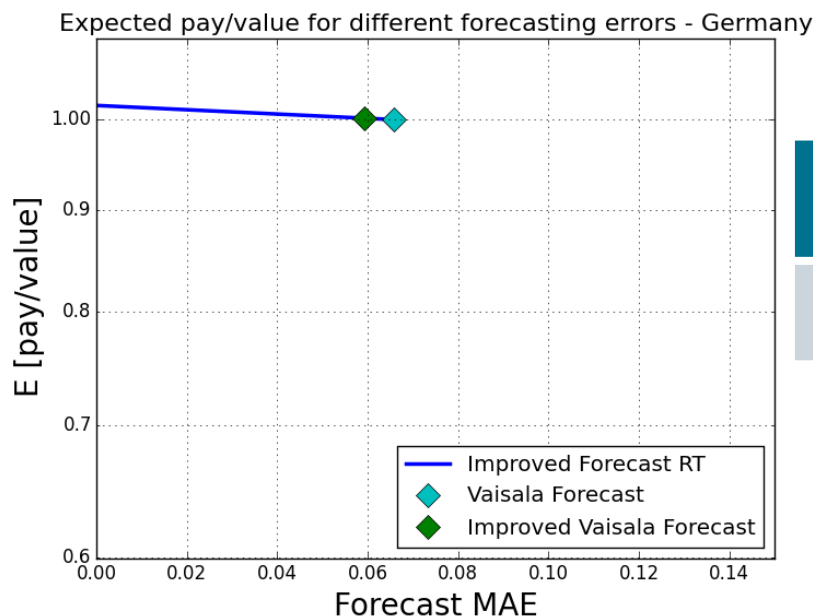
Now at 10:1

India Case (100 MW)	Incremental MAE Change	Incremental Profit (Proposed Rules)	Incremental Profit (New Rules)
Scheduled Power (customer)	+1.3 %pt	-\$558,788 / yr	-\$131,515 / yr
Improved Forecast	-1.41 %pt	\$421,212 / yr	\$112,424 / yr

But that's India.

Now let's look at a market that has a longer history with structure/design & imbalance costs?

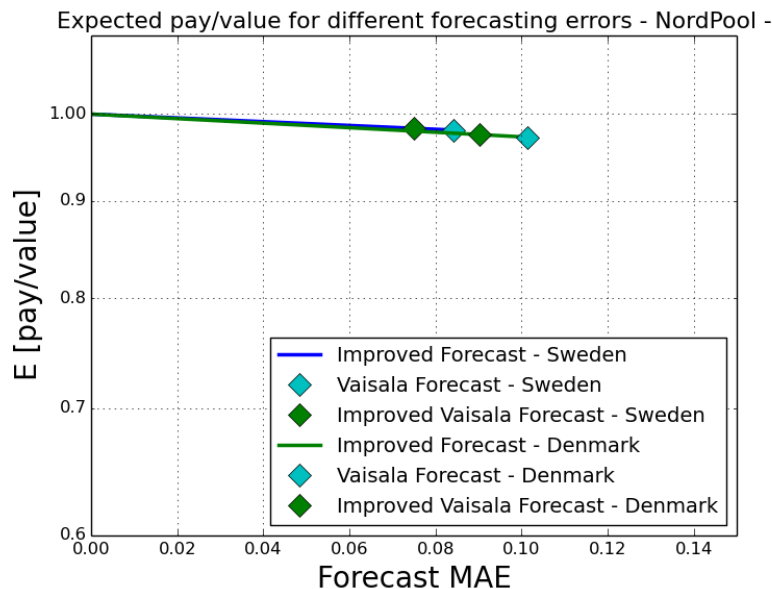
Germany Market Summary



Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
Germany	-0.66 %pt	\$11,256 / yr

- Day ahead and intra-day markets, only intra-day considered
- One-price balance settlement system (reBAP)
 - reBAP is a charge or a credit, depending on direction of overall system deviations
 - reBAP rate is generally larger than the intra-day price
 - Increased revenue is possible (pay/value > 1), if the producer deviates in the opposite direction of the overall system deviations

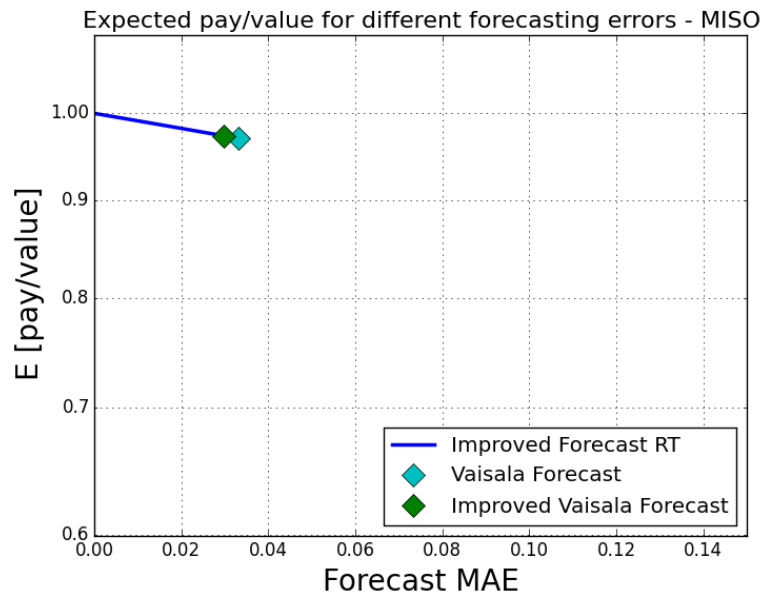
Nord Pool Market Summary



Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
Sweden onshore	-0.9 %pt	\$18,798 / yr
Denmark offshore	-1.1 %pt	\$37,718 / yr

- Day ahead and intra-day markets, assumed intra-day market not liquid
- Two-price balance settlement system
 - Separate imbalance charges for up/down regulating hours
- Average DA: ~ 32 €/MWh, Up-Reg: ~ 35 €/MWh, Down-Reg: ~ 29 €/MWh
 - Varies by country/zone

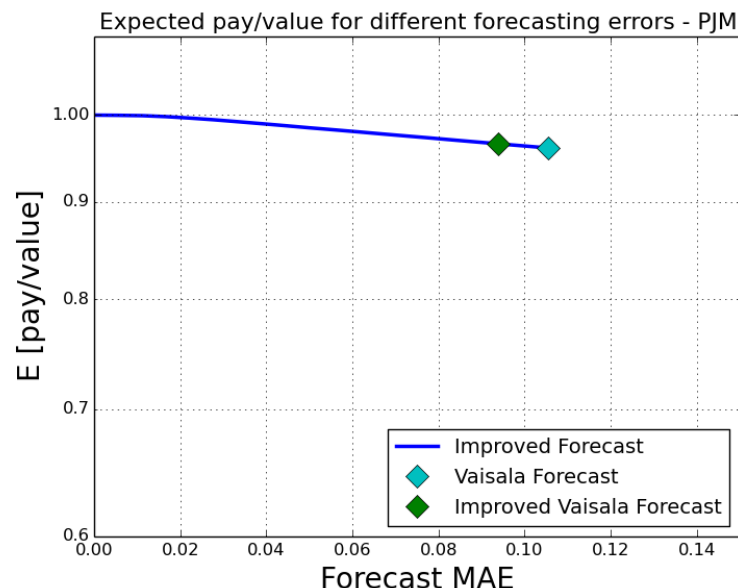
MISO Market Summary



Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
MISO	-0.33 %pt	\$4,191 / yr

- Day-ahead and real-time markets, including intra-hour dispatch market for intermittent resources (DIR program)
 - 10 min lead, 5 min intervals
- Imbalance charges (RT-RSG) for excessive/deficient energy
 - Apply if > 8% deviations occur for at least 4 intervals in an hour
 - Average RT-RSG is small: 0.71 \$/MWh, varies by node and in time

PJM Market Summary



Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
PJM	-1.16 %pt	\$23,484 / yr

- Day ahead market only (so Value changed to be w.r.t. DA price)
- Market participants are generation followers in real-time (must buy/sell back deviation from day-ahead award schedule)
- Imbalance (BOR) charges are small on average: ~ 2 \$/MWh
- Average prices favor day ahead: DA LMP \$38, RT LMP \$37.50

Market Comparison – Incremental Value

Country / Market	Market Type	Forecast MAE Today	Pay/ Value Ratio	Incremental Value Metric (\$ / 100 MW / -1.0 %pt MAE / yr)
India: old proposed new	RT	10.5%	-	-
	RT	10.5%	0.775	298,100
	RT	10.5%	0.968	79,600
China	DA + RT	<20%	-	0
Nord Pool: Denmark Sweden	DA	10.1%	0.973	34,290
	DA	8.4%	0.981	20,890
Germany	RT	6.6%	1.00015	17,050
USA: PJM MISO	DA	10.6%	0.961	20,240
	RT	3.3%	0.969	12,700

Primary Findings

- European markets had the most transparency for market rule and data discovery; market design was closest to the theory
- Rules for imbalance have a direct impact on producers' revenue
 - Usually negative, though not in all markets
 - Typical imbalance charges are near 3% (pay/value ~0.97)
 - More accurate forecasts have some incremental value, by reducing these charges:
 - A 100 MW wind facility @ 33% NCF @ 35 \$/MWh = **\$10 M / yr**
 - Typical imbalance charges = **\$300 K / yr**
 - Typical value of improved forecasting = **\$30 K / yr (~10% of the charges)**
- A tradeoff exists between the incremental value of forecasting and the lost revenue due to market participation
 - Imbalance charge design: not too low, not too high

Conclusions

- For market participants, the incremental value of more accurate wind power forecasting under current market rules is rather meager*.
 - Incentive to invest in more accurate forecasting is small.
- System operators should apply imbalance charges that are sufficiently high enough to cover the increased regulation costs of wind and also incentivize more accurate forecasting.
 - However, charges that are too large will act to discourage wind participation.
- POLICY CHALLENGE: Is it possible/advantageous to find a “Goldilocks” solution, where imbalance charges are high enough to incentivize more accurate forecasting, but not so much as to discourage wind participation on the system?

*only considering participants in the liquid markets closest to real-time

Thank you

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