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Evaluation of Wind Power Forecasting Technologies

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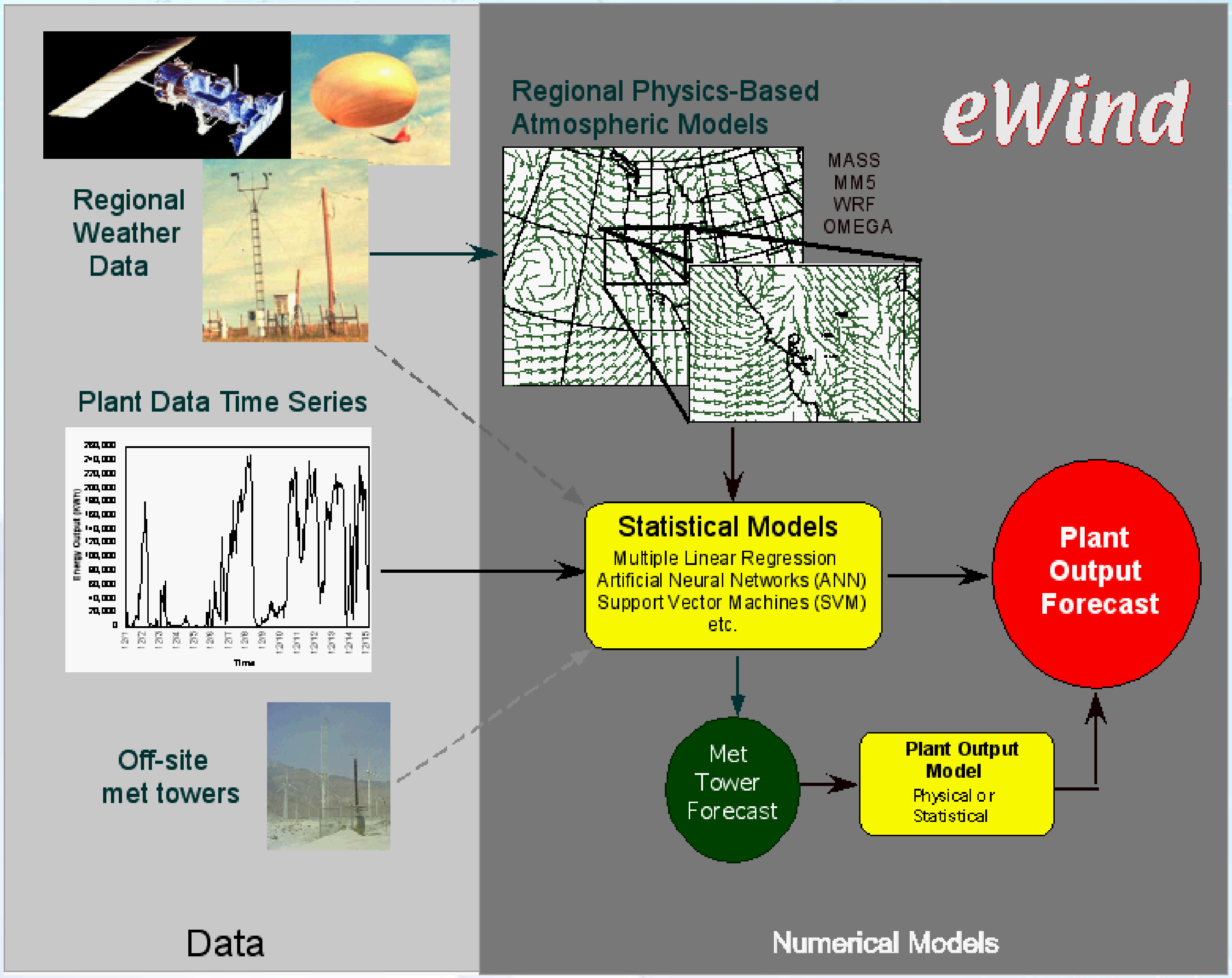
Overview

- Forecasting Tools
- Forecast Evaluation
- Estimated NY Forecast Performance
- Forecast System Design Considerations
- Deployment Strategies for Met Equipment
- Instrumentation and Communications

Forecasting Tools



Forecast Evaluation

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- Many metrics exist to evaluate forecast performance
  - Median error
  - Mean absolute error
  - Error distribution parameters
  - Correlation coefficient (forecasted to reported)
  - Skill score (% improvement) relative to a reference forecast
- Forecast system can be tuned to a specific metric
- Which metric should be used?
  - Should be related to the user's cost function
  - Should provide appropriate incentive to forecast provider

Estimated NY Forecast Performance

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- Based on Madison wind plant data
  - 11.55 MW Capacity (7 Vestas 1.65 MW turbines)
  - Simulated forecasts produced for Jan to Dec 2002
- "Day-Ahead" forecasts
  - Simulated delivery at 4 AM each day
  - 44-hr forecast period (HE 5 AM to HE midnight of next day)
  - Next-day period is 21 to 44 hr ahead forecast
- "Hour-Ahead" forecasts
  - Simulated delivery at 15 minute intervals
  - Forecasts of the 15-minute average power output for the next 4 hours
  - 16 forecast intervals per forecast

Day-Ahead Forecast Overall Performance
Annual Statistics and Error Distribution

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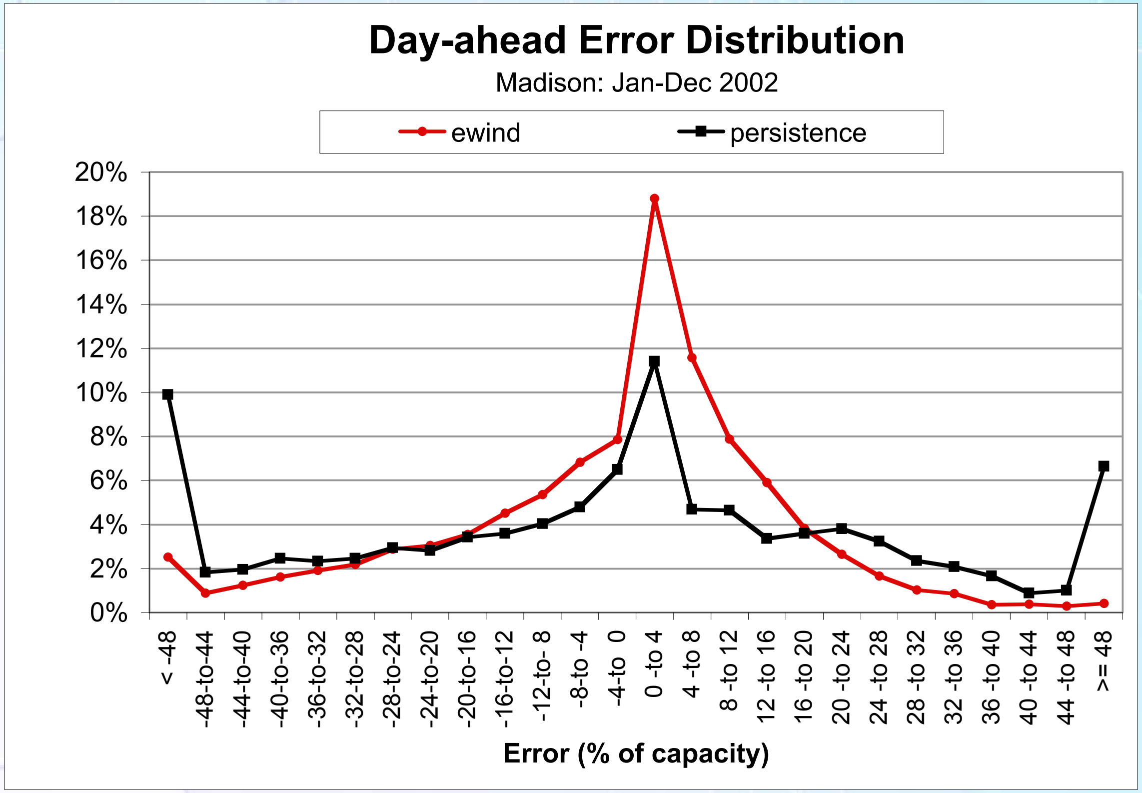
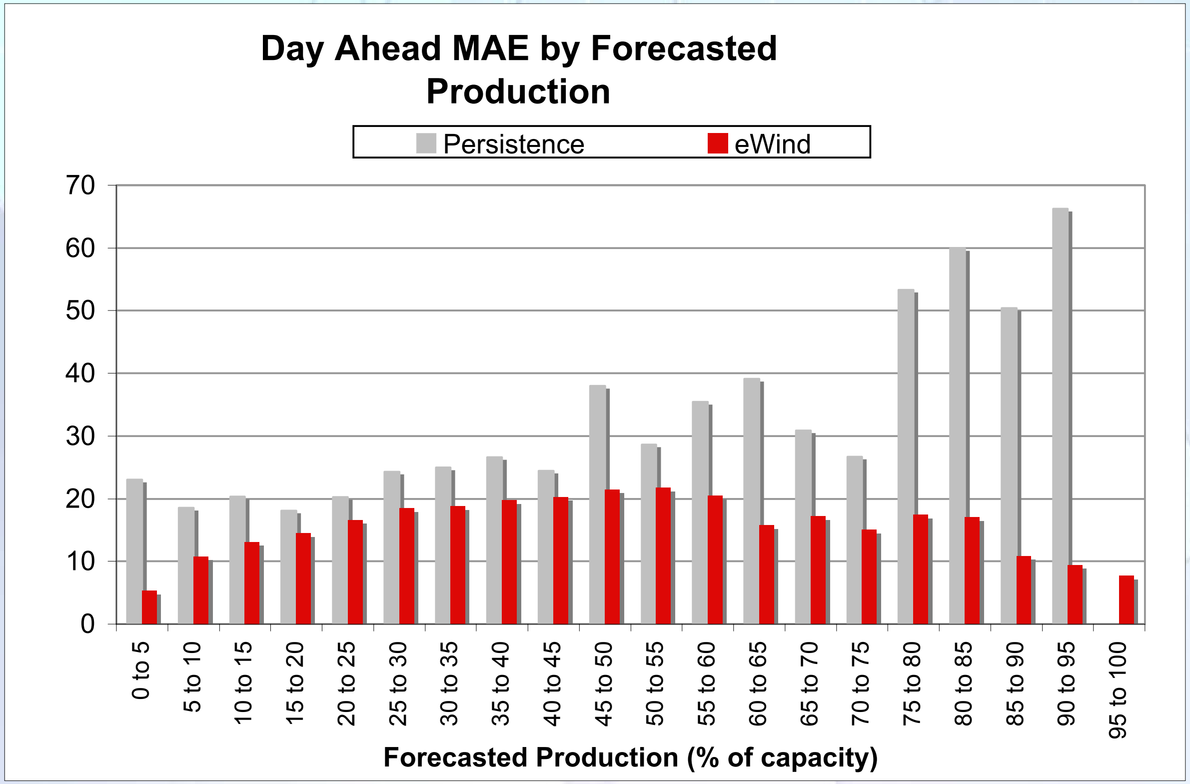
Annual Performance Statistics

Median Error
9.7%
Mean Absolute Error
13.6%
Persistence MAE
25.2%
Skill vs. Persistence
46.1%

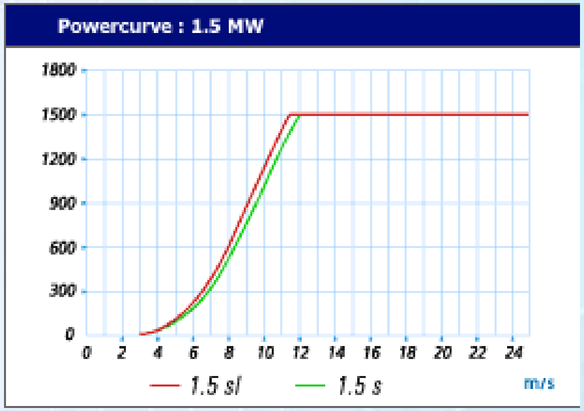


Day-Ahead Performance Variability: MAE by Forecasted Production

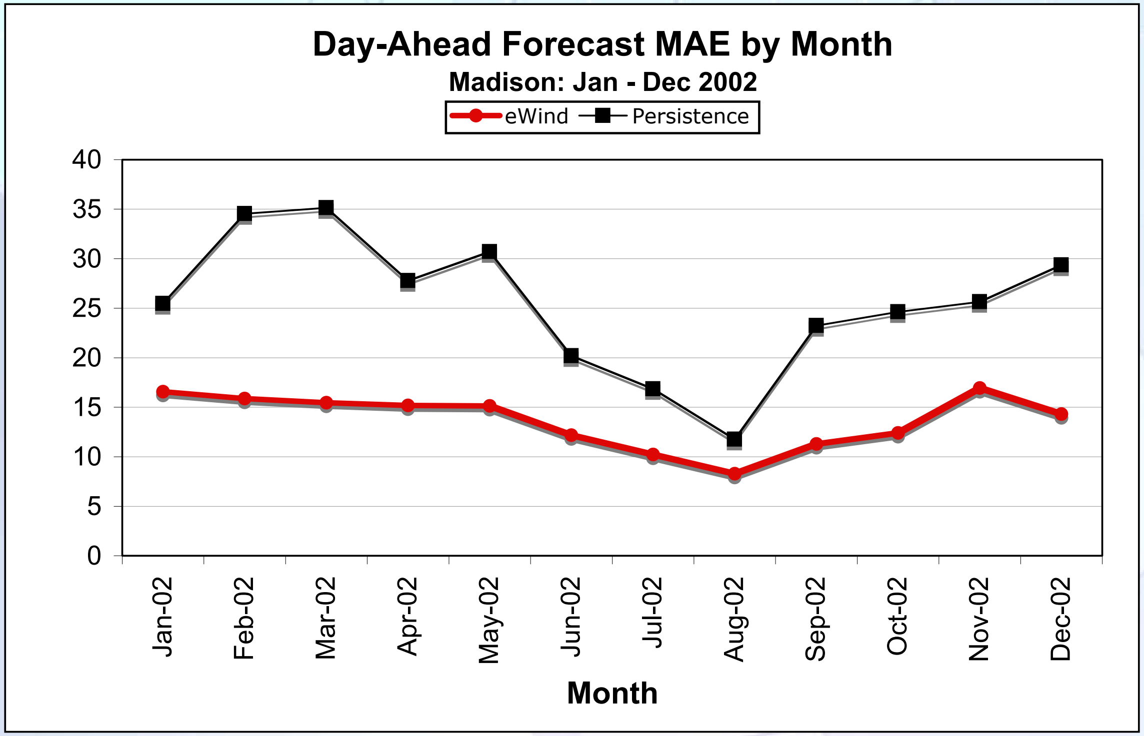


- Sensitivity to wind speed errors varies with position on the power curve

- **Result**: eWind MAE is strongly linked to the forecasted production



Day-Ahead Performance Variability: MAE by Month

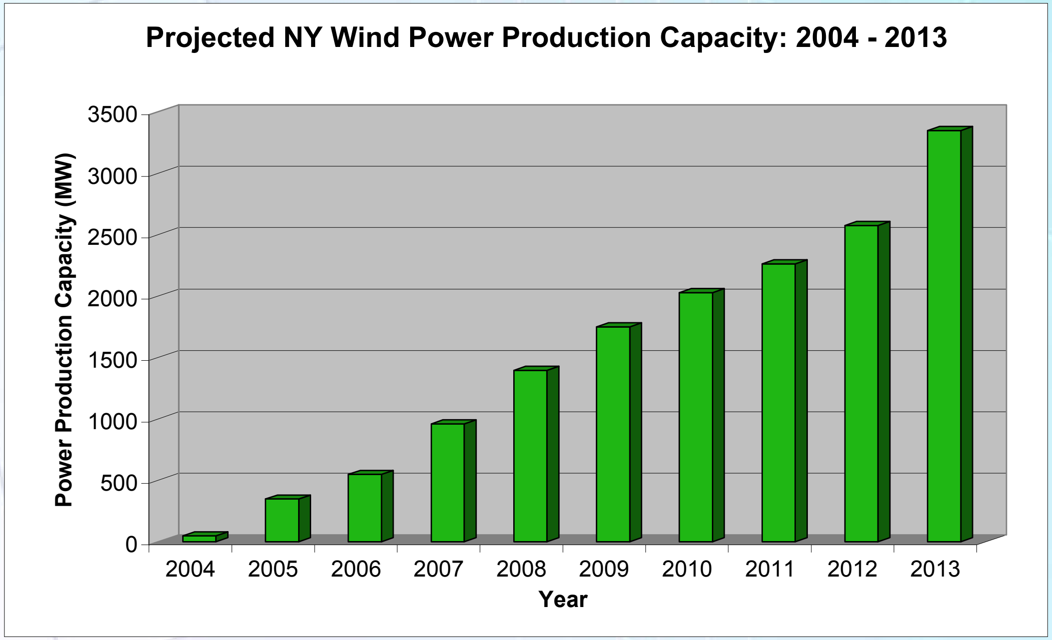


- MAE is higher in the cold season and lower in the warm season

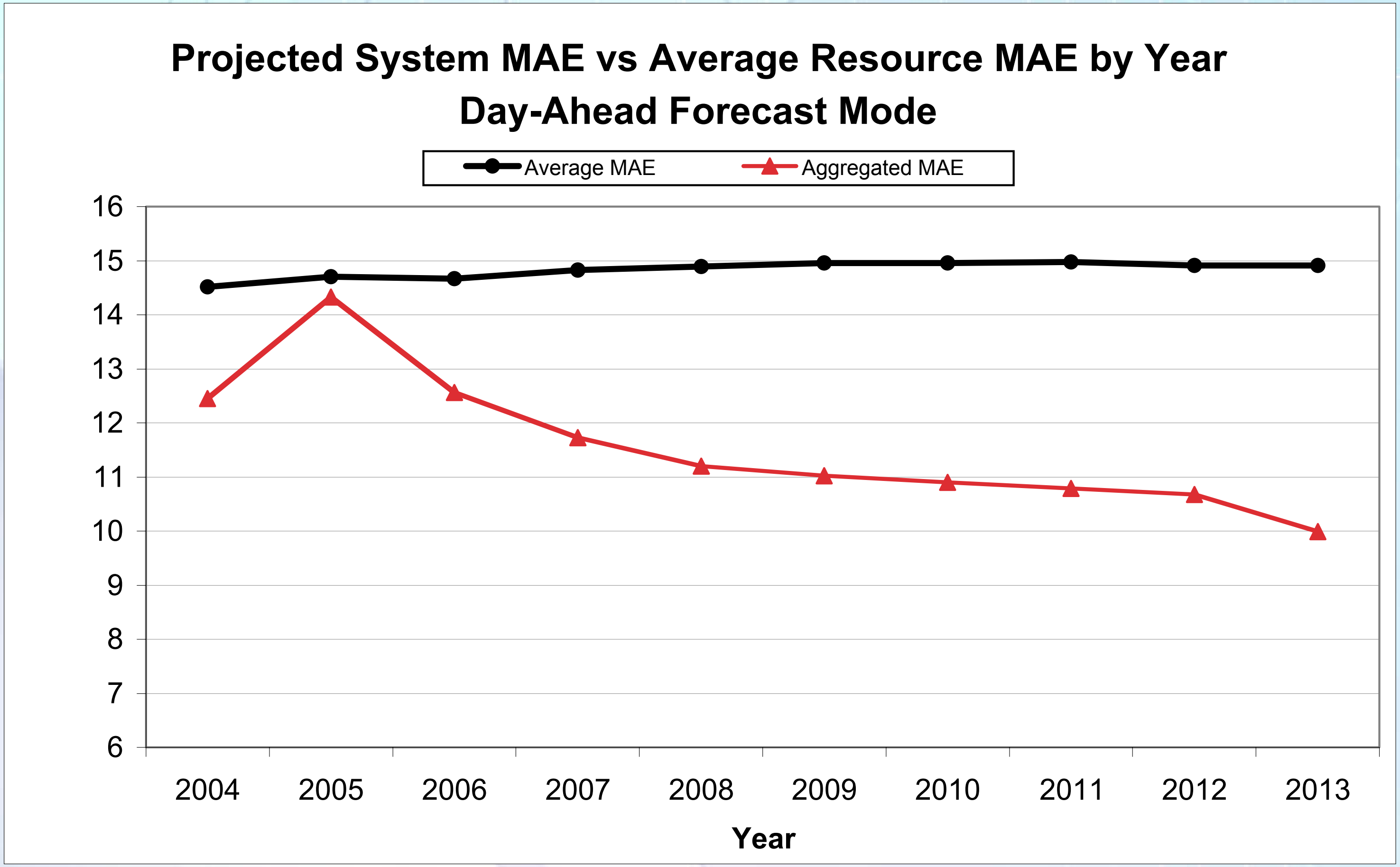
- **Primary Reason:** Differences in the distribution of hours along the power curve between the cold and warm seasons

Projected System-wide Day-Ahead Forecast Performance

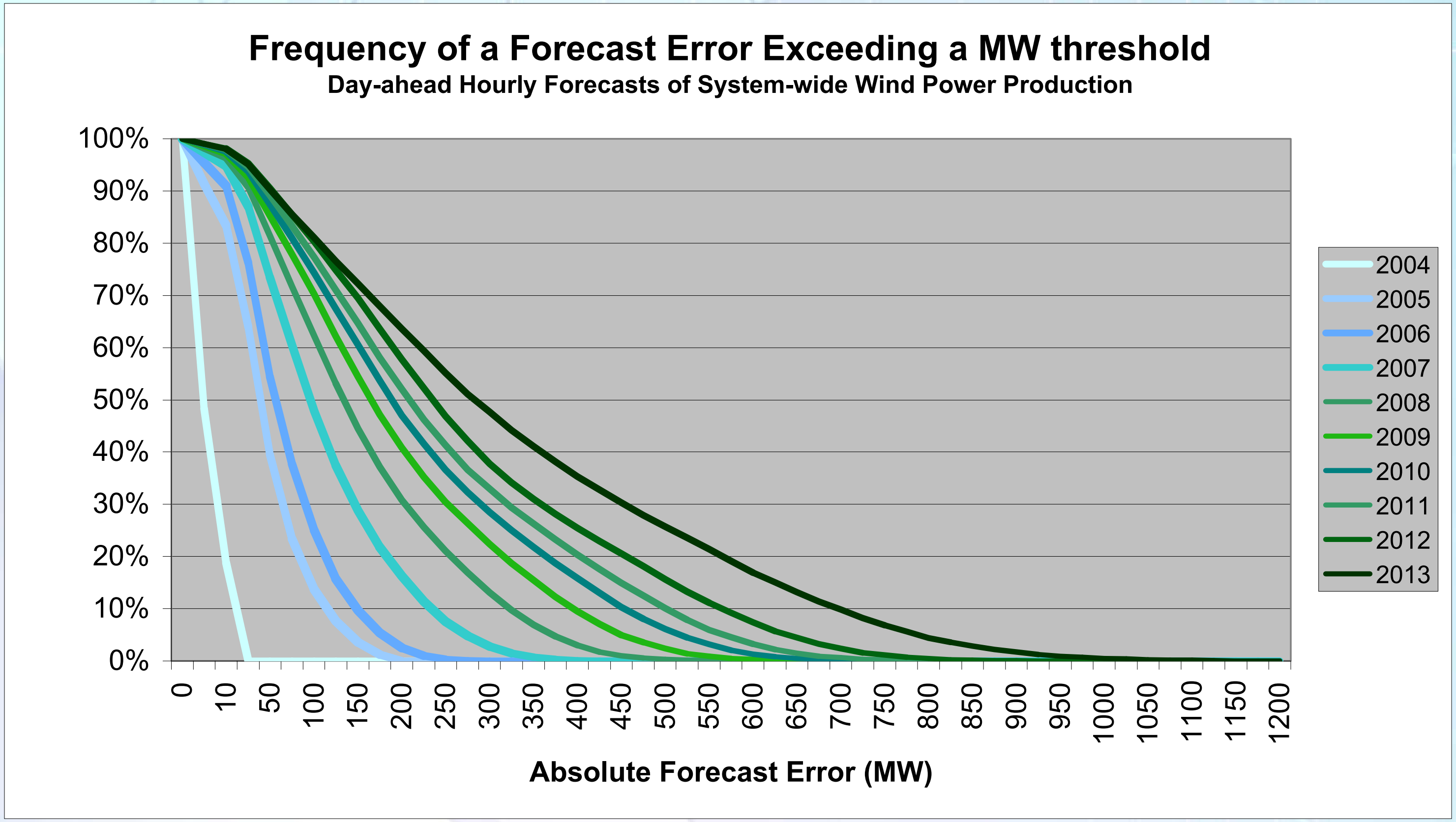
- Amount and distribution of wind plant development based on assumptions similar to those in GE study
- Hourly errors for each hypothetical wind plant are estimated from:
  - 2002 Madison error distributions & magnitudes
  - Numerical simulations of hourly winds for each site



System-wide Day-Ahead Forecast Errors: System MAE vs. Average Resource MAE



Projected System-wide Day-Ahead Forecast Absolute Error Distribution by Year



Hour-Ahead Forecast Overall Performance
Annual Performance Statistics

Hour 1 (0-60 min)

(four 15-min intervals)

MAE

5.7%

Skill (vs. Persistence)

5.1%

Hour 4 (180-240 min)

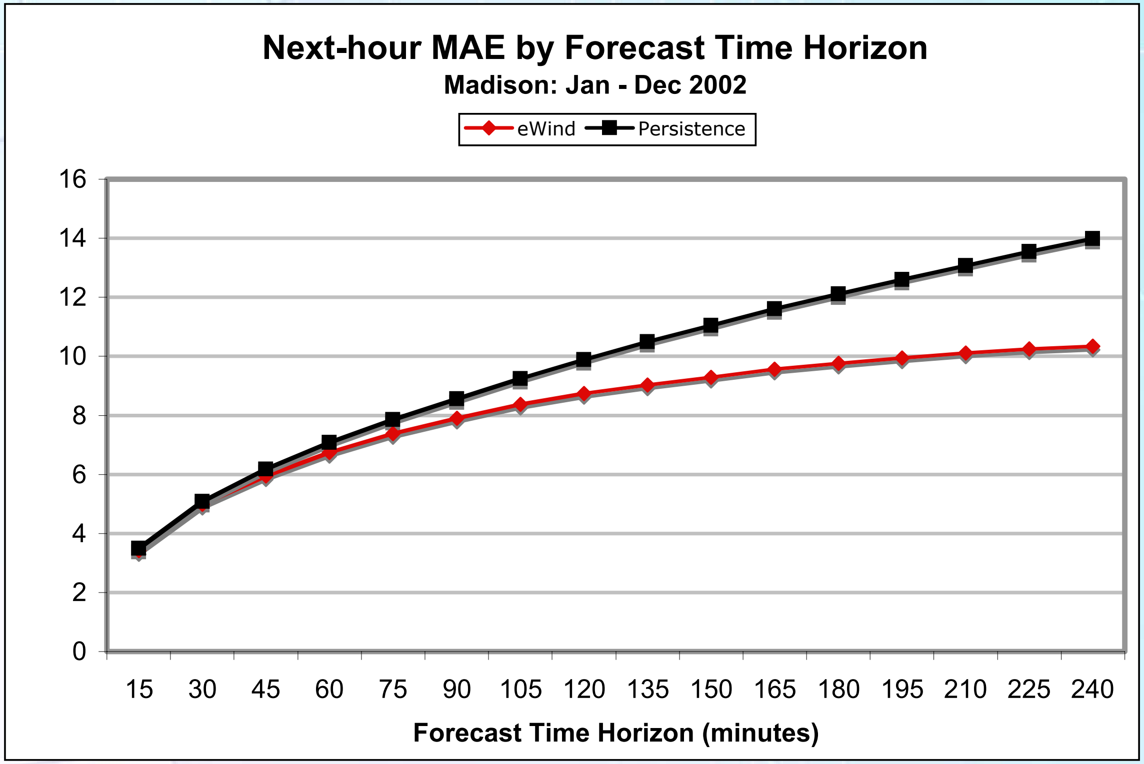
(four 15-min intervals)

MAE

10.1%

Skill (vs. Persistence)

22.3%



Hour-Ahead Forecast Overall Performance: Annual Error Distributions

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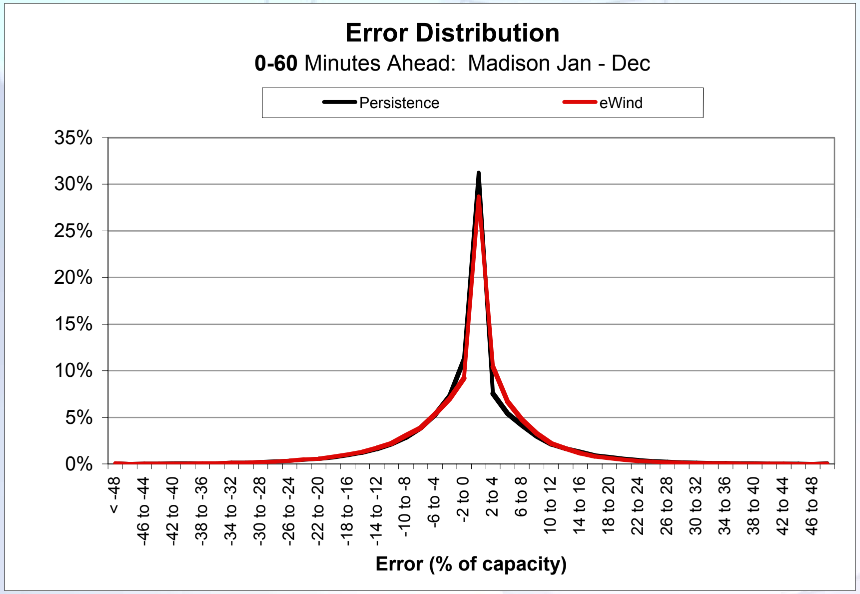
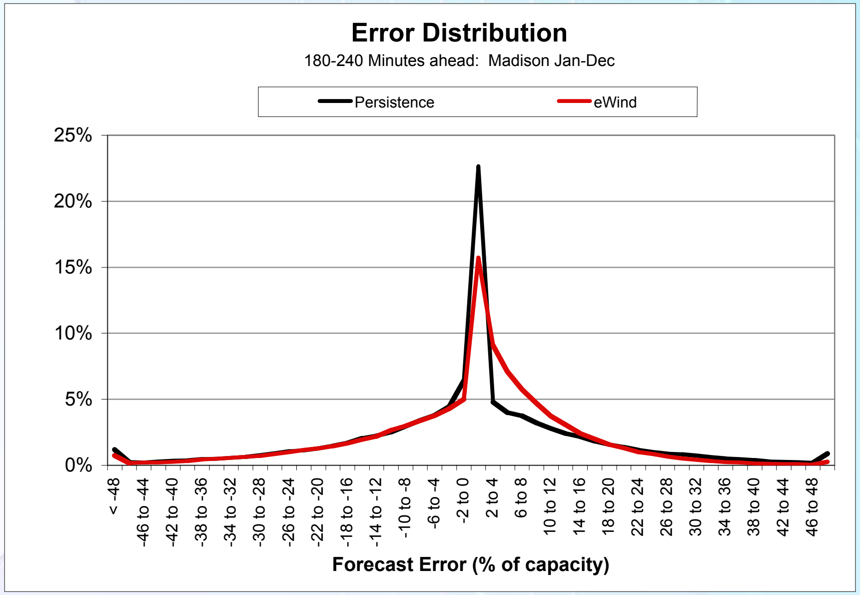
Hour 1: 0-60 min

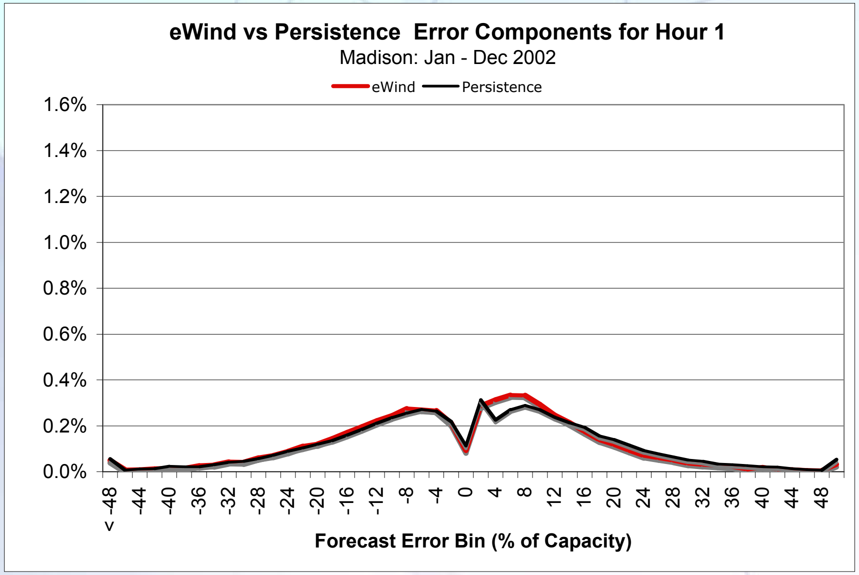


Hour 4: 180-240 min

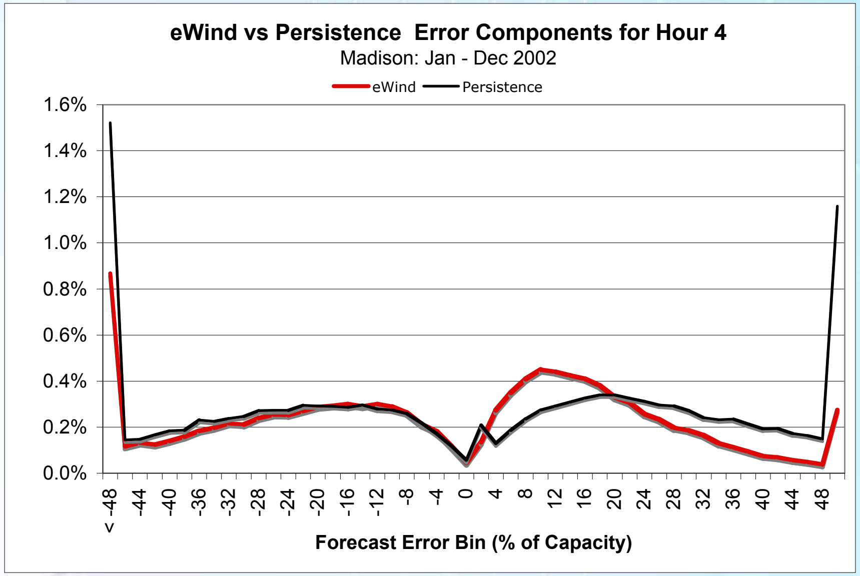


Hour-Ahead Forecast Overall Performance Contribution to the Annual MAE

Hour 1: 0-60 min
eWind MAE: 5.7% Skill:5.1%



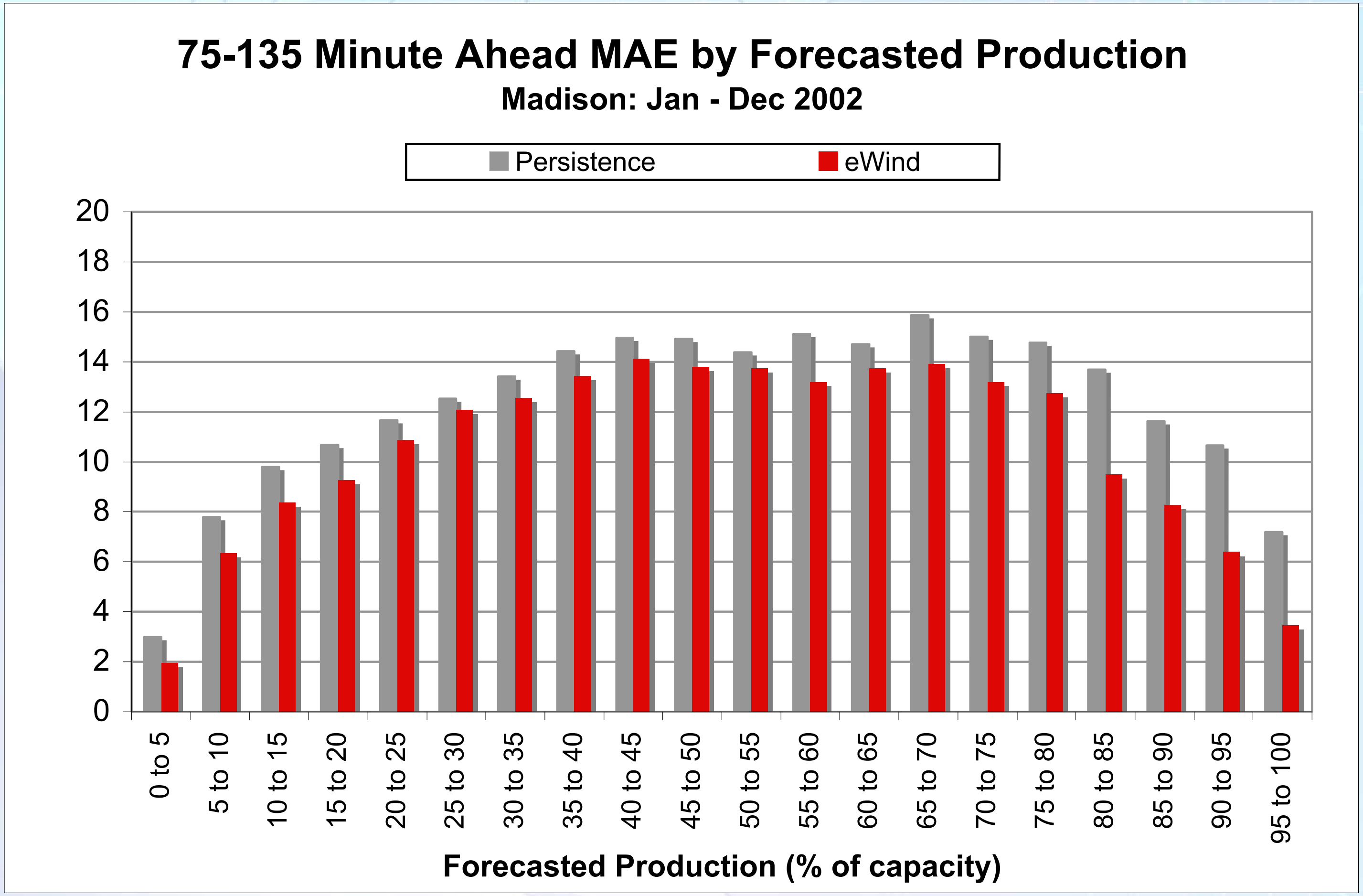
Hour 4: 180-240 min
eWind MAE: 10.1% Skill:22.3%



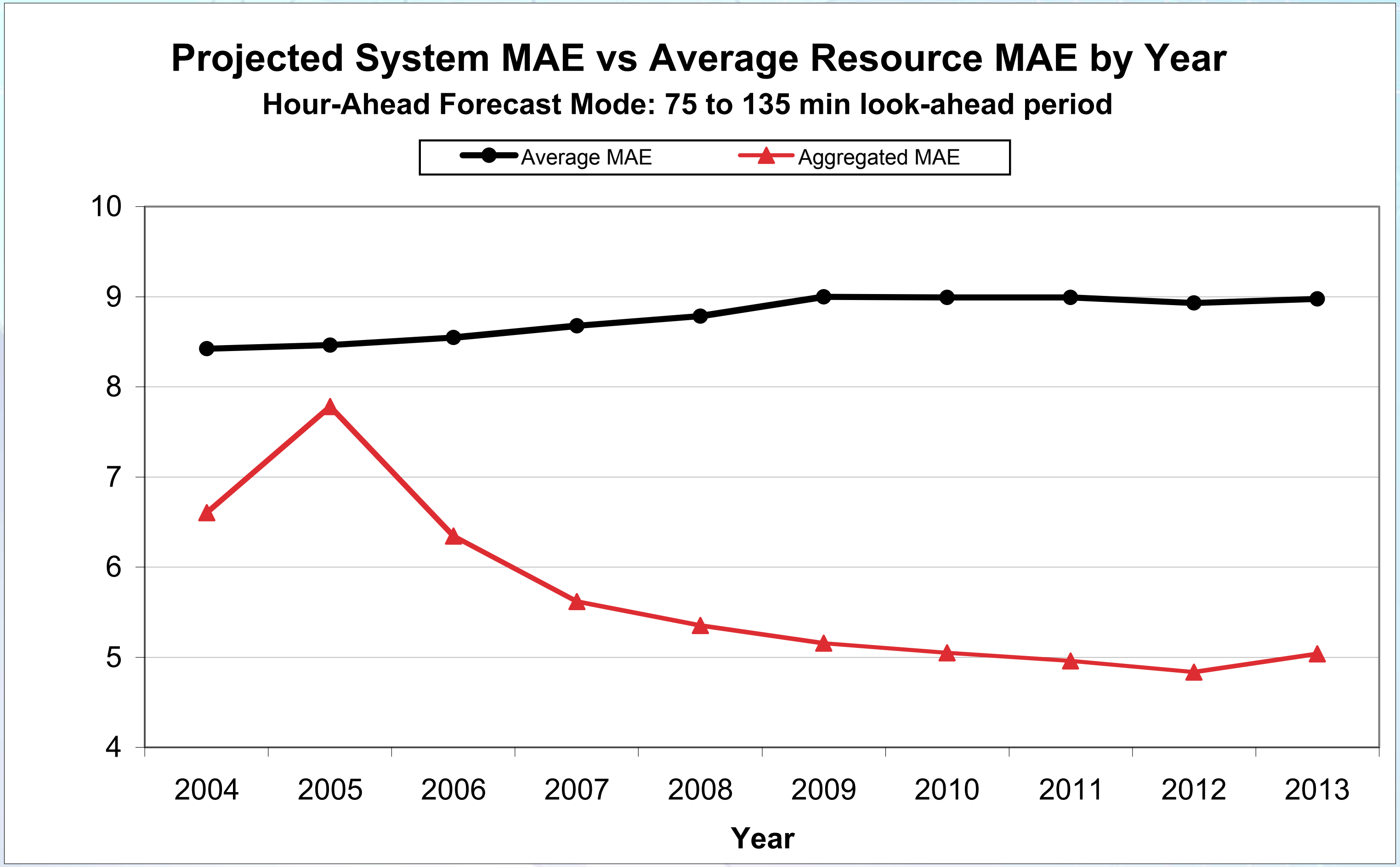
Note: Area under the curve is the annual MAE for each method

eWind skill is attributable to the reduction in the frequency of large errors, especially large positive ones (i.e. overpredictions)

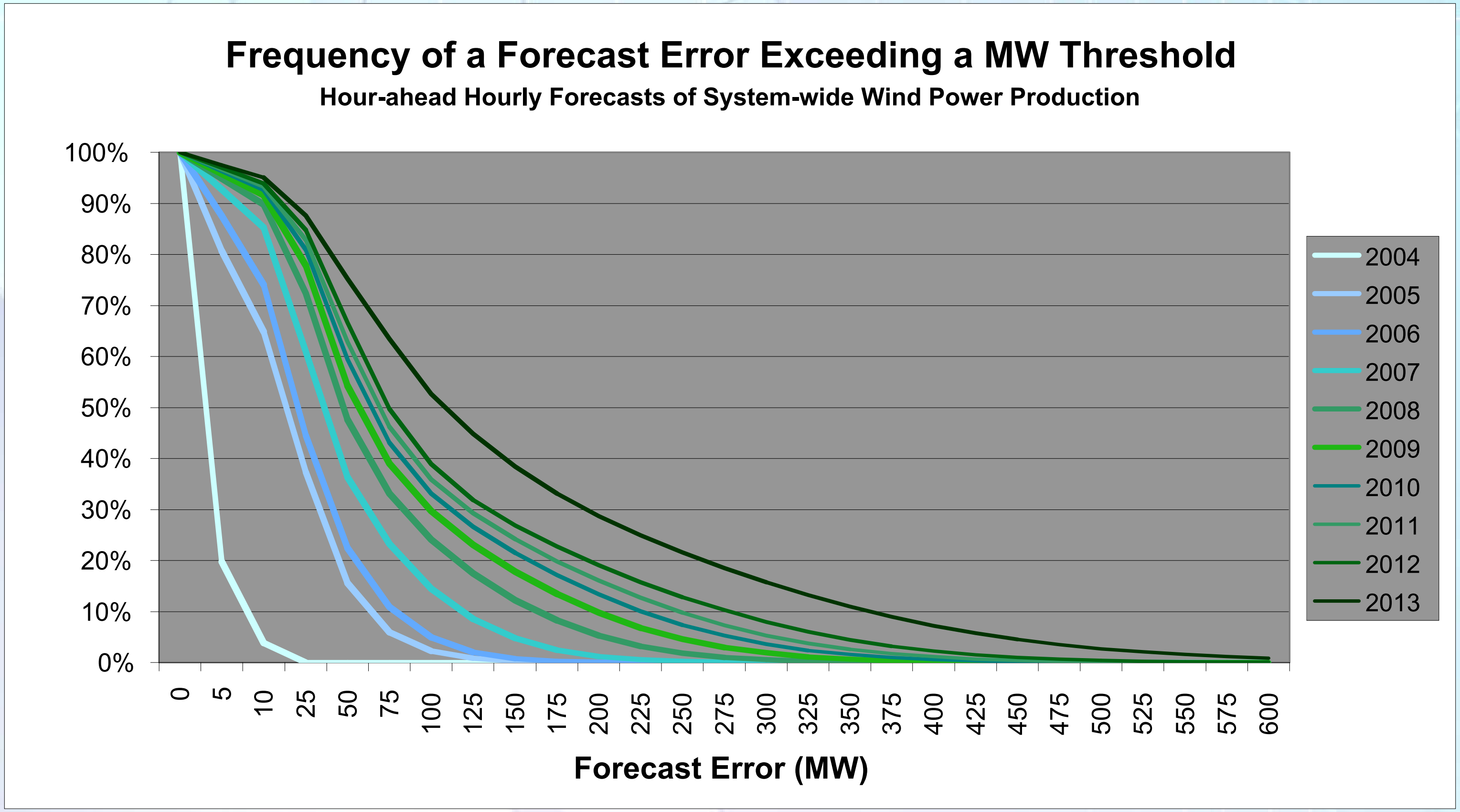
Hour-Ahead Performance Variability: MAE by Forecasted Production



System-wide Hour-Ahead Forecast Errors: System-wide MAE vs. Average Resource MAE



Projected System-wide Hour-Ahead Forecast Absolute Error Distribution by Year



Forecast System Design Factors

- Collection of input data
- Quality control of data
- Sharing of data in forecast production
- Data security
- Level of forecast delivery reliability
- Economies of scale in forecast production
- Forecast performance requirements and incentives
- Provision for Ongoing Research

These factors will determine the cost and the forecast performance level of the system

Alternative Forecast System Configurations

- Options for centralized system operated by NYISO
  - Forecast provider gathers measurement data from resources
  - NYISO gathers measurement data from resources and relays it to the forecast provider
  - Provider sends forecasts to NYISO
  - Provider sends forecasts to resources
- Centralized system operated by forecast provider
  - Provider gathers all data and sends forecasts to all users
- Decentralized system
  - Each wind farm schedules with its own forecast

AWST's recommendation based on experience with CAISO's PIRP and other systems is highlighted in red

Alternative Forecast System Configurations:
Important Considerations for a Centralized System

- Wind farms should have a strong incentive to maintain a reliable and high quality flow of production and meteorological data
- Data quality control rules should be clearly defined and known by all participating parties and the data providers should receive timely and clear feedback on the quality of their data
- There should be an efficient and effective channel of real-time communication between the forecast provider and the data collection entities (e.g. wind farms) regarding data outage and quality issues
- There should be a formal mechanism (such as periodic workshops) for the forecast provider, NYISO and wind farm schedulers/operators to address issues and questions

Deployment Strategies for Meteorological Equipment: Data Use Concepts

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- Three roles of onsite & offsite data in forecasting
  - (1) Define relationship between meteorological parameters and concurrent power production
  - (2) Determine systematic errors in the forecasts and provides a basis for statistically correcting them
  - (3) Specify current and recent state of the atmosphere to serve as a starting point for the forecasts
- Onsite vs. offsite data
  - Onsite data can be used in roles 1,2 and 3
  - Offsite data can only be used in role 3
- Value of data for role 3 varies with space & time scales
  - Forecast look-ahead time scale
  - Spatial scale of off-site observation points

Deployment Strategies for Meteorological Equipment: Nearby Offsite Data

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- "Hour-ahead" (0-6 hours) forecasts
  - Well-located offsite data can improve forecast performance
  - Optimal offsite locations depend on:
    - Forecast look-ahead period
    - Meteorological relationship of observing site to forecast site
  - Optimal location can be found with physics-based models
    - Generate a sample of simulations for region around wind plant
    - Use simulation data to find locations with most predictive power
- "Day-ahead" (1-2 days) forecasts
  - Nearby offsite data has little benefit for forecast performance
  - Information is required from much more distant locations

Instrumentation and Communication Requirements: Roles of Each Entity

- Wind Farms
  - Reliably collect high quality production and met data at the farm
  - Communicate the data to NYISO & forecast provider
- Forecast Provider
  - Assemble comprehensive set of input data for the forecast process
  - Produce the forecasts
  - Disseminate the forecasts in a timely & secure manner
- NYISO
  - Receive and use forecasts for grid & market management
  - Act as conduit for data from farms to forecast provider

These roles determine the hardware, software and communication requirements for each entity

Key Points - Part 1

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- Forecast Tools
  - Forecasts are produced with both physics-based and statistical models using a diverse mix of onsite, offsite and regional data
- Forecast Evaluation
  - Forecast system can be tuned to optimize performance for a specific performance metric
- Forecast Performance
  - Likely performance range for **individual** wind plants in NY:
    - Day-ahead: MAE 13 to 20% Skill 30% to 60%
    - 4-hours ahead: MAE 8% to 12% Skill 10% to 30%
    - 1-hour ahead: MAE 4% to 7% Skill 5% to 15%
  - System-wide forecasts will achieve a 2% to 5% lower MAE once a geographically diverse mix of plants with significant capacity are in operation

Key Points - Part 2

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- Forecast System Design
  - It is critical that the forecast system be designed to maximize the and quality and reliable communication of wind plant production and meteorological data
  - Efficient and effective communication between data providers (wind farms) and the forecast provider is important
- Deployment Strategies for Meteorological Equipment
  - Well-located offsite meteorological towers may have a substantial benefit for 0 to 6 hr forecasts but have little value for day-ahead and longer periods.
- Prospects for Future Forecast Improvement
  - New space-based remote sensing systems have the potential to produce a substantial improvement in forecasts in 5 to 10 years