The Value of More Accurate Power Forecasting in Global Electricity Markets

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SECONDWIND by Vaisala | & 3TIER by Vaisala | **VAISALA**

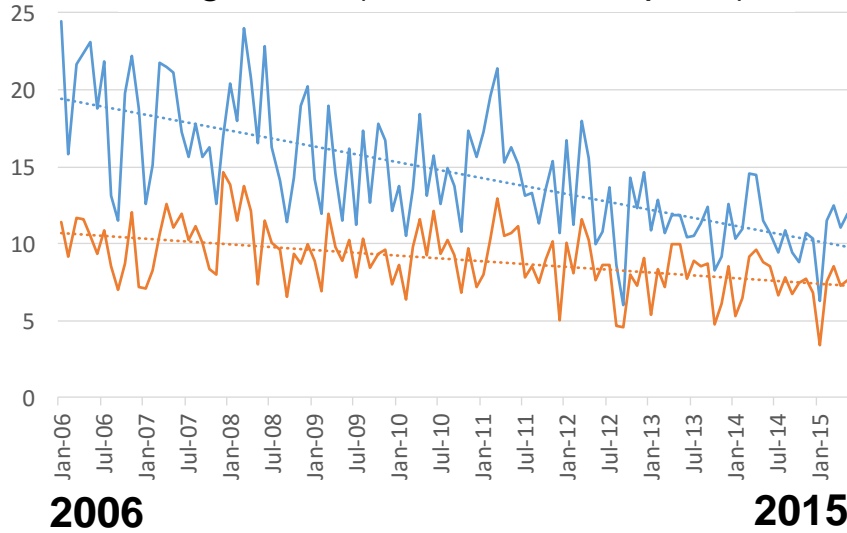**UVIG 2017 Forecasting Workshop, Atlanta, GA**

Session 2

Wind Forecast Improvement Over Time

Single Site (100 MW nameplate)

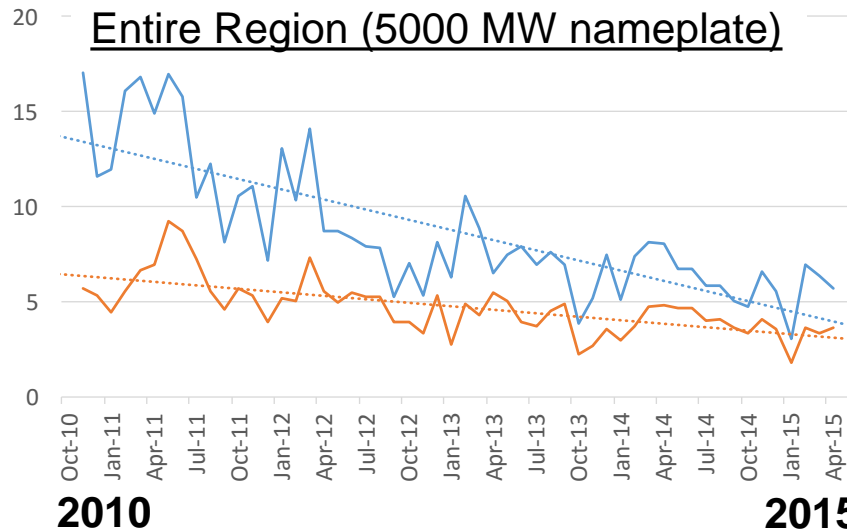Entire Region (5000 MW nameplate)

Mean Absolute Error (% of Nameplate)

DAY AHEAD: 20% → 10% MAE
HOUR AHEAD: 12% → 7% MAE

WE'VE COME A LONG WAY BUT…

1) DOES IT HAVE VALUE?
2) DO FURTHER IMPROVEMENTS
PROVIDE ADDITIONAL VALUE?

DAY AHEAD: 15% → 5% MAE
HOUR AHEAD: 7% → 3% MAE

Contents

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- Methodology

- Detailed Market Example: India
    - Proposed rules
    - New rules
    - Implemented rules

- More Global Markets

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- Conclusions and Challenges

Motivation and Project Description

- The <u>incremental value</u> of more accurate wind/solar power forecasts <u>depends on the market rules</u> that control energy scheduling and imbalances.
  - Some markets penalize large deviations, driving down the profits of the 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 generation facilities, physically located in each market
  - Collected appropriate prices/imbalance charges and applied them

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Methodology

- Model rules that directly impact power producers' revenue
- Ignore:
  - Capacity markets
  - Transmission rights
  - Curtailment / Set points (and make whole payments)
- Use historical time series of:
  - Actual generation (1 hr, 15 min, or 5 min)
  - Real forecasts at the appropriate lead times
  - A set of synthetic forecasts with incremental improvements
  - Real price/charge data (DA, RT, imbalance)
- 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)
- Assume that the offer schedule/forecast are the same (no hedging)

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We Considered Pay and Value

- **Value** = Real-Time Price * Actual Generation

- **Pay** = Actual revenue to producer including imbalance charges/credits

- **Pay / Value**
  - Ratio used to determine economic impact of imbalance charges

- **Incremental Value Metric** = ($ / 100 MW / -1.0 %pt MAE / yr)
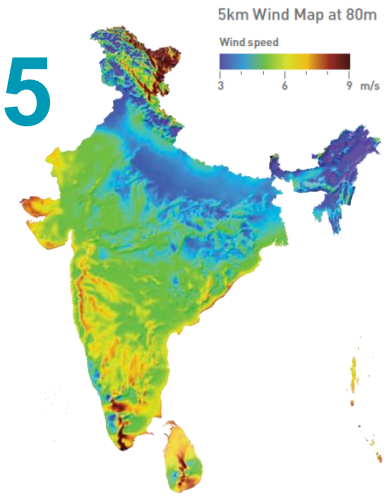
Electricity Market Overview

	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)

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Market Example: India
CERC Proposed Rules Mar-2015

5km Wind Map at 80m

Wind speed

3   6   9 m/s

- Forecast requirement:

1.5 hour ahead
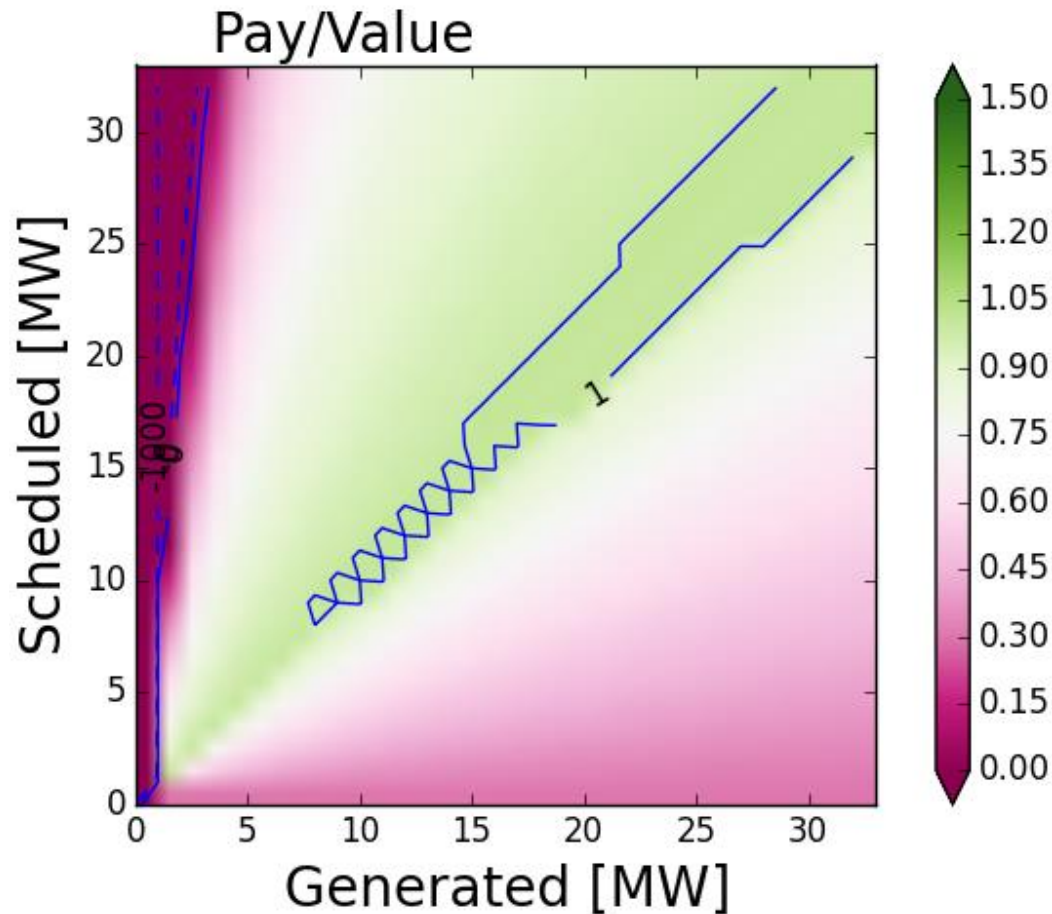
1.5 hour interval

| 15 min | 15 min | 15 min | 15 min | 15 min | 15 min |
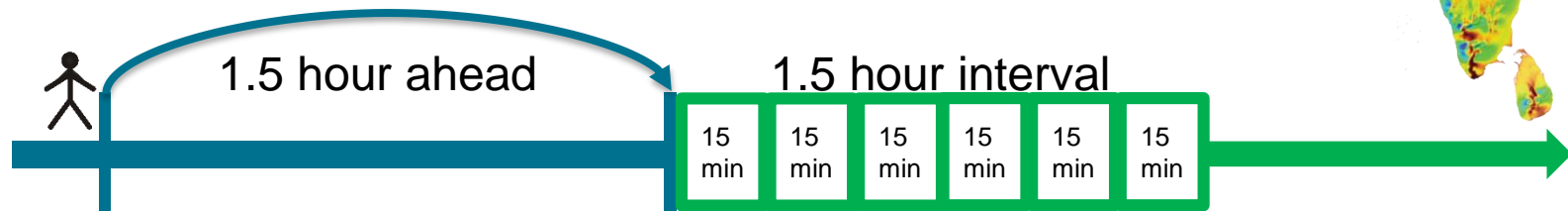
- Incentive to maintain low absolute error
  - Tolerance band: errors within 12% of generation
  - Charges levied at the contract (UI) rate

- Reduced incentive toward high-biased schedule

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India CERC Proposed Market Rules
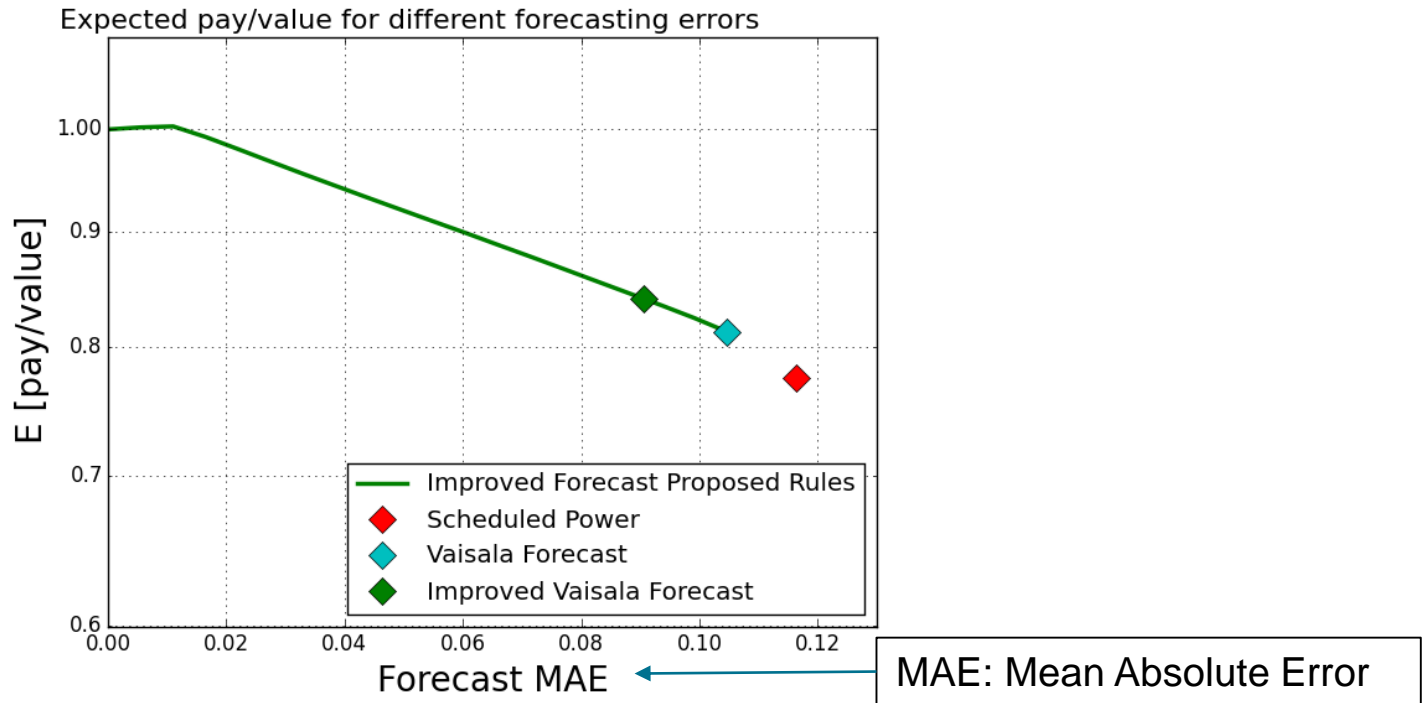

Pay/Value

Scheduled [MW] vs Generated [MW]

- **Full Decision Surface of Pay/Value** for any possible combination of forecast (scheduled) and actual (generated).

- **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 CERC Proposed Market Rules
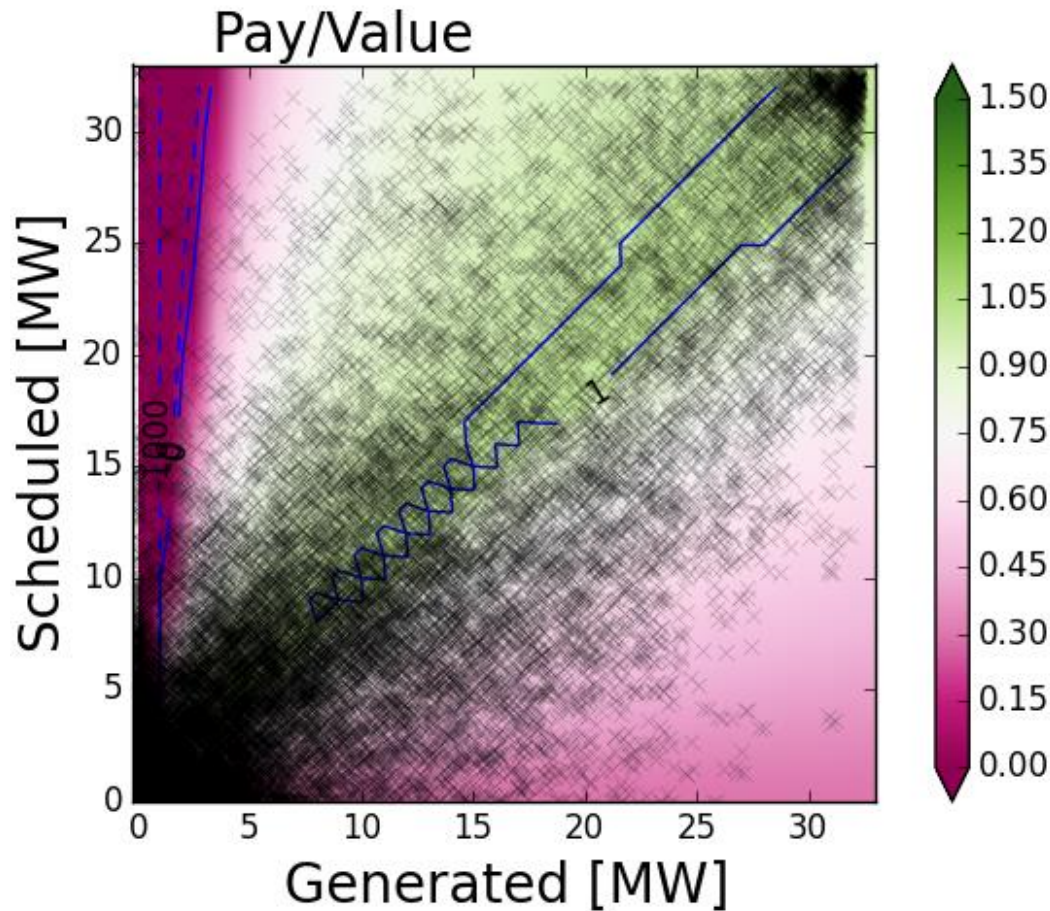
- One year of real values plotted on same surface

- Market prices and structure fixed
  - Easy to calculate changes to **Pay/Value** based on incremental improvements in forecast accuracy

- Huge scatter due mostly to poor timeliness of data for scheduling into RT market
  - Still, forecast is 20% better than persistence.

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Value of Improved Forecast

Expected pay/value for different forecasting errors

Legend:
- Improved Forecast Proposed Rules
- Scheduled Power
- Vaisala Forecast
- Improved Vaisala Forecast

Y-axis: E [pay/value]
X-axis: Forecast MAE

MAE: Mean Absolute Error

India – Proposed Rules	Incremental Profit (100 MW)
Improved Vaisala forecast	$421,212 / yr

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Market Example: India CERC New Rules Nov-2015
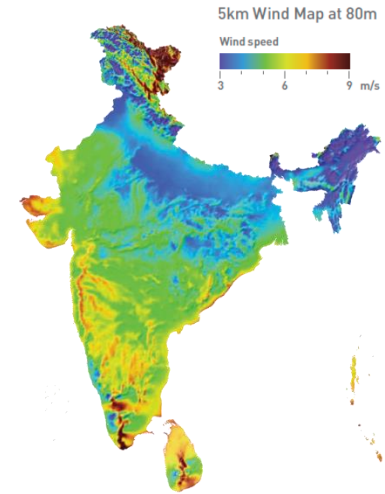
- Proposed market rules subject to comments.

1 hour ahead

1.5 hour interval

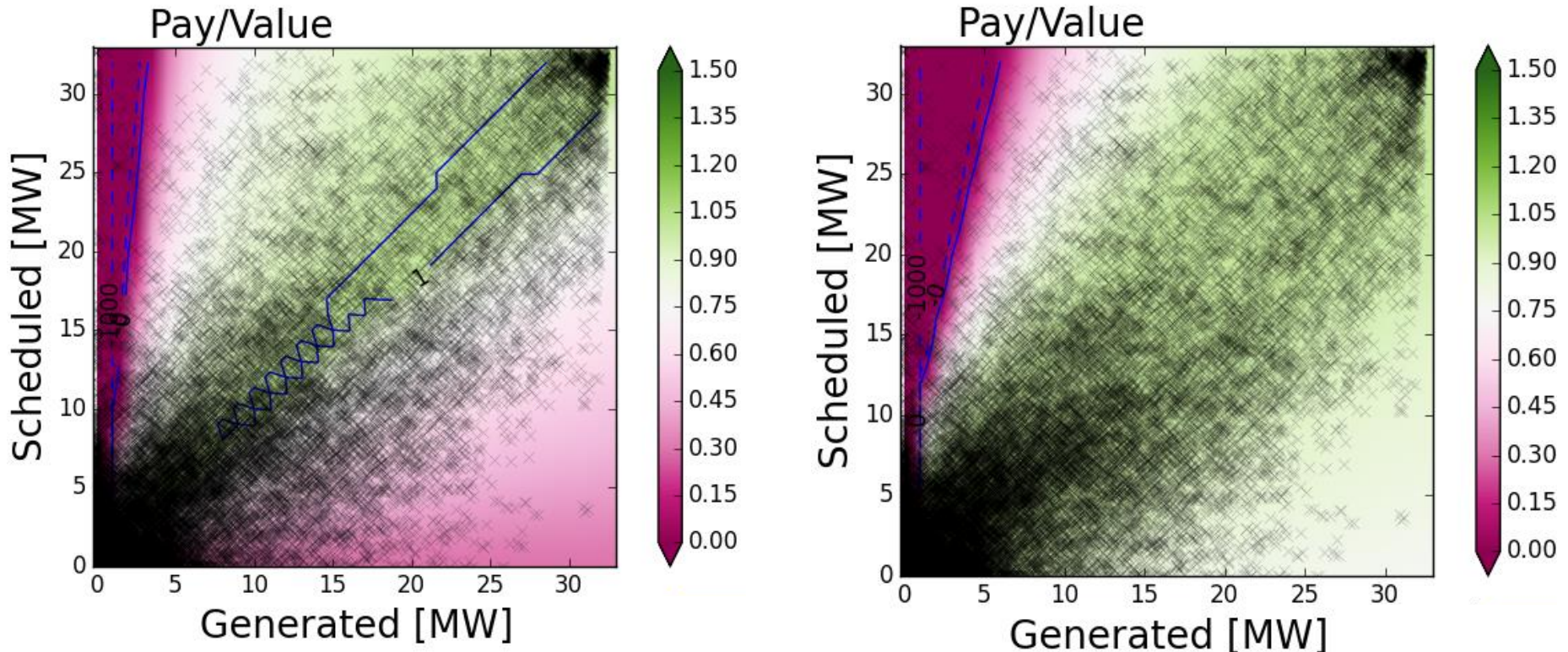| 15 min | 15 min | 15 min | 15 min | 15 min | 15 min |
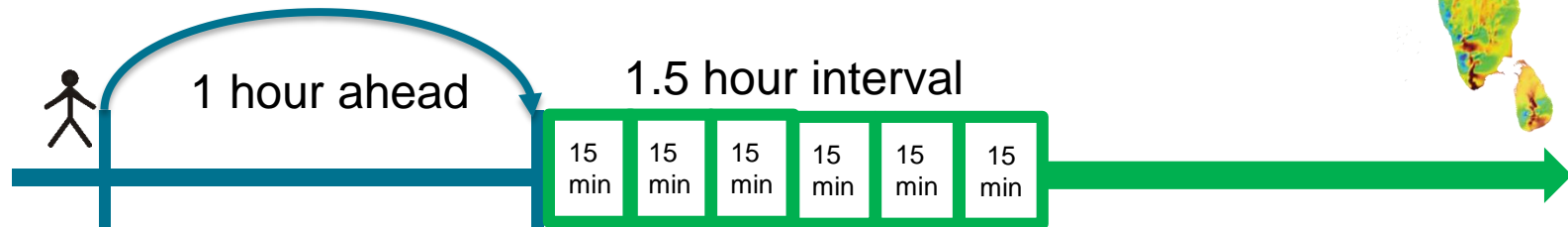
- Refinements:
  - Shorter lead time (from 90 min to 60 min)
  - Error based on nameplate capacity rather than generation
  - Loosening the zero-charge band (from 12% to 15%)
  - Lowering the tiered charges to 10%-30% of contract (UI) rate
    - 10% (15-25% deviation)
    - 20% (25-35% deviation)
    - 30% (>35% deviation)

5km Wind Map at 80m
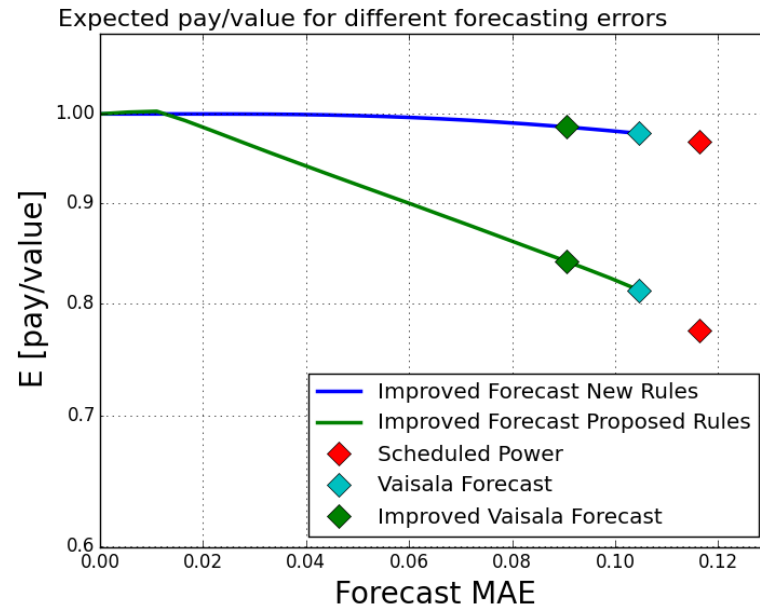Wind speed
3   6   9 m/s

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India Market Rule Comparison
Proposed   *New*

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

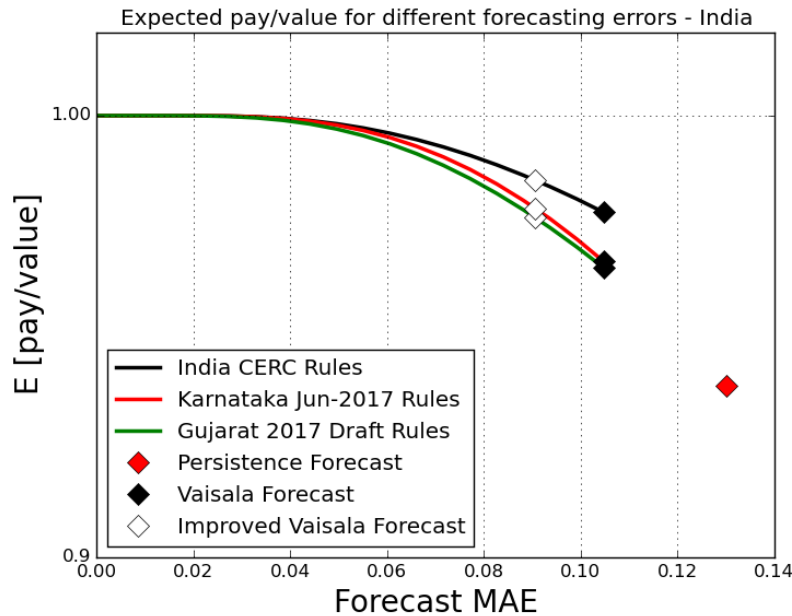# India Market Rule Evaluation

Expected pay/value for different forecasting errors

More pay to producers; Less value for incremental improvement

India Case (100 MW)	Incremental MAE Change	Incremental Profit (Proposed Rules)	Incremental Profit (New Rules)
Improved Forecast	-1.41 %pt	$421,212 / yr	$112,424 / yr

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India Market Summary

Expected pay/value for different forecasting errors - India

India Rules	Incremental MAE Change	Incremental Profit (100 MW)
India CERC (Nov-2015)	-1.41 %pt	$112,510 / yr
Karnataka (Jun-2017)	-1.41 %pt	$184,772 / yr
Gujarat (2017 Draft)	-1.41 %pt	$173,907 / yr

- Day-ahead and intra-day scheduling required, delivered to SLDC
  - Near real-time: 60 min lead, 150 min horizon, 15 min intervals

- Tiered imbalance charges (DSM) recommended in national standard (CERC)
  - Regional implementation left up to the states
  - Karnataka: deviations >15% 0.50 INR/kWh, >25% 1 INR/kWh, >35% 1.50 INR/kWh
  - Gujarat: deviations >12% 0.35 INR/kWh, >20% 0.70 INR/kWh, >28% 1.05 INR/kWh

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Germany Market Summary

Expected pay/value for different forecasting errors - Germany
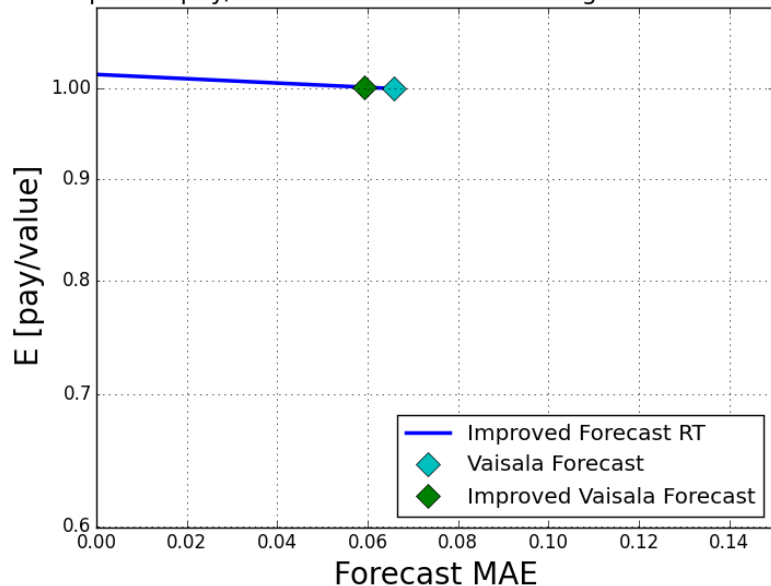
Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
Germany	-0.66 %pt	$11,256 / yr

- 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

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Nord Pool Market Summary

Expected pay/value for different forecasting errors - NordPool -

Y-axis: E [pay/value], X-axis: Forecast MAE

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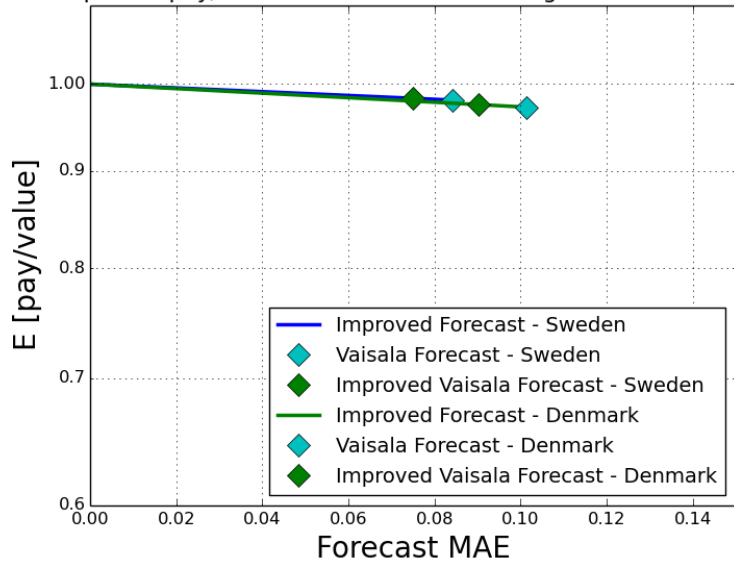
Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
Sweden onshore	-0.9 %pt	$18,798 / yr
Denmark offshore	-1.1 %pt	$37,718 / yr

- 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
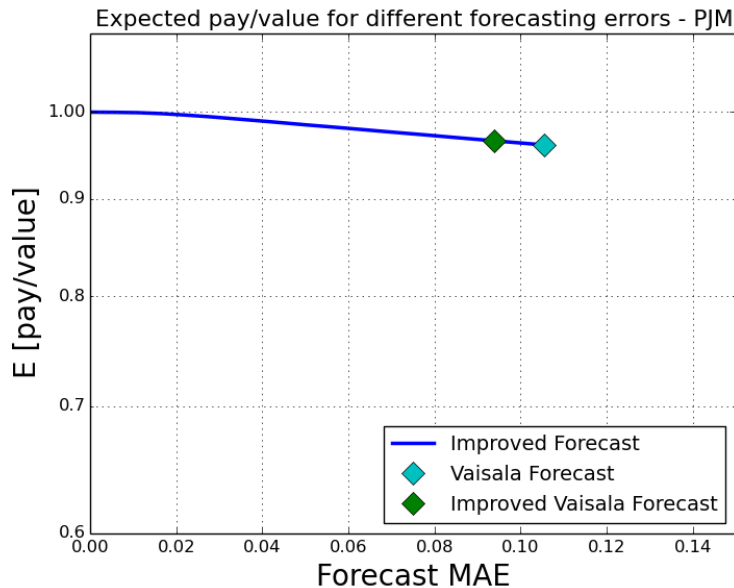 - Varies by country/zone

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MISO Market Summary

Expected pay/value for different forecasting errors - MISO
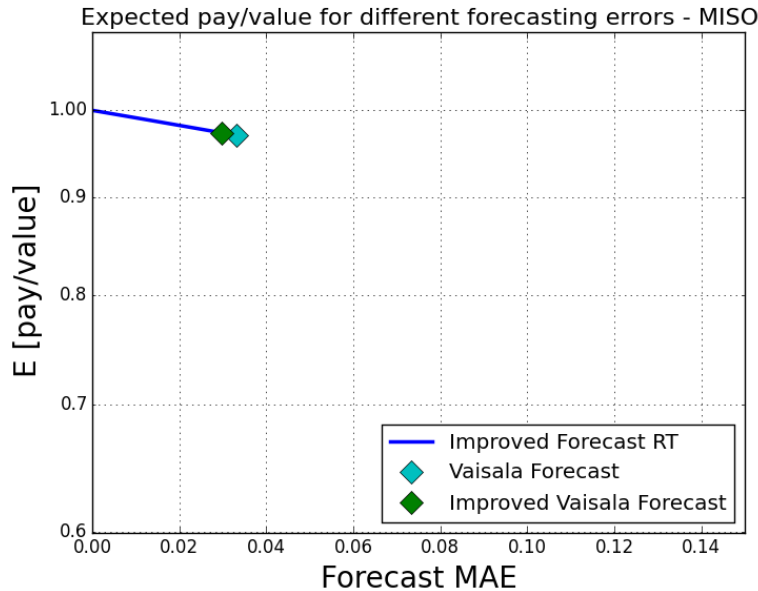
Forecast Location	Incremental MAE Change	Incremental Profit (100 MW)
MISO	-0.33 %pt	$4,191 / yr

- 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

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PJM Market Summary

Expected pay/value for different forecasting errors - PJM

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

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Market Comparison – Incremental Value

Country / Market	Market Type	Forecast MAE Today	Pay/Value Ratio Today	Incremental Value Metric ($ / 100 MW / -1.0 %pt MAE / yr)
India:				
CERC	RT	10.5%	0.977	79,794
Karnataka	RT	10.5%	0.966	131,044
Gujarat	RT	10.5%	0.964	123,339
Nord Pool:				
Denmark	DA	10.1%	0.973	34,290
Sweden	DA	8.4%	0.981	20,890
Germany	RT	6.6%	1.00015	17,050
USA:				
PJM	DA	10.6%	0.961	20,240
MISO	RT	3.3%	0.969	12,700

Conclusions

- For market participants, the incremental value of more accurate wind power forecasting under current market rules is rather meager*.
    - Typical imbalance charges are clustered near 3% (pay/value ~0.97).
    - Incentive to invest in more accurate forecasting is currently small.

- System operators should apply imbalance charges that are sufficiently high enough to cover the increased regulation costs and also incentivize more accurate forecasting.
    - However, charges that are too large will act to discourage wind participation.

- <u>POLICY CHALLENGE:</u> 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

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Thank You

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