

Forecasting for Utility-Scale Wind Farms: The Power Model Challenge

Craig Collier, Garrad Hassan America, Inc.

Jonathan Collins, Garrad Hassan & Partners Ltd.

Jeremy Parkes, Garrad Hassan & Partners Ltd.



Bonneville Power Administration / California ISO

International Wind Forecasting Workshop

Portland, Oregon

July 24-25, 2008

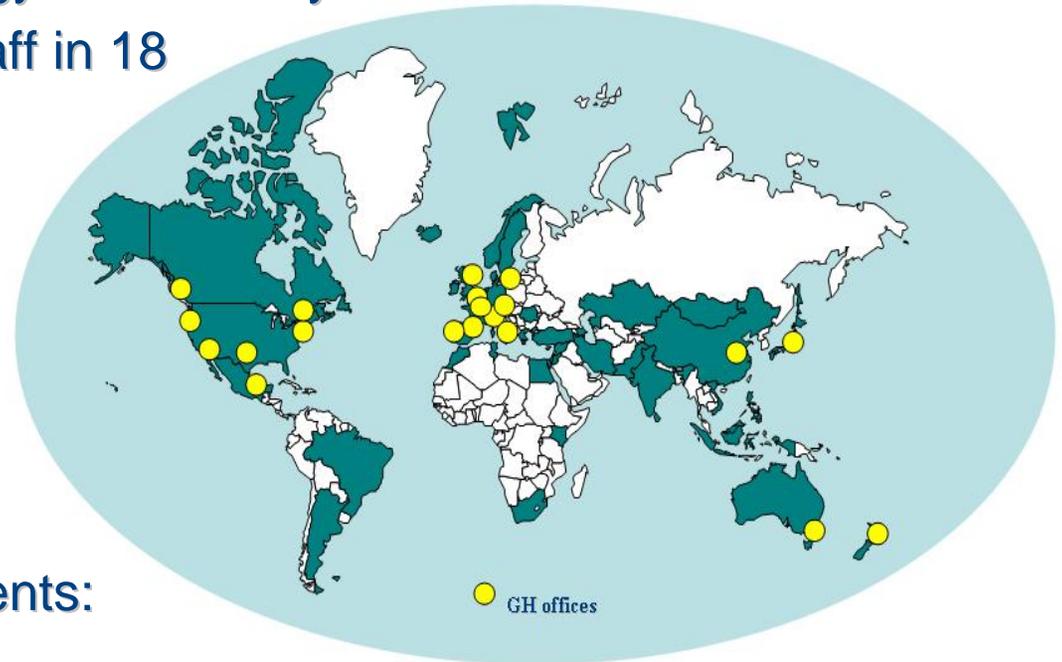
Contents

- Brief introduction to Garrad Hassan
- Forecasting Method
- Basic and Advanced Methods of Power Curve Modeling
- Effects on Forecast Accuracy
- Benefits for Forecast Certainty Estimates
- Conclusions



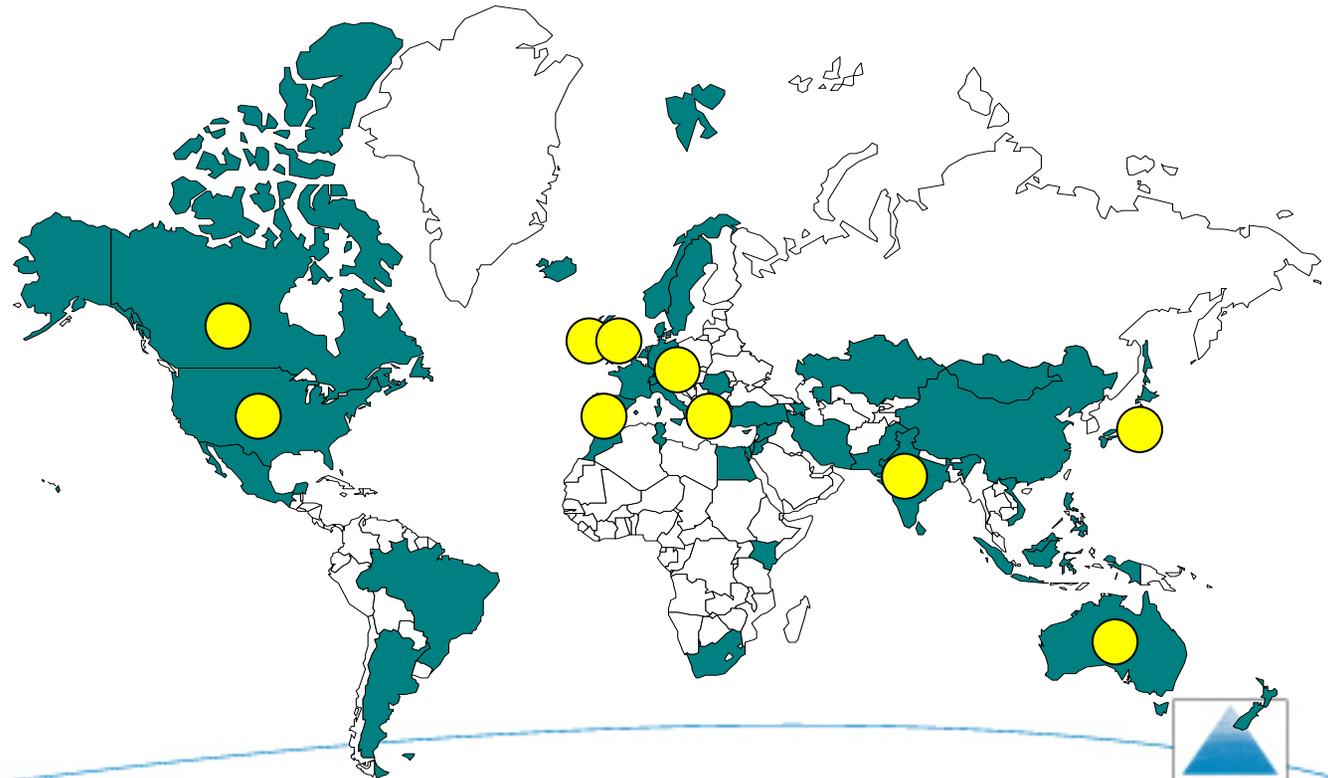
GARRAD HASSAN GROUP

- Independent renewable energy consultancy established 1984 with 270 staff in 18 countries
- Technical Advisor for 15 GW operational plant
- Wind Farm Energy Assessments: > 60 GW in 60 countries



- Forecasting began in a research framework in 2000, provided commercially as service in 2001 with assistance from the U.K. Meteorological Office.
- Currently, GH provides forecasting for wind farms in 10 countries on 4 continents, totaling more than 6.5 GW installed capacity globally:

1. Australia
2. Canada
3. Greece (all)
4. Hungary
5. India
6. Ireland
7. Japan
8. Spain
9. U.K.
10. U.S.A.



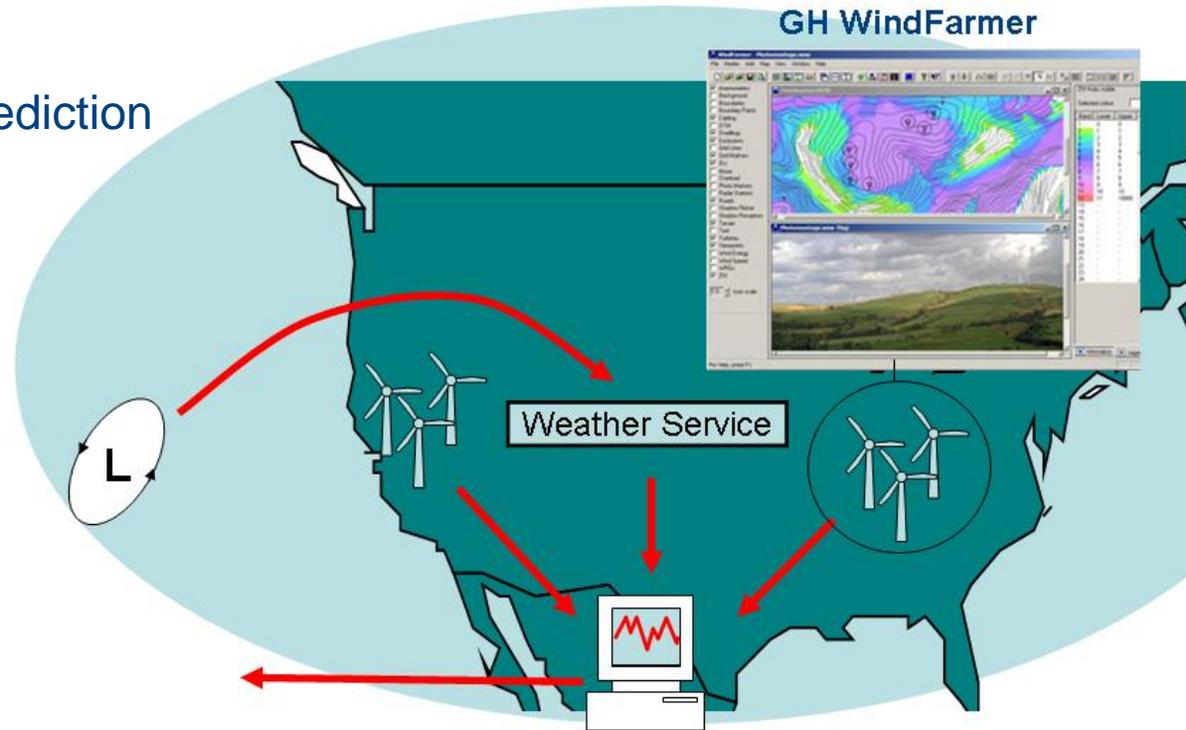
Overview of GH Forecasting Method

Inputs

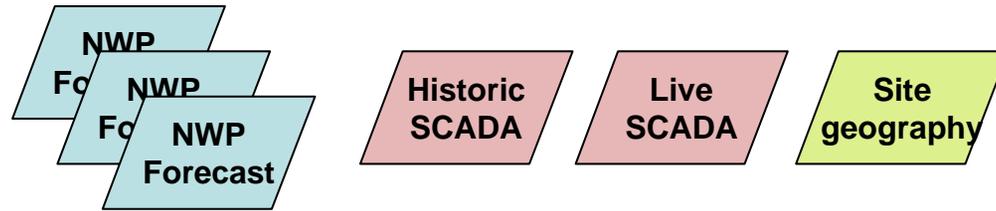
- Numerical Weather Prediction
- Site Topography
- SCADA System

Output

- Power Forecast

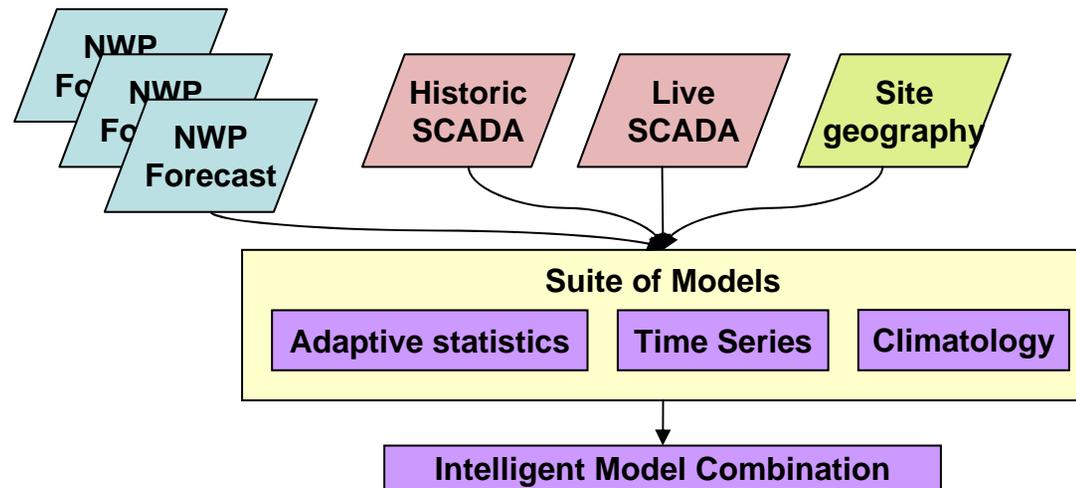


Forecasting Method



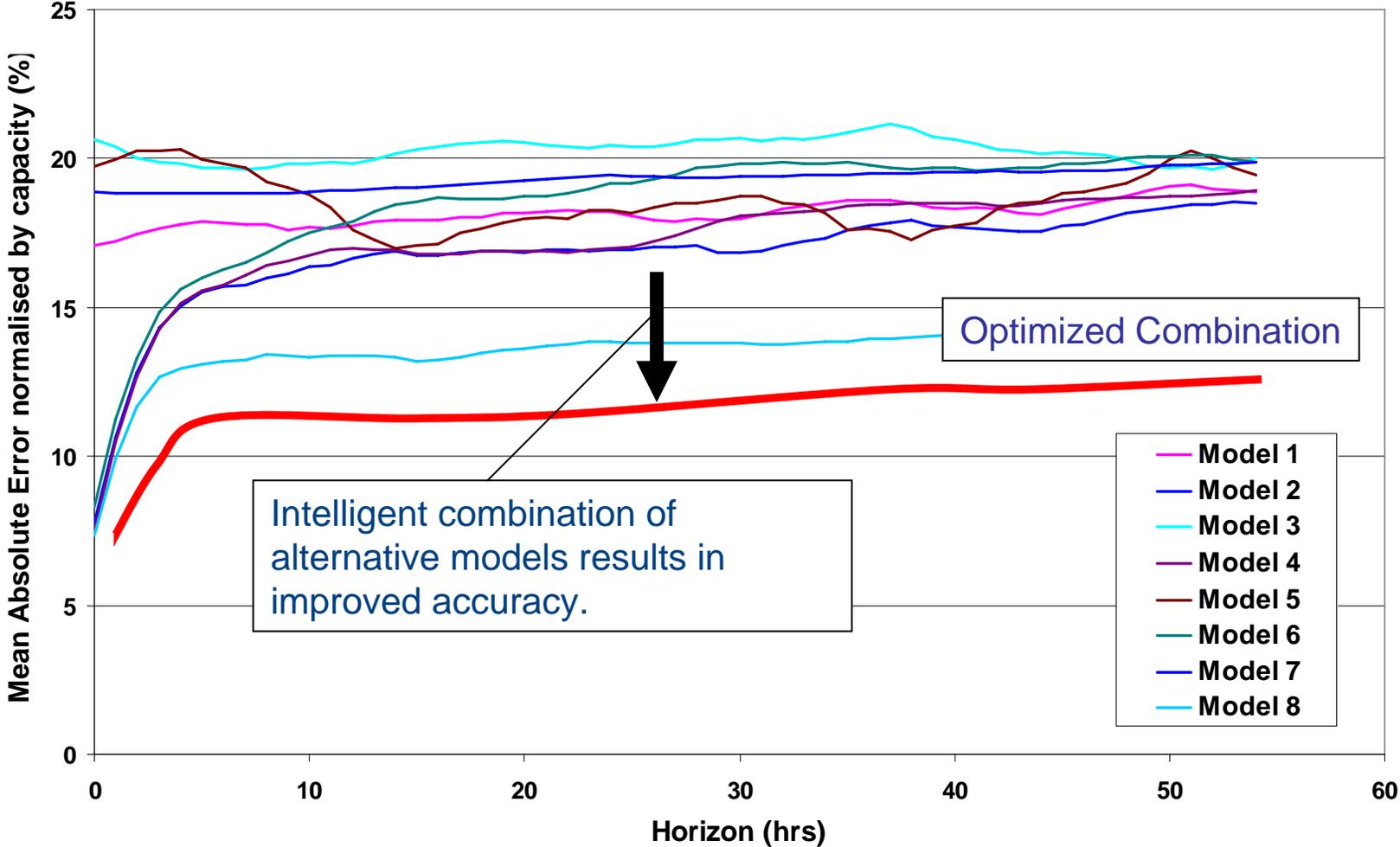
- Optimized combination of NWP suppliers
- Regular live feedback from the wind farm

Forecasting Method

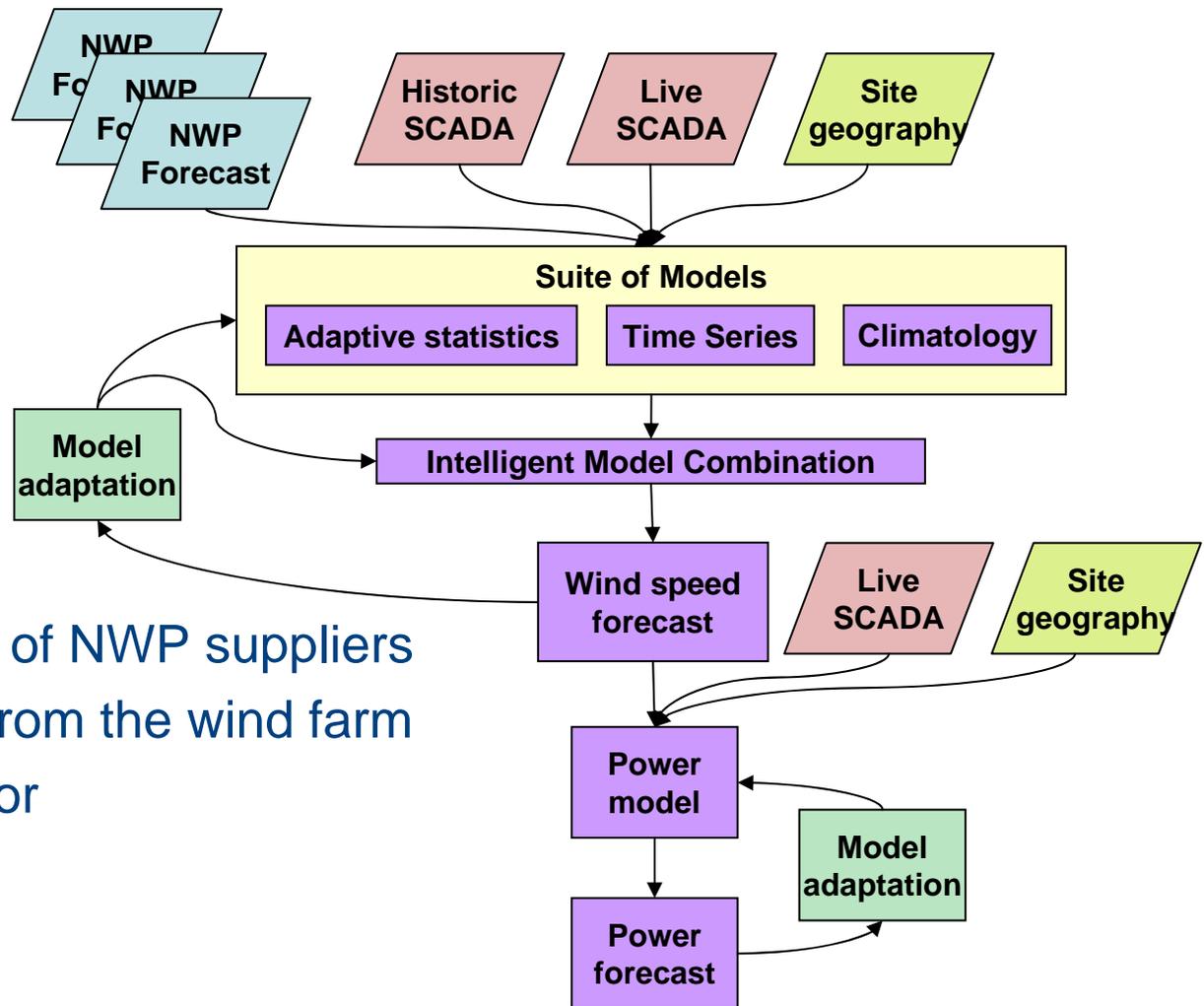


- Optimized combination of NWP suppliers
- Regular live feedback from the wind farm

Intelligent Model Combination

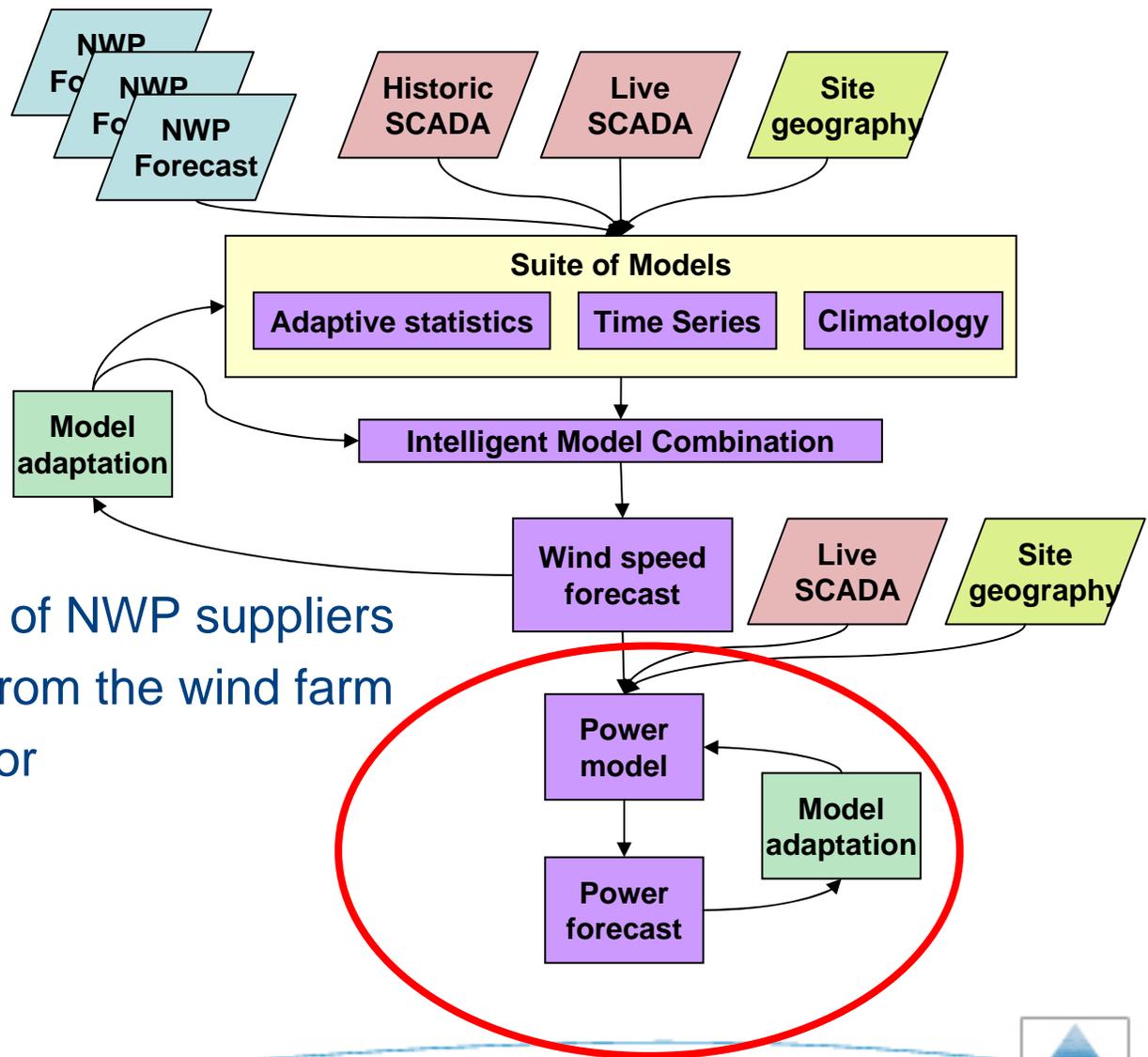


Forecasting Method



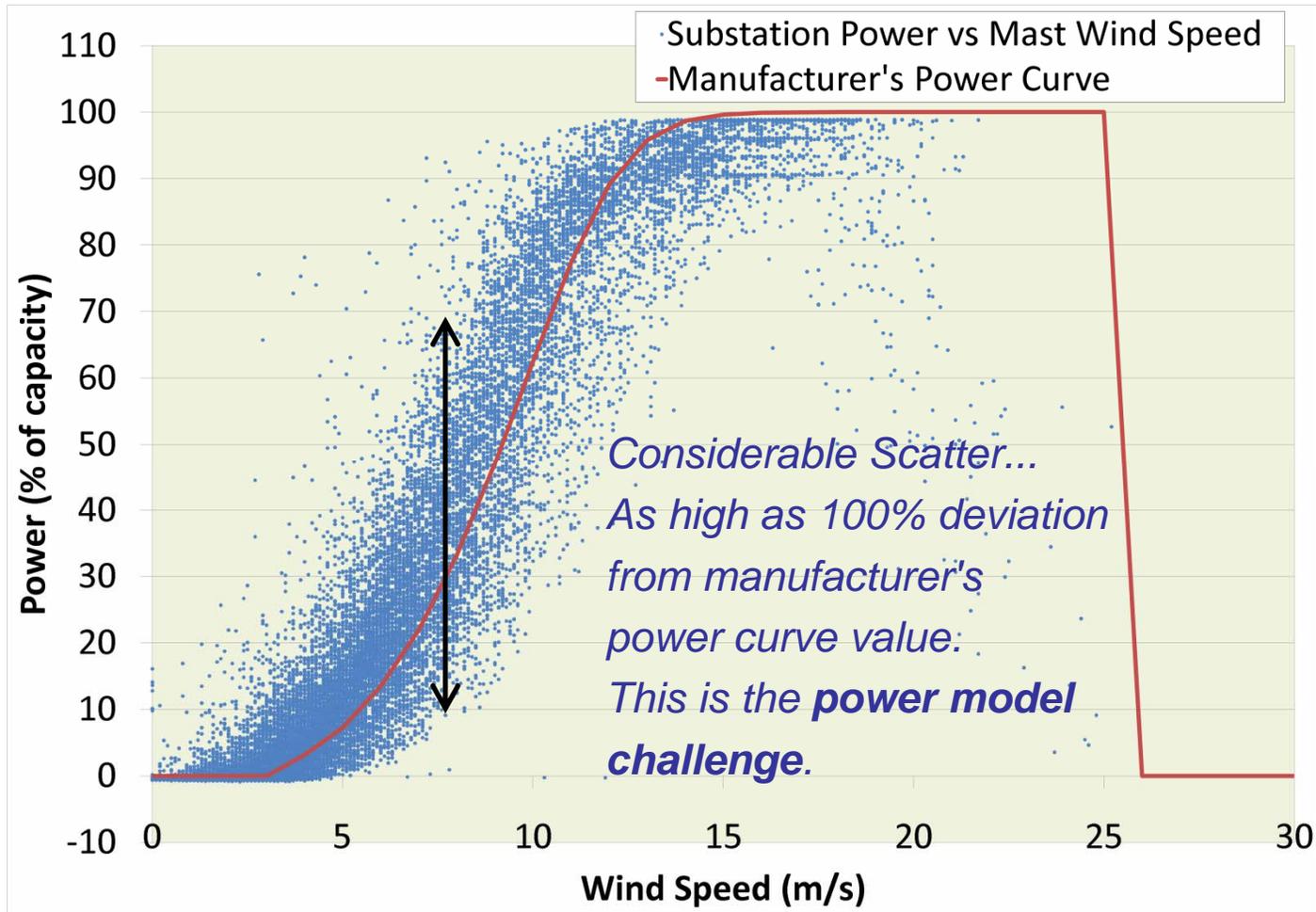
- Optimized combination of NWP suppliers
- Regular live feedback from the wind farm
- “Learning” Algorithms for
 - Meteorology
 - Power Models

Forecasting Method

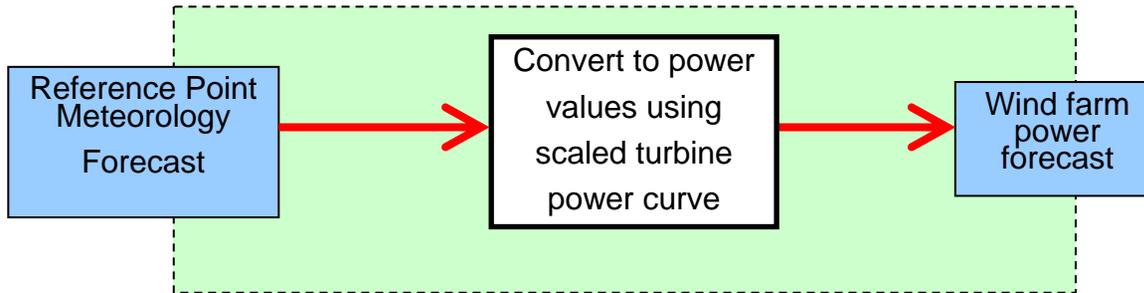


- Optimized combination of NWP suppliers
- Regular live feedback from the wind farm
- “Learning” Algorithms for
 - Meteorology
 - Power Models

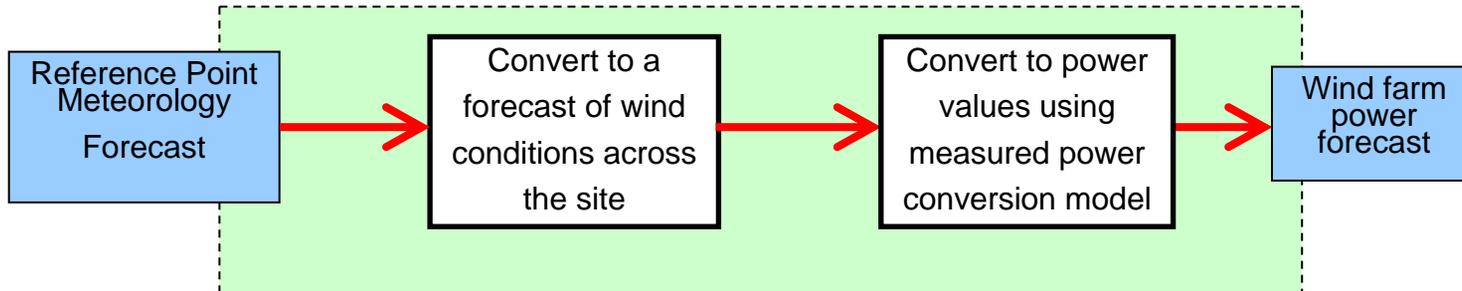
Always Possible to Scale Up to the Site a Manufacturer's Power Curve:



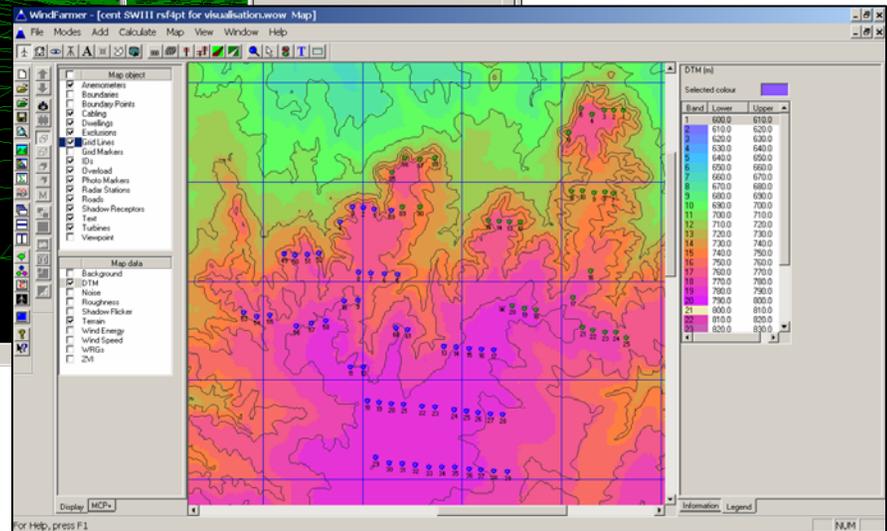
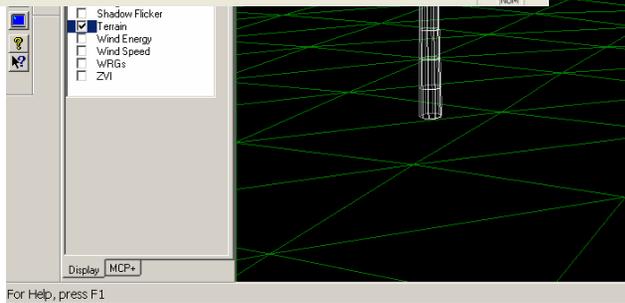
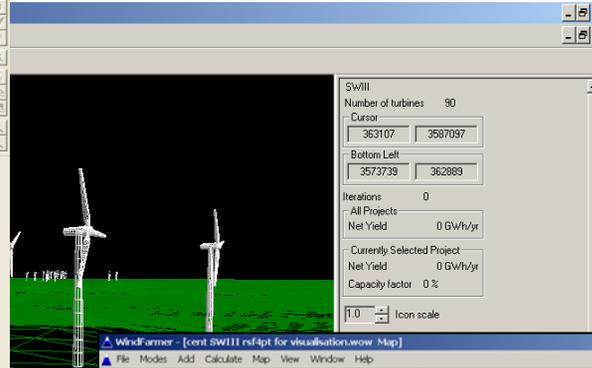
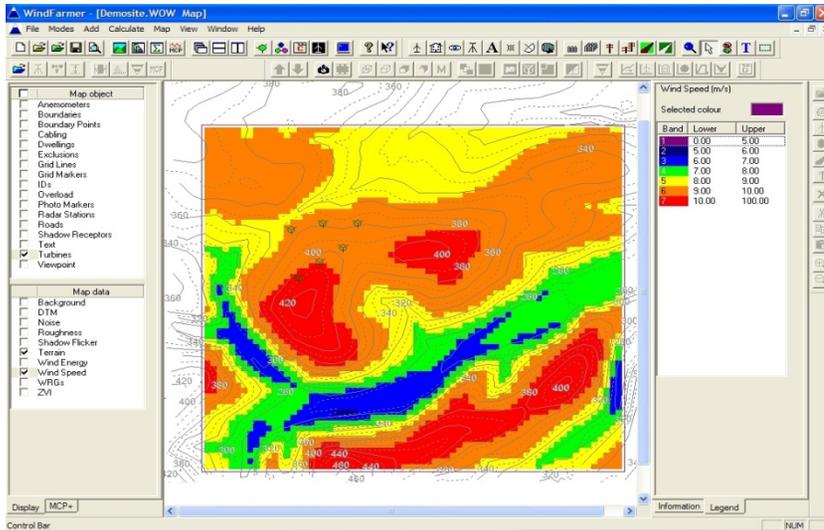
1.) The Basic Model



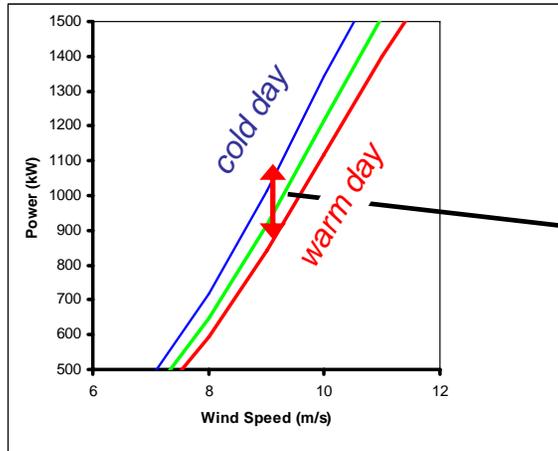
2.) The Advanced Model



- Accounts for Site / Topographical Wake Effects



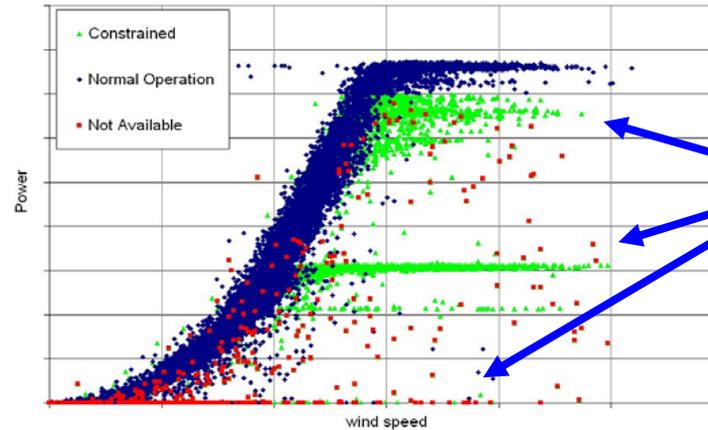
- Accounts for Density Differences



$$WS_{Corrected} = WS_{Forecast} \left(\frac{Forecast\ Density}{Reference\ Density} \right)^{1/3}$$

200 KW difference

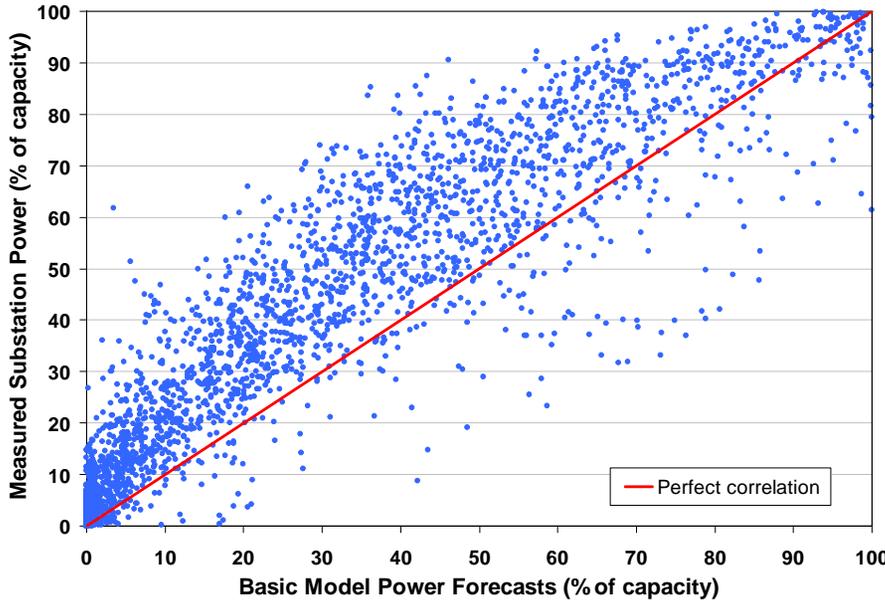
- Leverages measured on-site data



*Account for
anomalous situations*

Results

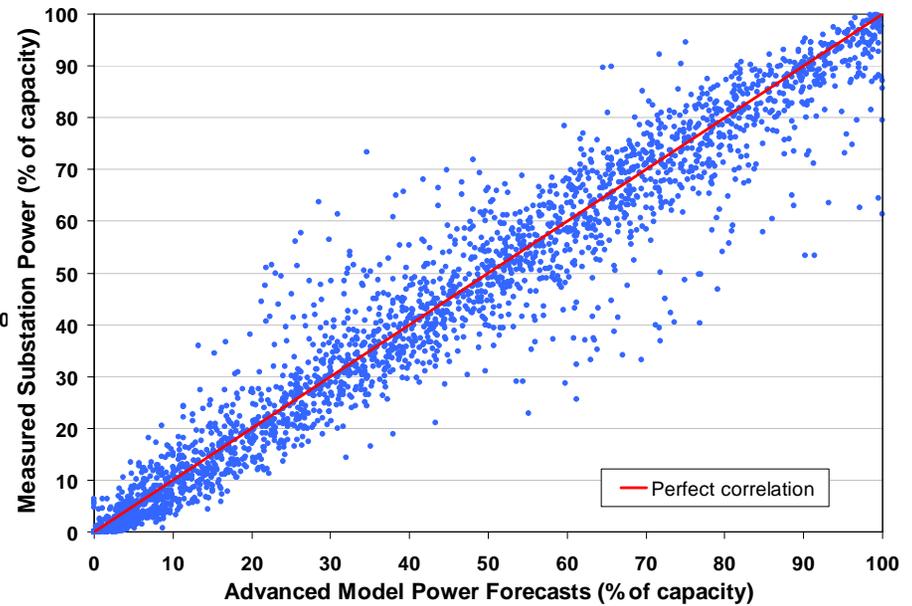
Basic Model



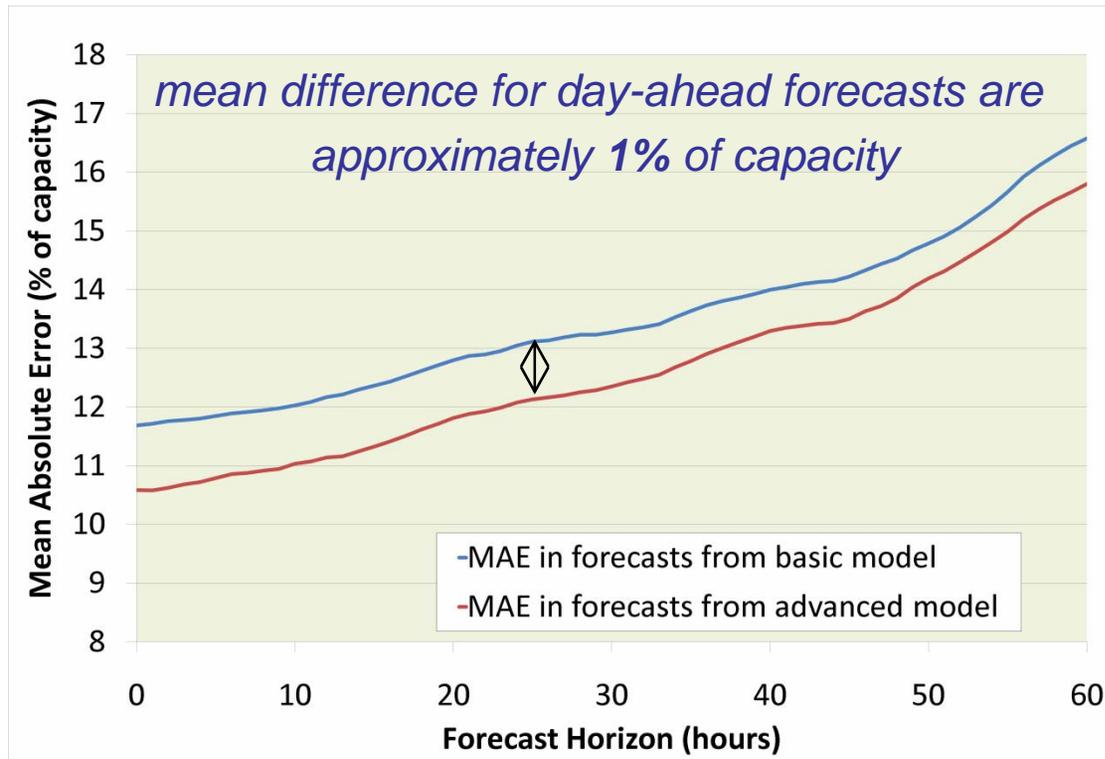
MAE ~ 11.6% of Capacity

MAE ~ 4.6% of Capacity

Advanced Model

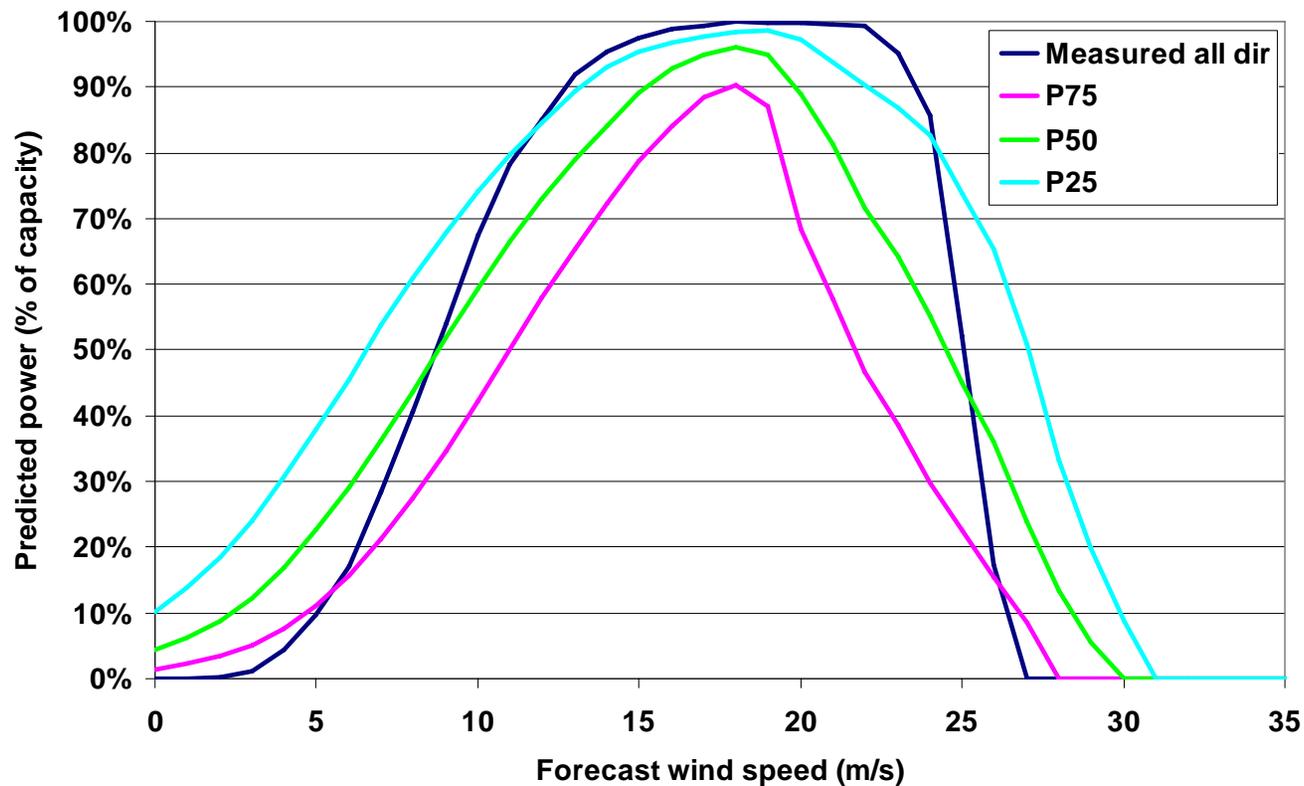


Impact on Forecast Accuracy



Probability Power Curves

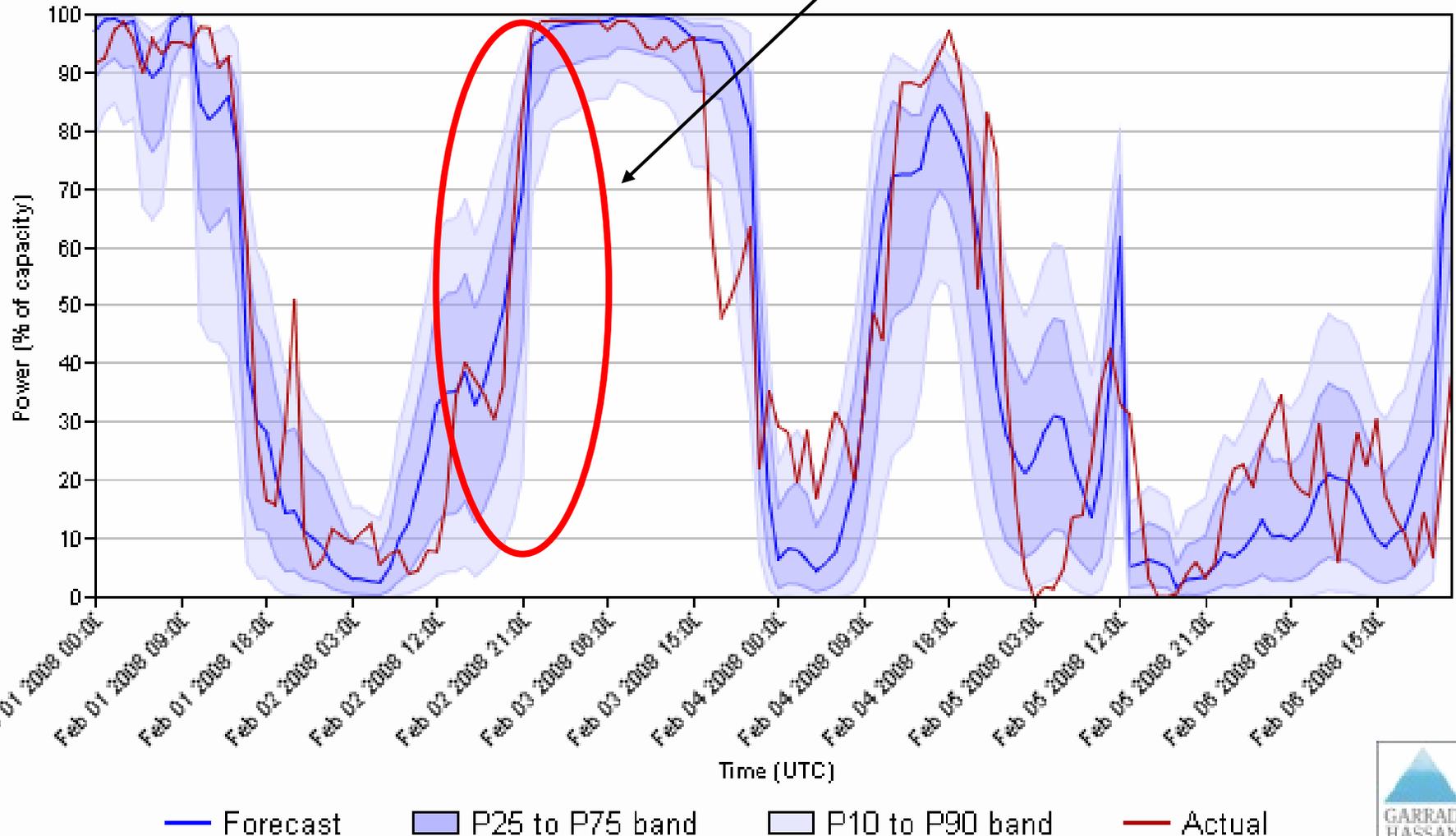
Interrogate the power model with a forecast wind speed distribution



Forecast Certainty

Hourly data 24 hours in advance

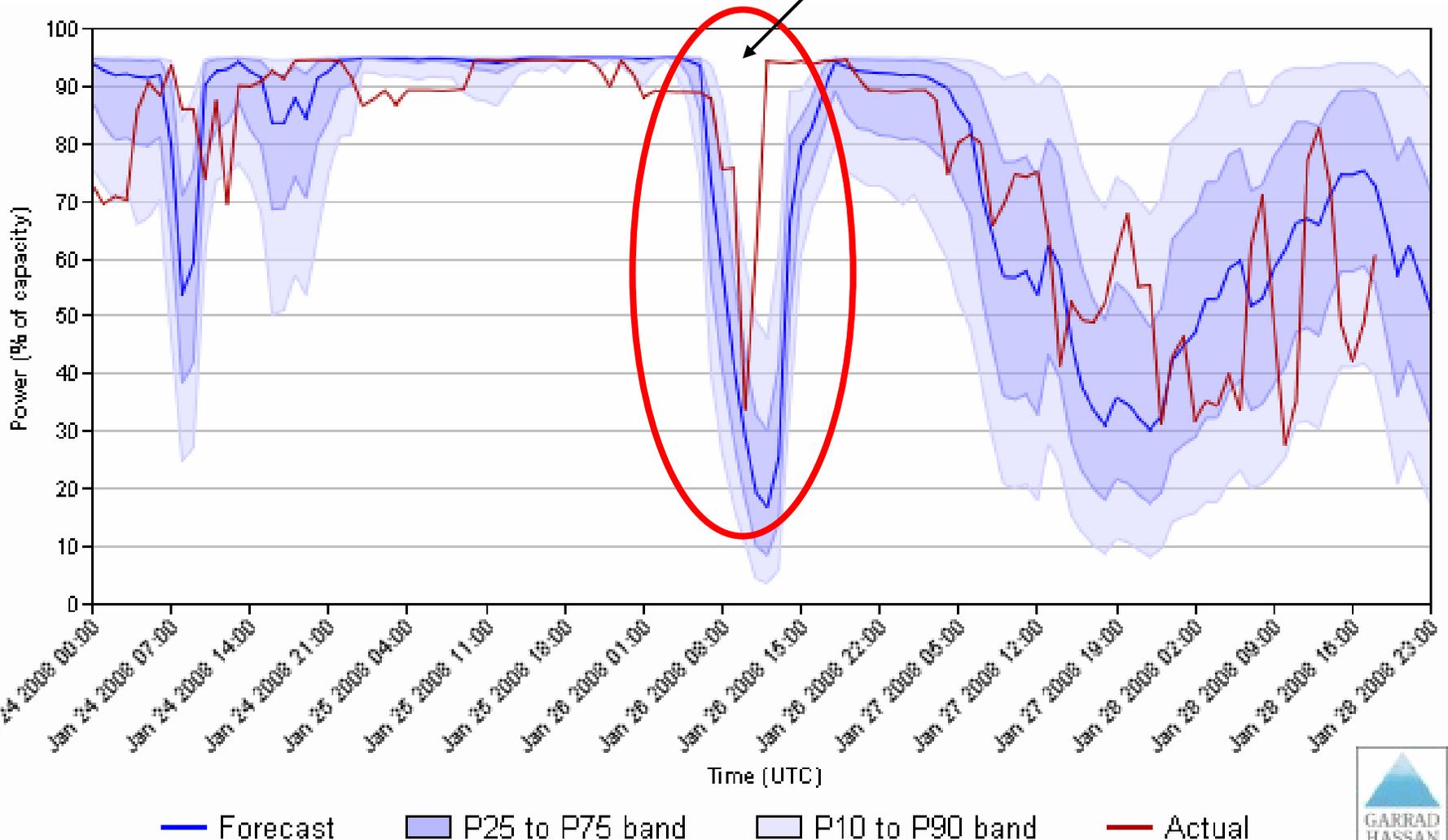
Certainty information particularly useful for rapid ramp events



Forecast Certainty

Hourly data 24 hours in advance

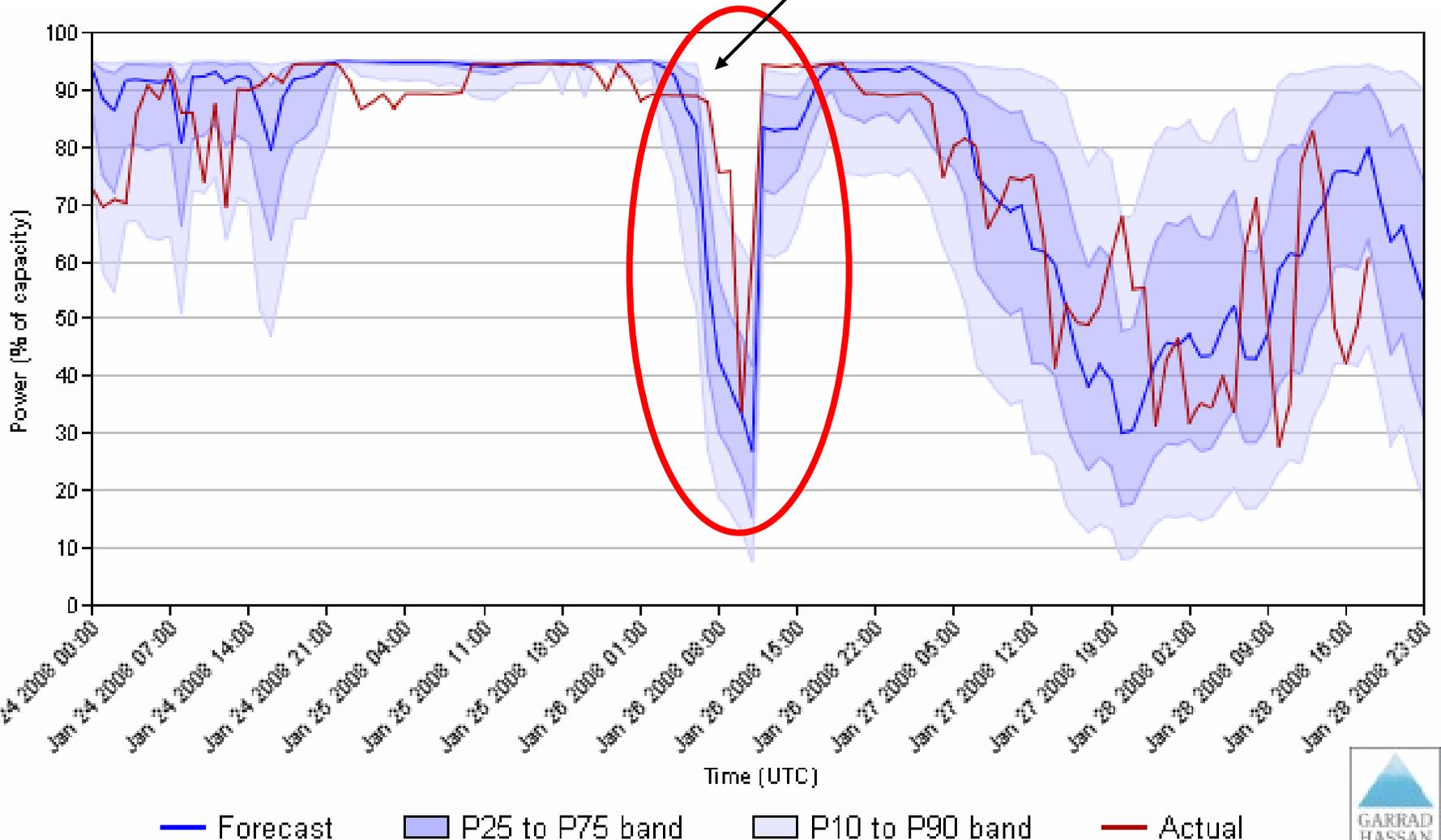
Certainty information particularly useful for high wind speed shut down.



Forecast Certainty

Hourly data 12 hours in advance

Better forecasts at shorter forecast horizons



Conclusions

- **The power model challenge is to appropriately estimate power output under non-ideal conditions.**
- **Use of purely the manufacturer's power curve can limit overall accuracy.**
- **Site-specific flow and wake modeling + historic measured power production data + onsite meteorological data for advanced power modeling improves accuracy.**
- **Assuming perfect wind speed forecast, advanced model yields mean reduction of MAE on the order of 7% installed capacity.**
- **Given that wind speed forecasts are not perfect, our data shows that the advanced approach yields a 1% reduction in MAE of day-ahead (24-hour) forecasts.**



Conclusions

- **Advanced Power Model Interrogation → confidence bands on forecast power, useful for anticipation of ramp events.**
- **Considerable work to be done to improve extreme fluctuation prediction → GH planning investigatory studies of new techniques in event forecasting.**

