Are Policies to Encourage Wind Energy Predicated on a Misleading Statistic?

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Trends in Public Policy

- There is almost no chance that the United States Congress will pass either a carbon tax or cap-and-trade legislation any time soon.

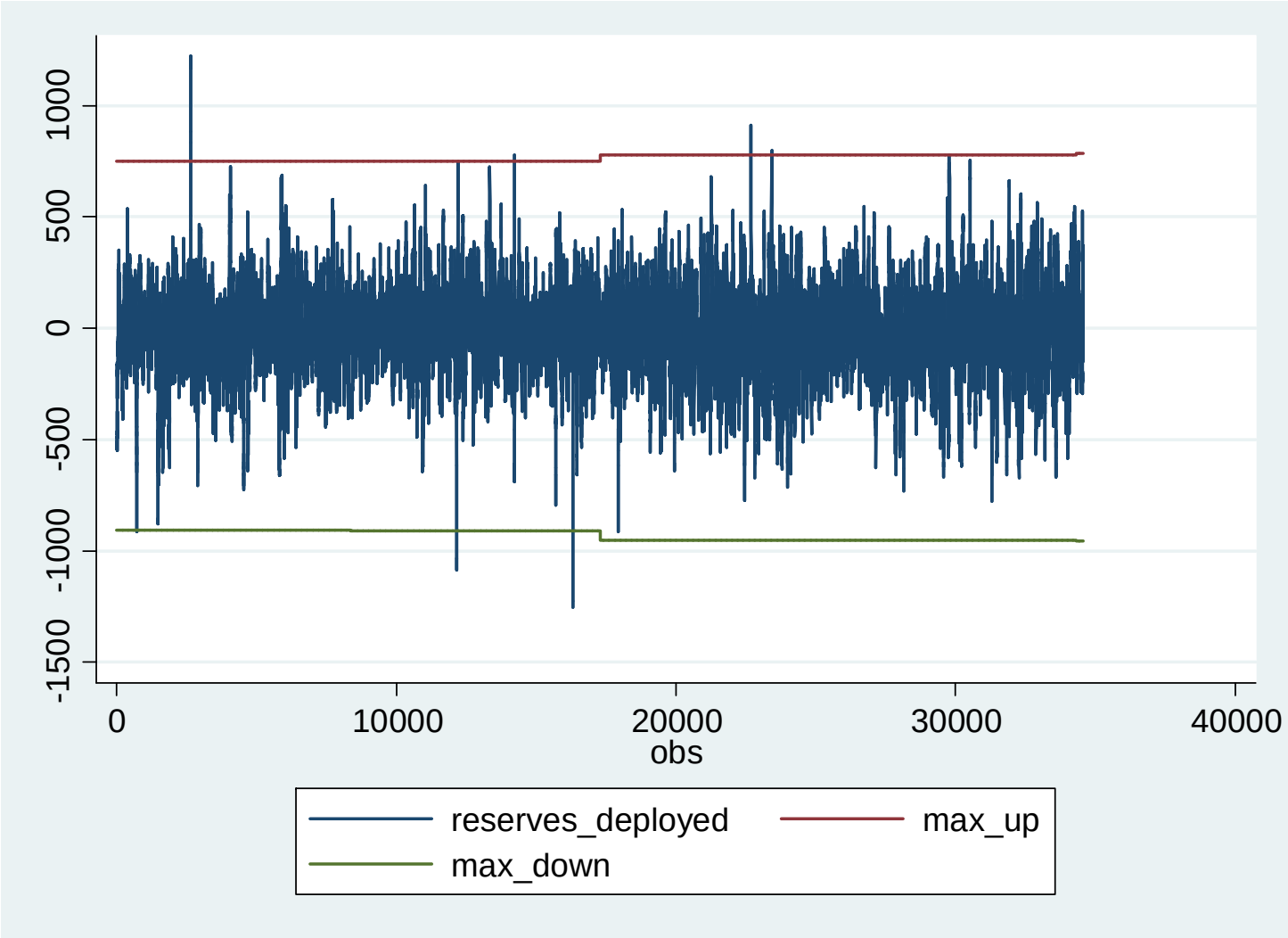
- There is broad political support for increasing substantially the share of electricity generation from wind.

- Some have advocated that policymakers should strive to have 20 percent of generation be accounted for by renewable energy by 2030 with most of the increase accounted for by wind energy.

Keeping the Lights On

- Blackouts have large societal costs.
- The stability of the power grid requires that the supply of power equal demand at all times, not just on average.
- To avoid blackouts, reserve power is dispatched when there is an imbalance between electricity supply and demand.

Reserve Deployments by the Bonneville Power Administration, 2 November - 1 March 2011



Wind Energy and the Power Grid

- Wind energy is not fully dispatchable

- System Operators integrate wind energy into the generation mix by forecasting wind energy production levels

Wind Energy and the Power Grid (cont'd)

The proposed increases in wind energy are implicitly predicated on the belief that wind energy, while not capable of "upward dispatch", is *fairly predictable*.

But is it?

The “Consensus” View

1) Forecasting wind energy is critical to system reliability when wind energy penetration is high

2) The uncertainty in wind forecasting is not necessarily greater than the uncertainty in forecasting load

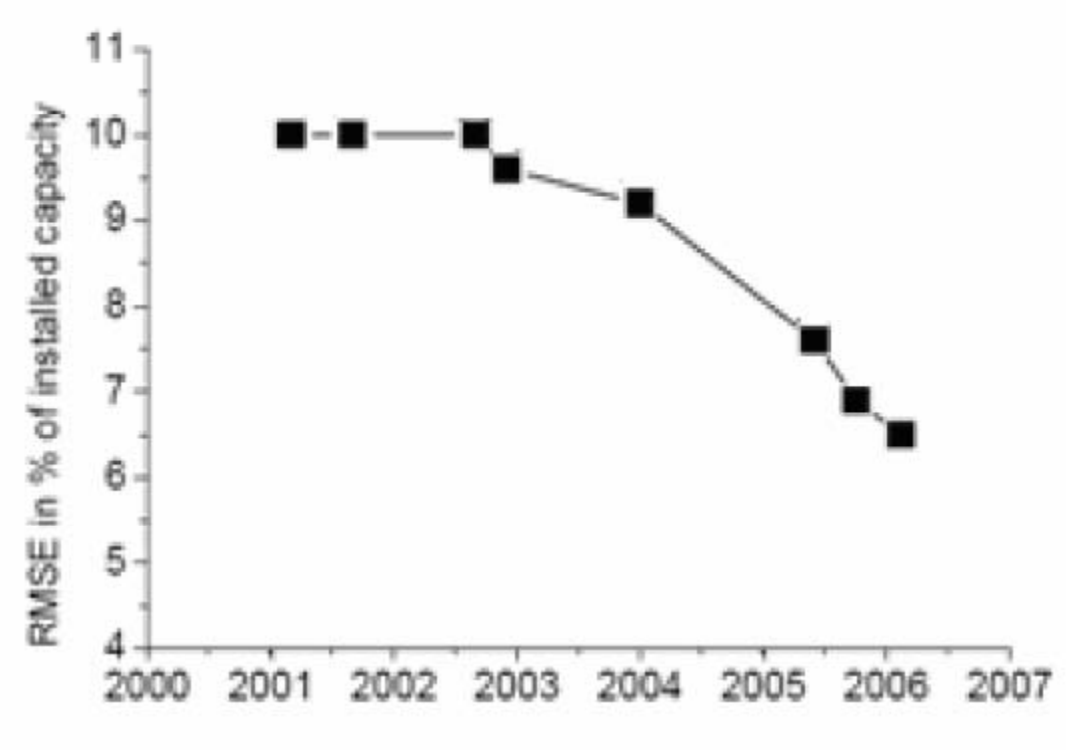
3) The many advances in forecasting wind in Europe over the past decade that makes it possible to achieve high levels of wind integration with little or no effort.

NERC's Views on Wind Energy

"…in many areas where wind power has not reached high penetration levels, uncertainty associated with the wind power has normally been less than that of demand uncertainty. … Consequently, power system operators have been able to accommodate current levels of wind plant integration and the associated uncertainty with little or no effort.

Forecasting the output of variable generation is critical to bulk power system reliability in order to ensure that adequate resources are available for ancillary services and ramping requirements. The field of wind plant output forecasting has made significant progress in the past 10 years. The progress has been greatest in Europe, which has seen a much more rapid development of wind power than North America." (NERC, 2009, p. 54)

Evidence of Declining Day-Ahead Wind Energy Forecast Errors



Source: Cali, et. al. (2006)

Is the evidence compelling?

- Though the forecasting error *relative to installed wind energy capacity* may have declined, *is such a metric even relevant*?

- Note that load forecasting errors are *not* weighted by the capacity of the equipment that consumes electricity.

Is the evidence compelling? (cont'd)

- An error weighted by the mean level of actual wind energy (or the mean forecasted level) would seem far more relevant.
- Weighting by capacity makes it difficult to compare the accuracy of the wind forecasts with the accuracy of the load forecasts.
- Weighting by capacity makes it difficult to compare the accuracy of the wind forecasts by one system operator with another since capacity utilization varies across systems. Ignoring this reality makes systems with low wind energy utilization "look" more accurate even if they are not.
- A capacity-weighted error can decline over time even if the unweighted error is not declining.
- There seems to be ***no legitimate reason*** to weight errors by capacity.

Measuring Forecast Errors

- Wind forecasting errors will be measured as the root-mean-squared-error of wind forecasts relative to mean wind energy production.

- Load forecasting errors will be measured as the root-mean-squared-error of load forecasts relative to the mean electricity load.

The Root-Mean-Squared-Error (RMSE)

$$RMSE = \sqrt{\frac{\sum(Forecasted - Actual)^2}{n}}$$

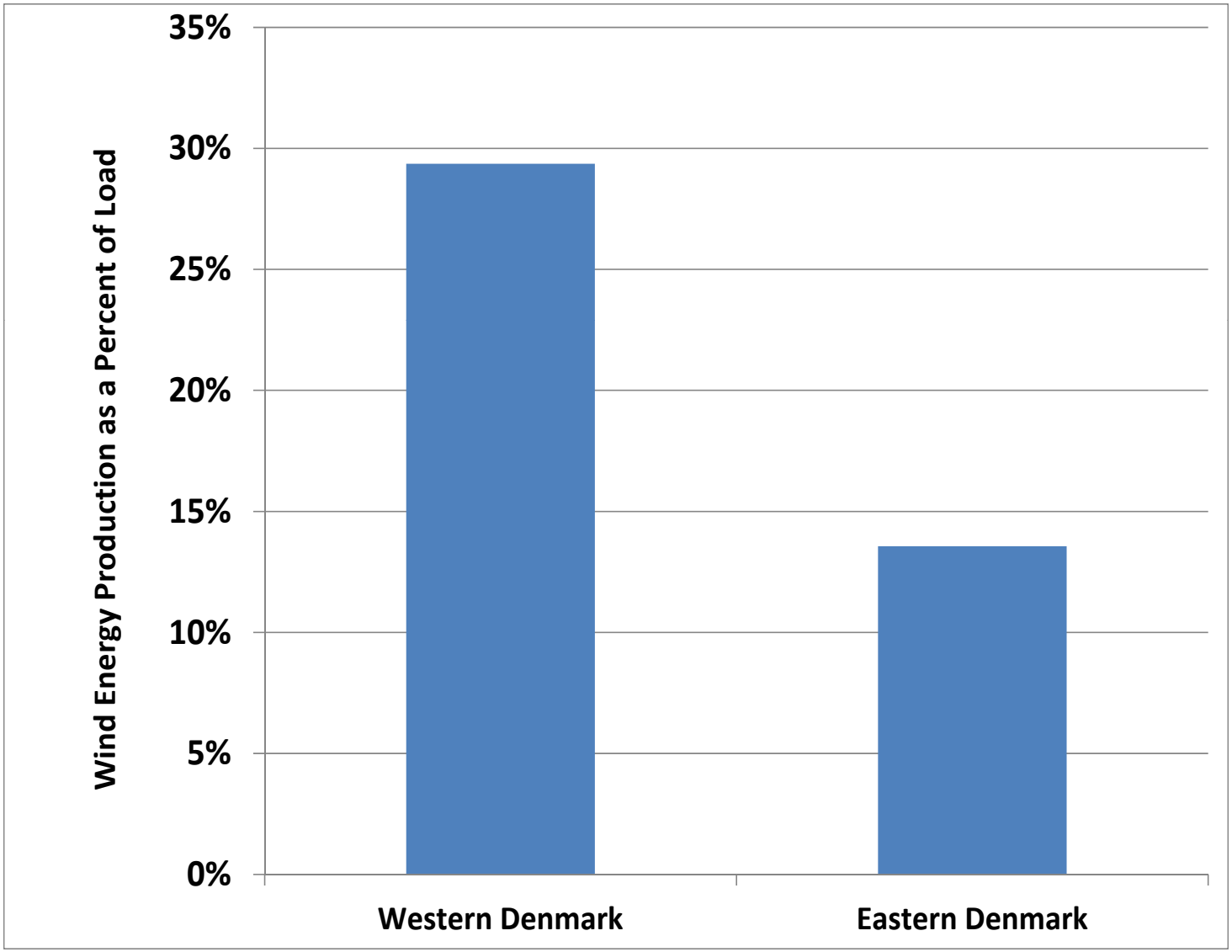
Electricity Control Areas Examined

- Western Denmark
- Eastern Denmark
- 50Hertz in Eastern Germany
- TenneT in Central Germany
- Amprion in Western Germany
- Italy

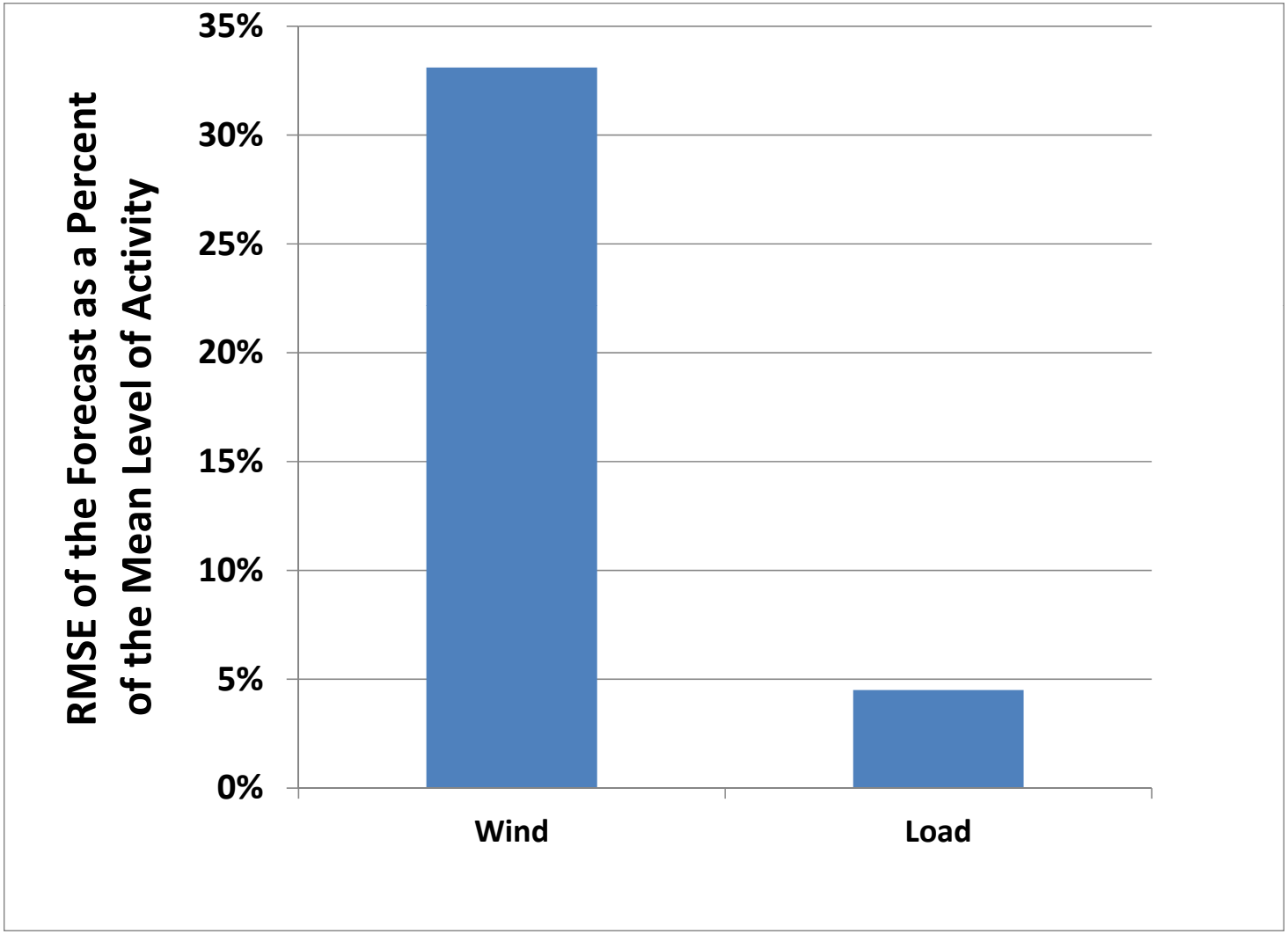
Electricity Control Areas Examined (cont'd)

- United Kingdom
- Ireland
- ERCOT (USA)
- The Midwest ISO (USA)
- Bonneville Power Administration (USA)

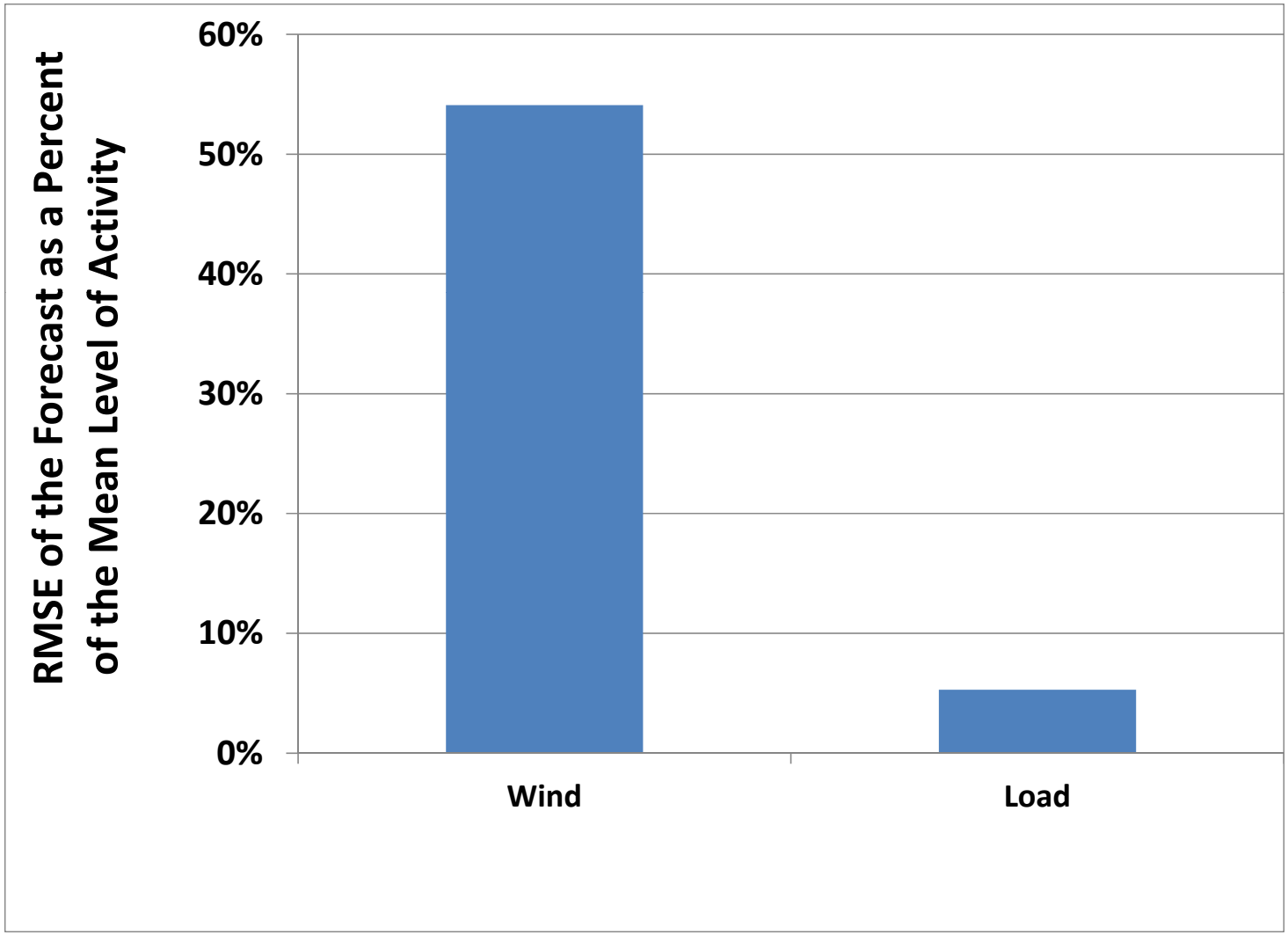
Wind Energy Production Relative to Load in Western and Eastern Denmark, 14 September 2009 – 31 December 2010



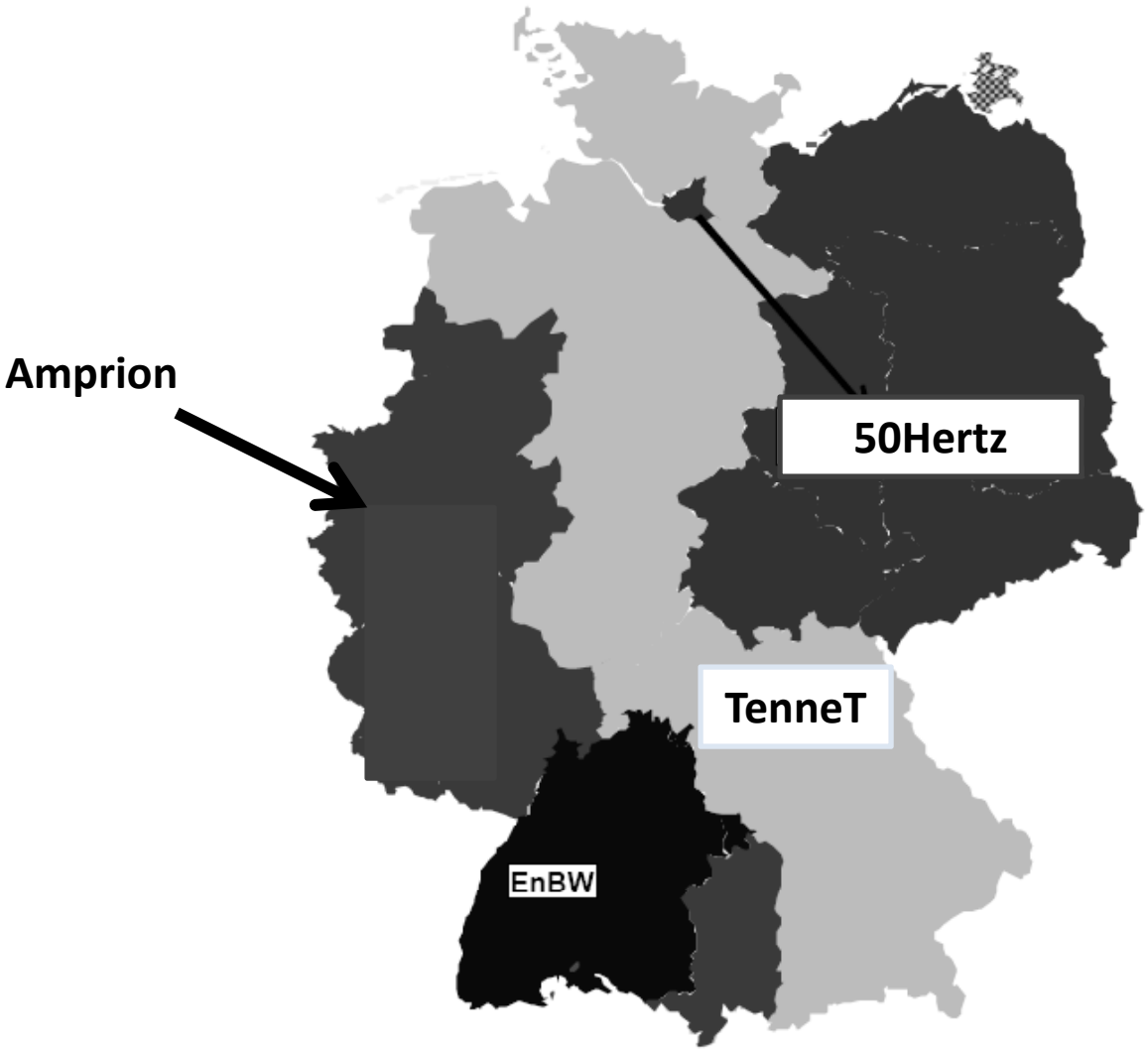
Forecast Errors in Western Denmark
14 September 2009 – 31 December 2010



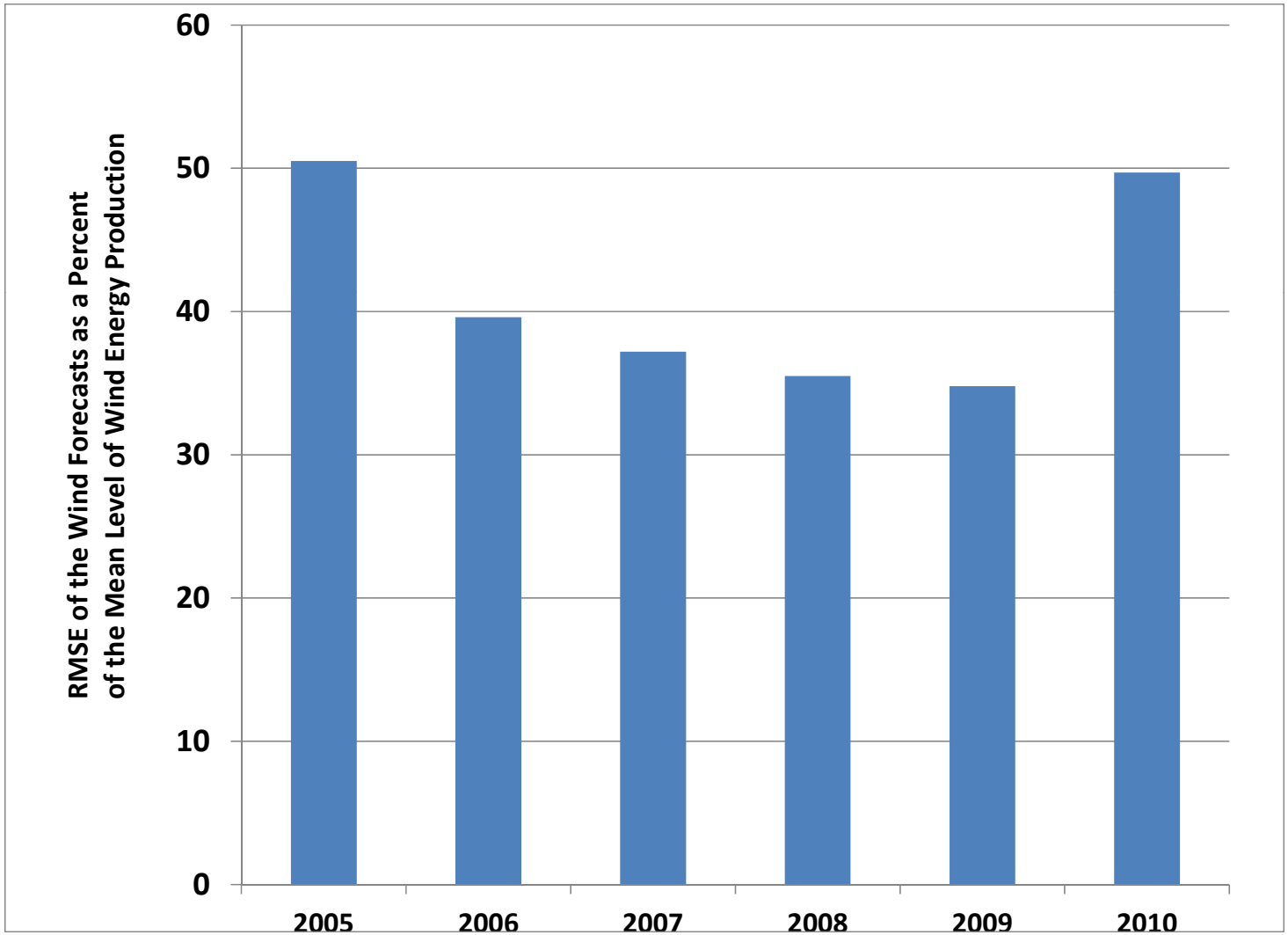
Forecast Errors in Eastern Denmark
14 September 2009 – 31 December 2010



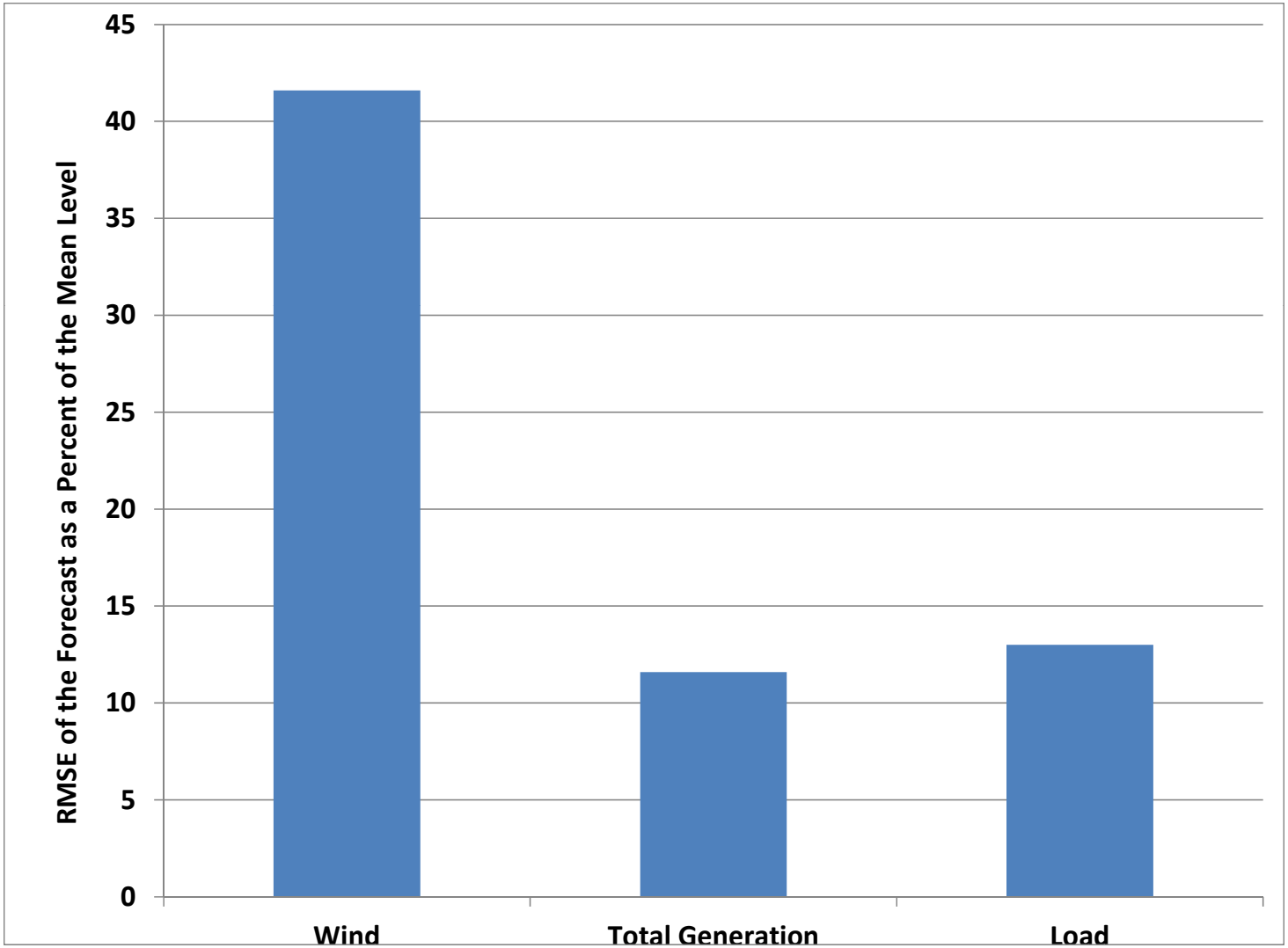
Electricity Control Areas in Germany



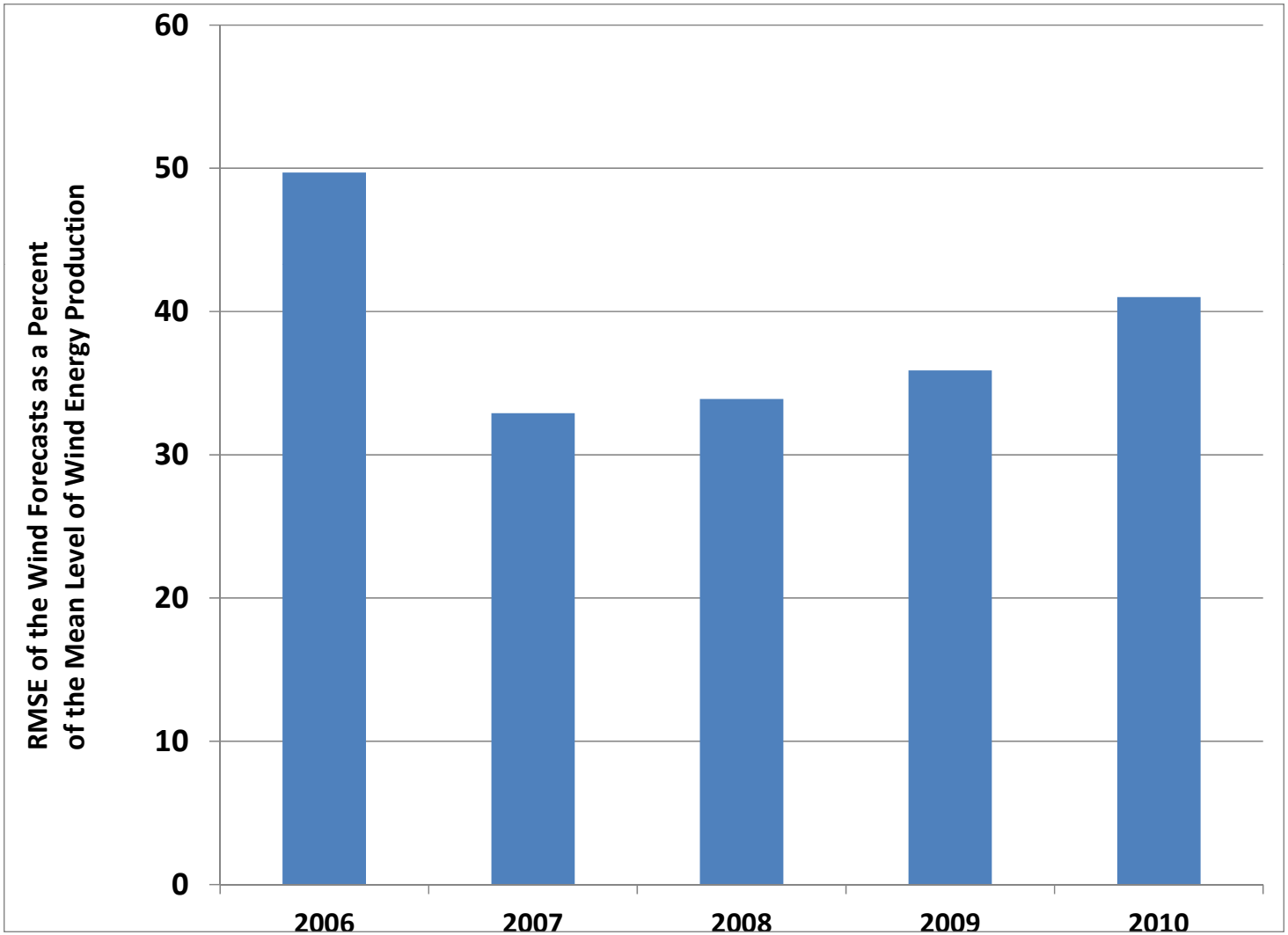
Day-Ahead Wind Forecast Errors in 50Hertz, 2005-2010



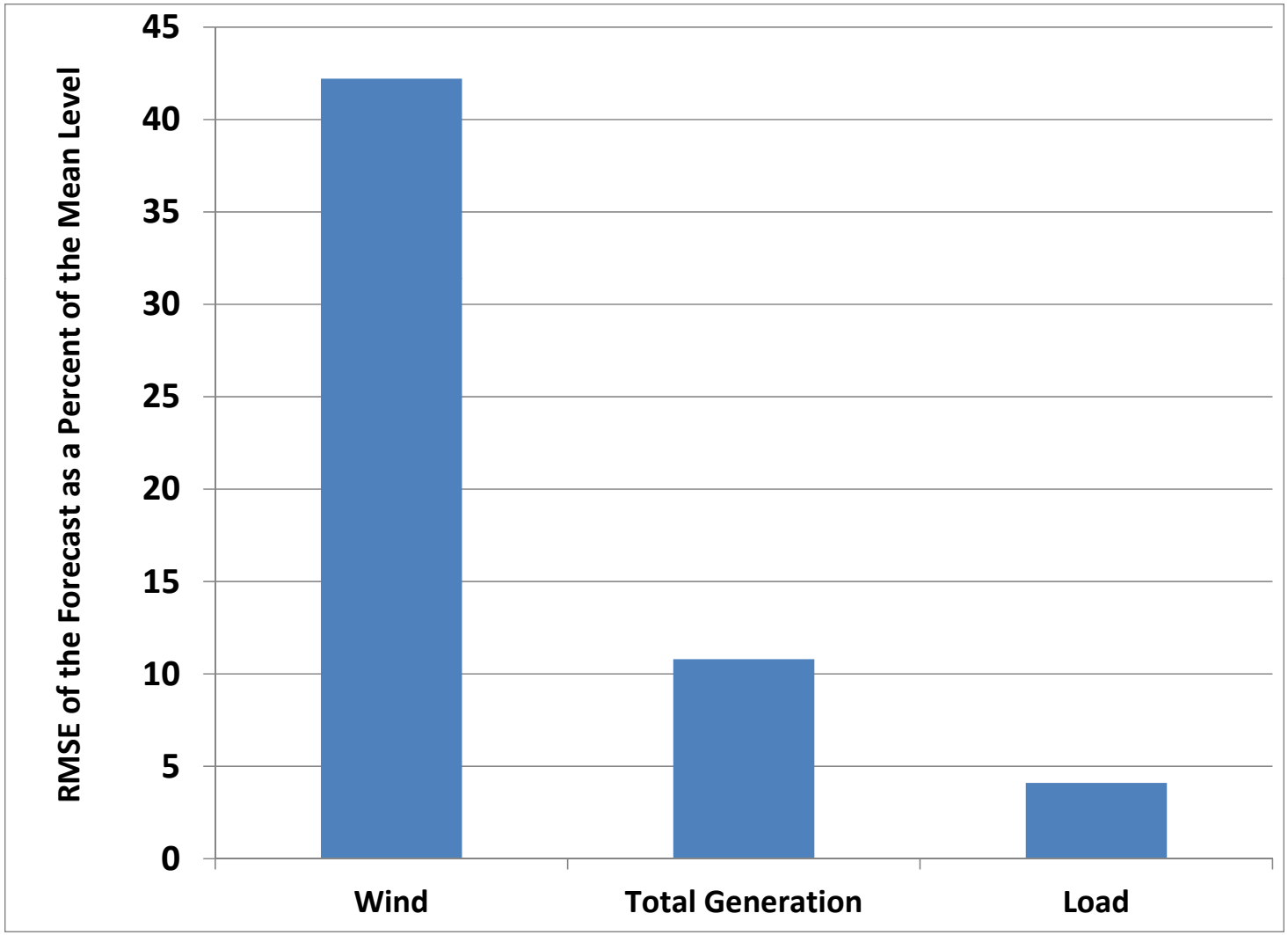
Forecasting Errors in 50Hertz
1 May 2008 – 30 November 2010



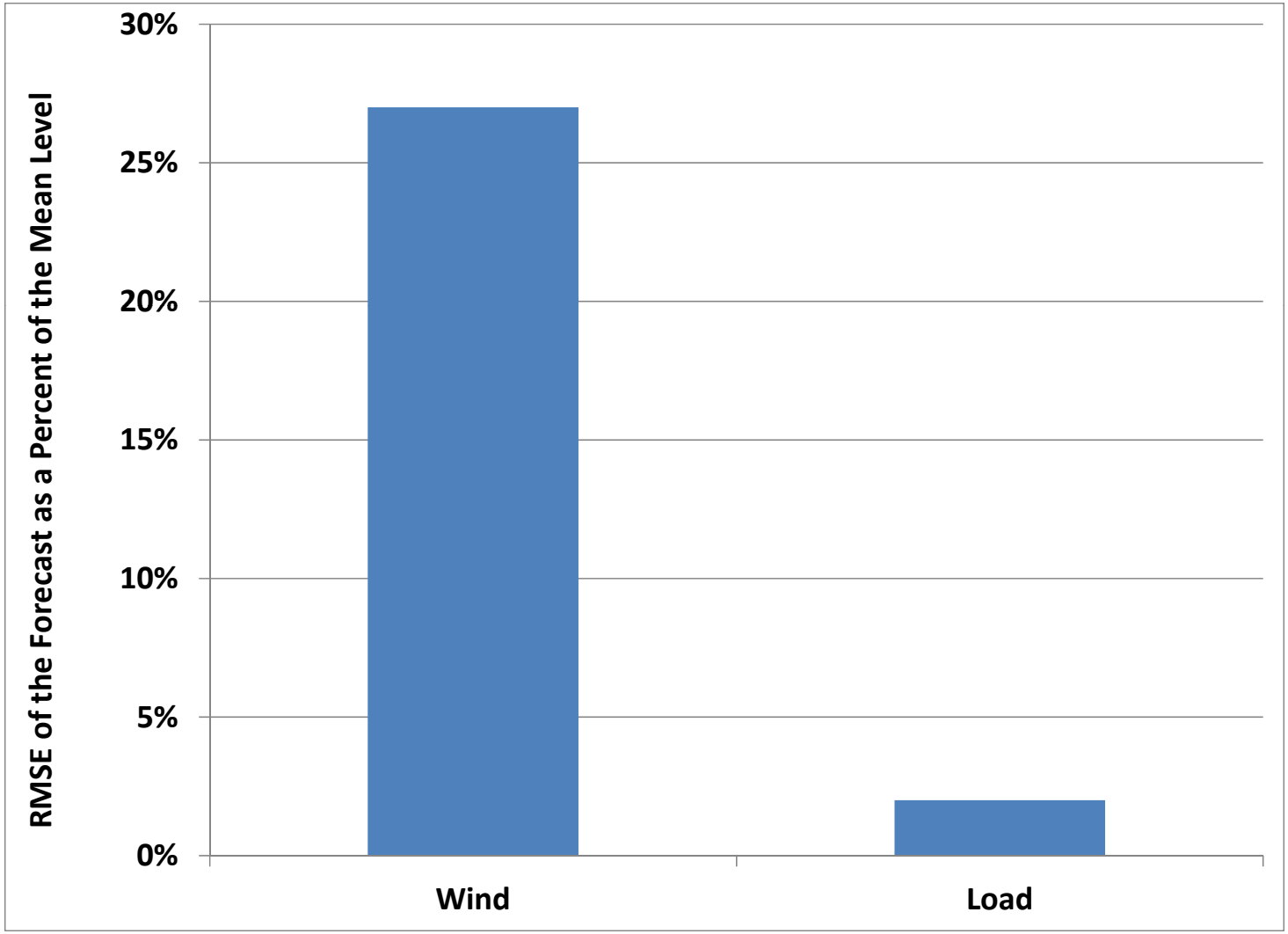
Day-Ahead Wind Forecast Errors in TenneT in Central Germany, 2006-2010



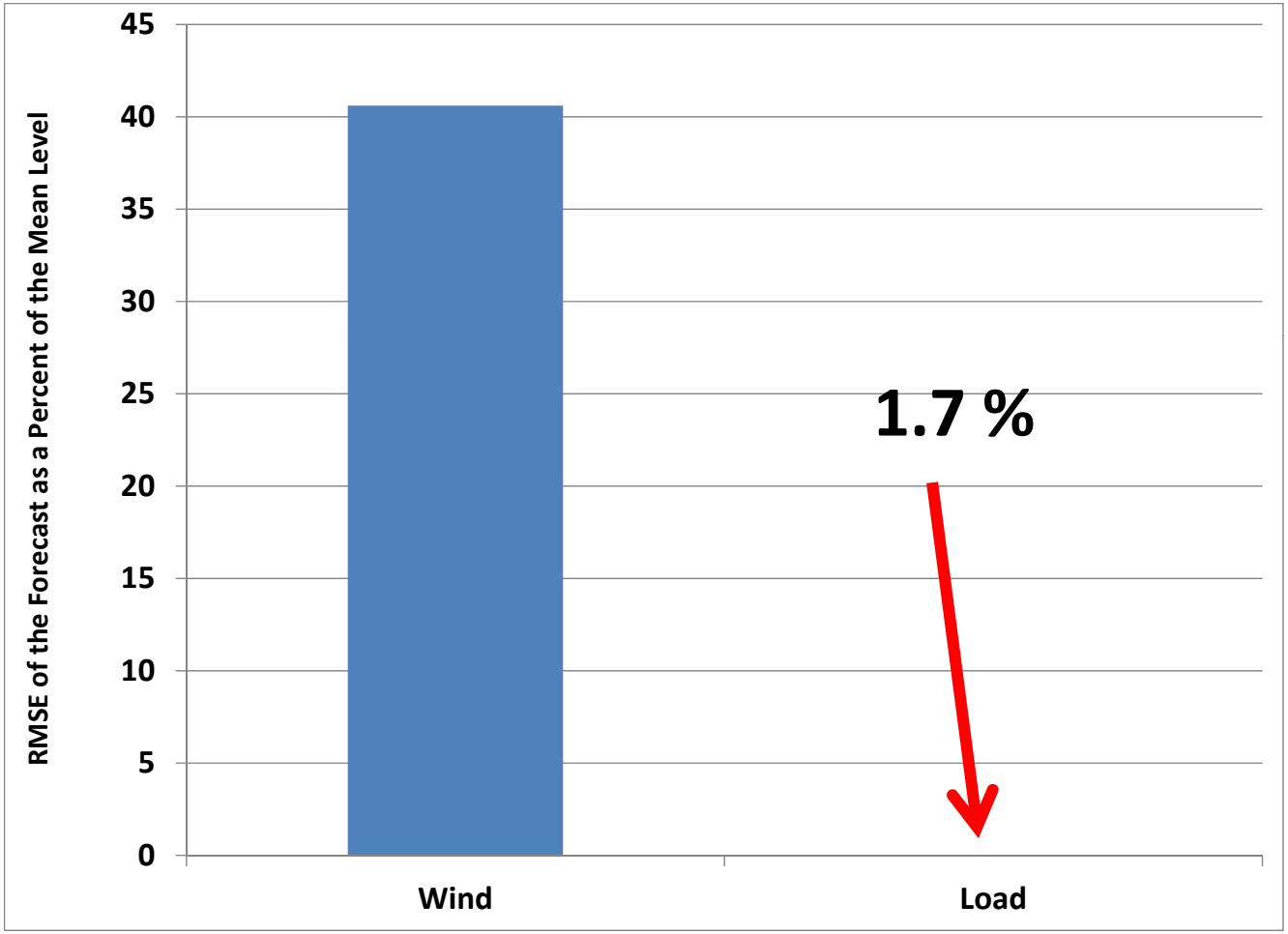
Forecast Errors in Amprion
1 April 2008 – 15 December 2010



Forecast Errors in Italy
1 March – 31 December 2010

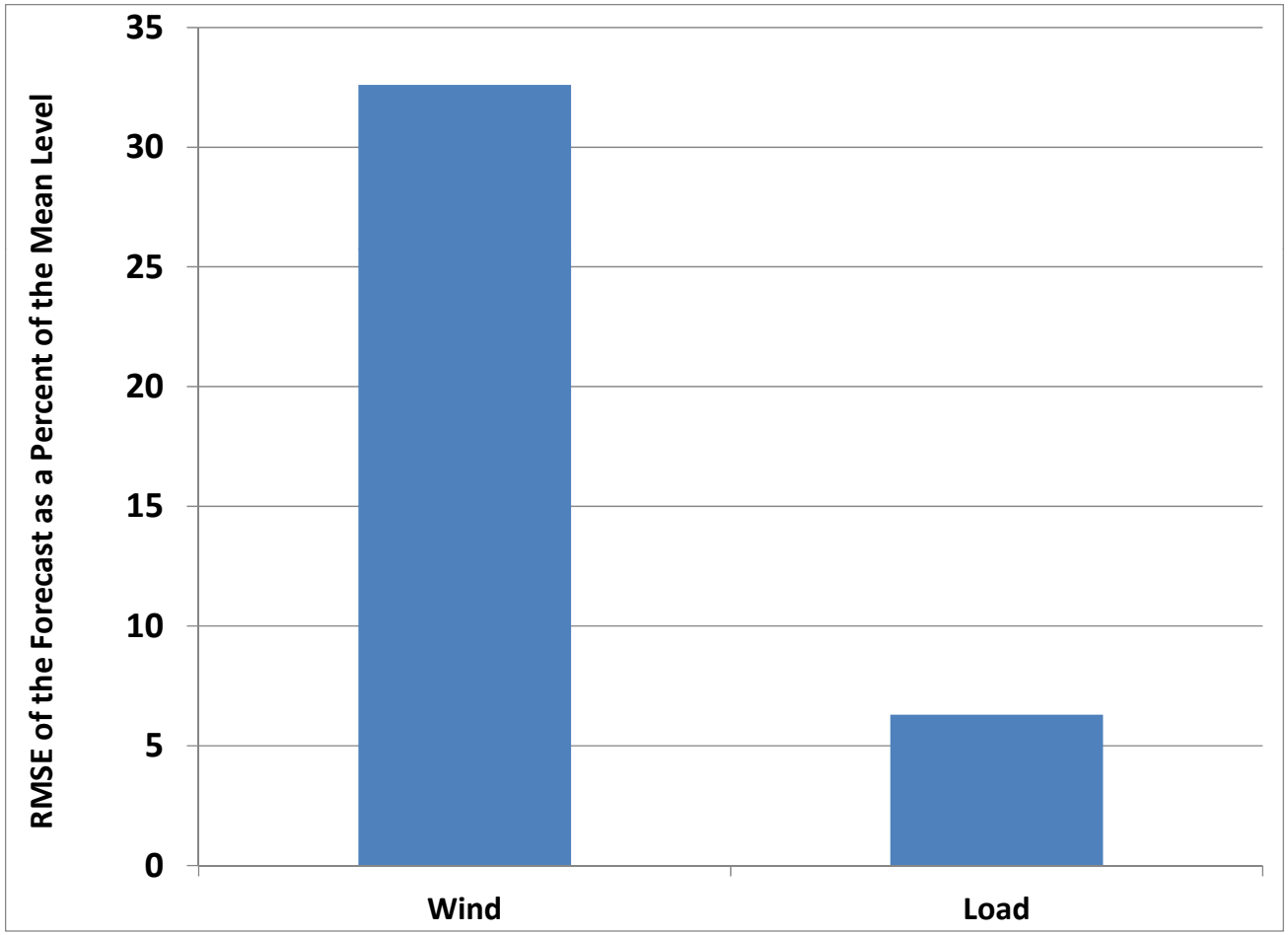


Forecast Errors in the UK Power Grid
5 November 2008 – 9 October 2010



Note: Wind forecasts based on 30 minute data; load forecasts based on hourly data.

Wind Forecasting Errors in Ireland
2 February 2010 – 31 December 2010



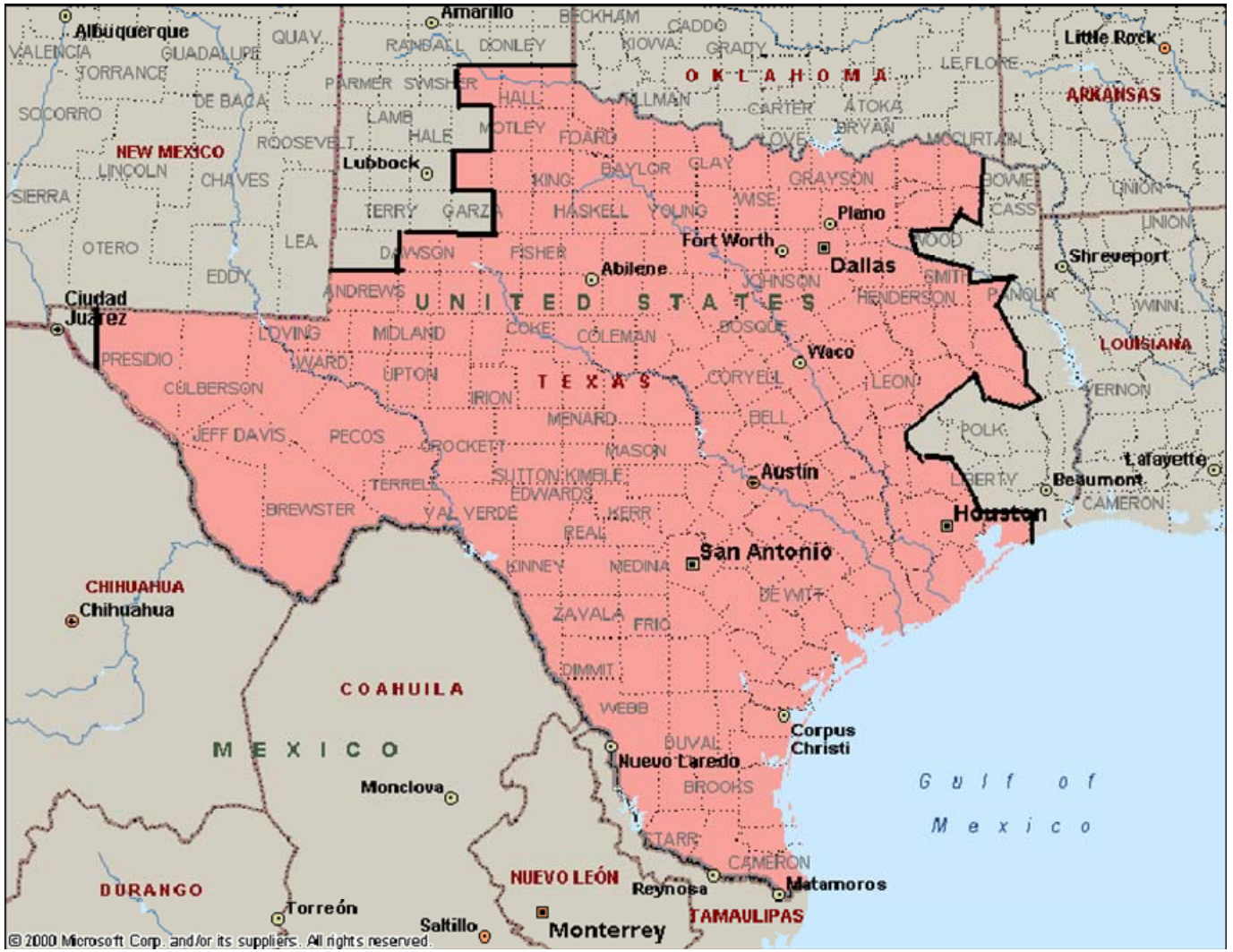
Forecasting Wind Energy in ERCOT

- ERCOT is the system operator that serves the vast proportion of Texas.

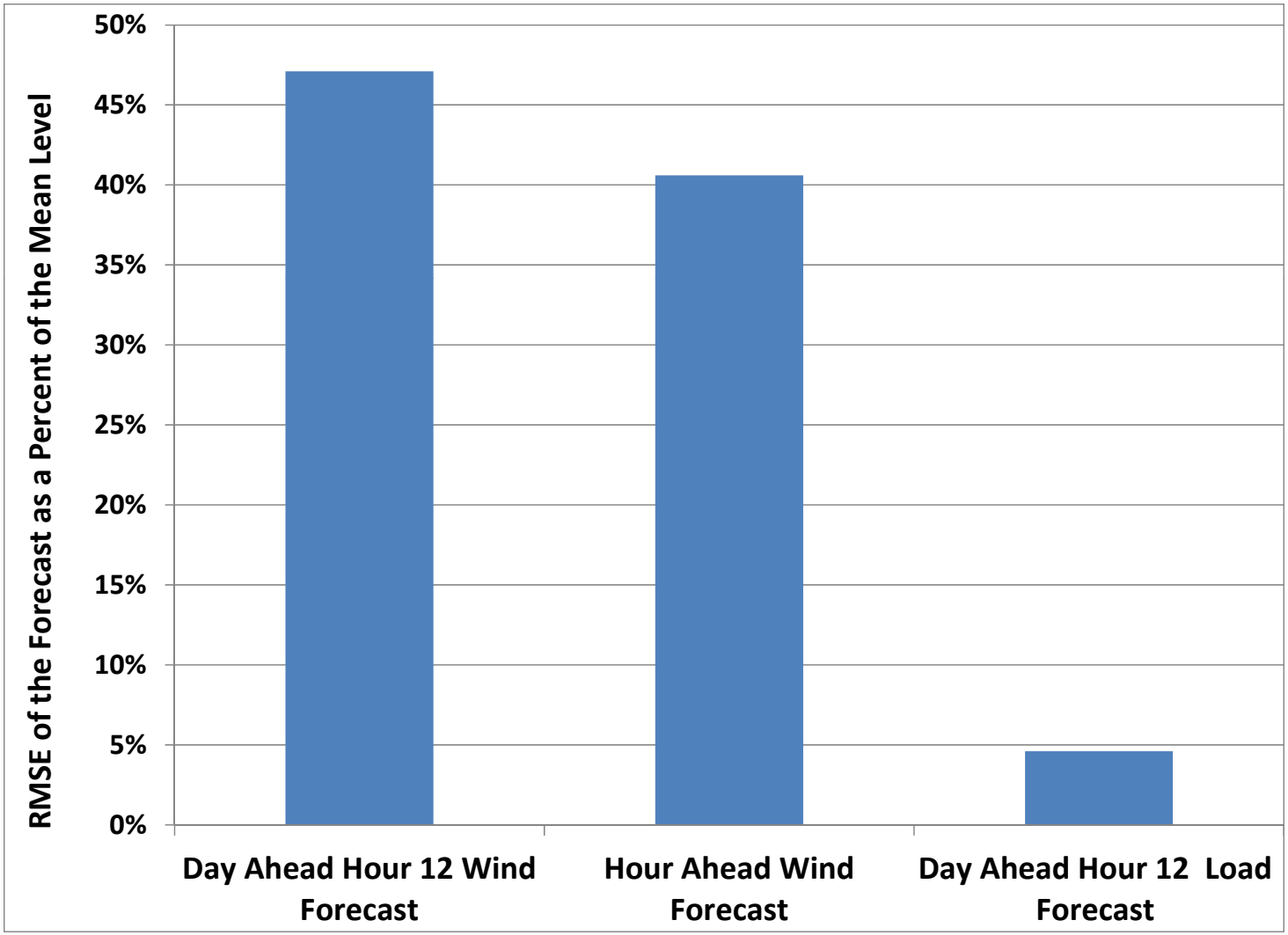
- Over the period 5 December 2009 – 30 November 2010, wind energy accounted for approximately 7.4 percent of load.

- Porter and Rogers (2010, p. 5) report that the mean absolute wind forecasting errors in ERCOT ranged from 8.28% to 10.73% of capacity for all hours over the May 2009-August 2009 period.

The ERCOT Control Area



Forecast Errors in ERCOT
5 December 2009 – 30 November 2010



The Midwest ISO

The MidWest ISO's Assessment of Wind Forecast Accuracy

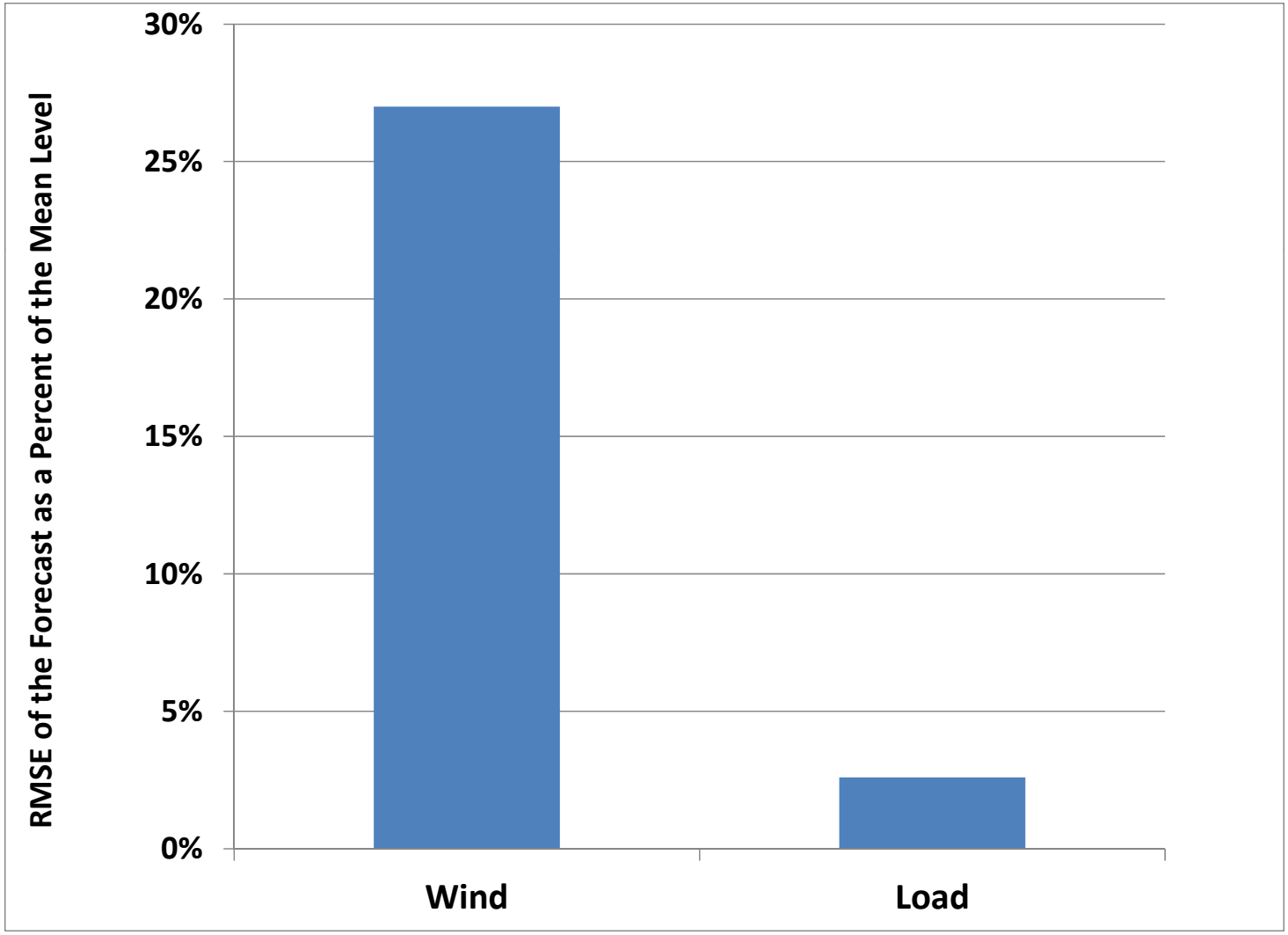
"The Midwest ISO's wind forecasting accuracy for 2009 was 92.83%. (emphasis added)
Wind forecasting accuracy data prior to 2009 is not available. Wind forecasting accuracy is calculated using an industry-wide methodology called Mean Absolute Error (MAE). The MAE is the average of the absolute value of the difference between forecasted and actual wind power output and is expressed as a percent of installed wind nameplate capacity. The wind forecasting accuracy is represented as one minus MAE.

The wind forecasting calculation methodology differs from the calculation methodology used for the load forecasting accuracy metric because the wind forecasting calculation methodology expresses the absolute error value as a percent of installed wind nameplate capacity whereas the load forecasting calculation methodology expresses the absolute error value as a percent of total forecasted load. **The wind forecasting calculation methodology "softens " the true error in forecasting. (emphasis added)**

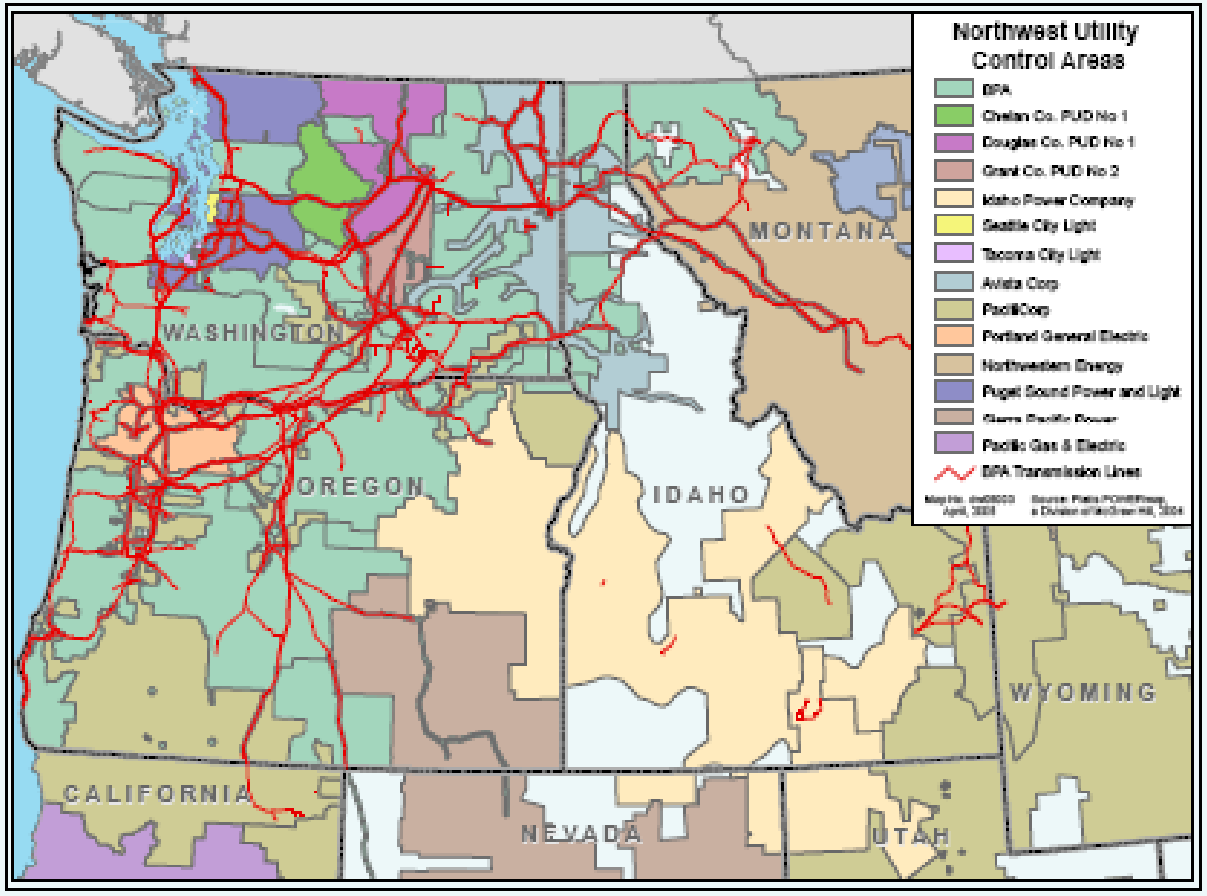
The Midwest ISO is continuing to explore methods for improving the accuracy of its wind forecasting, but **our current accuracy appears to be consistent with the accuracy obtained in other regions throughout the world(emphasis added)."**

RTO/ISO Performance Metrics, AD10-5-000 , 2010, p 151

Forecast Errors in the Midwest ISO
June 15 – 31 December 2010

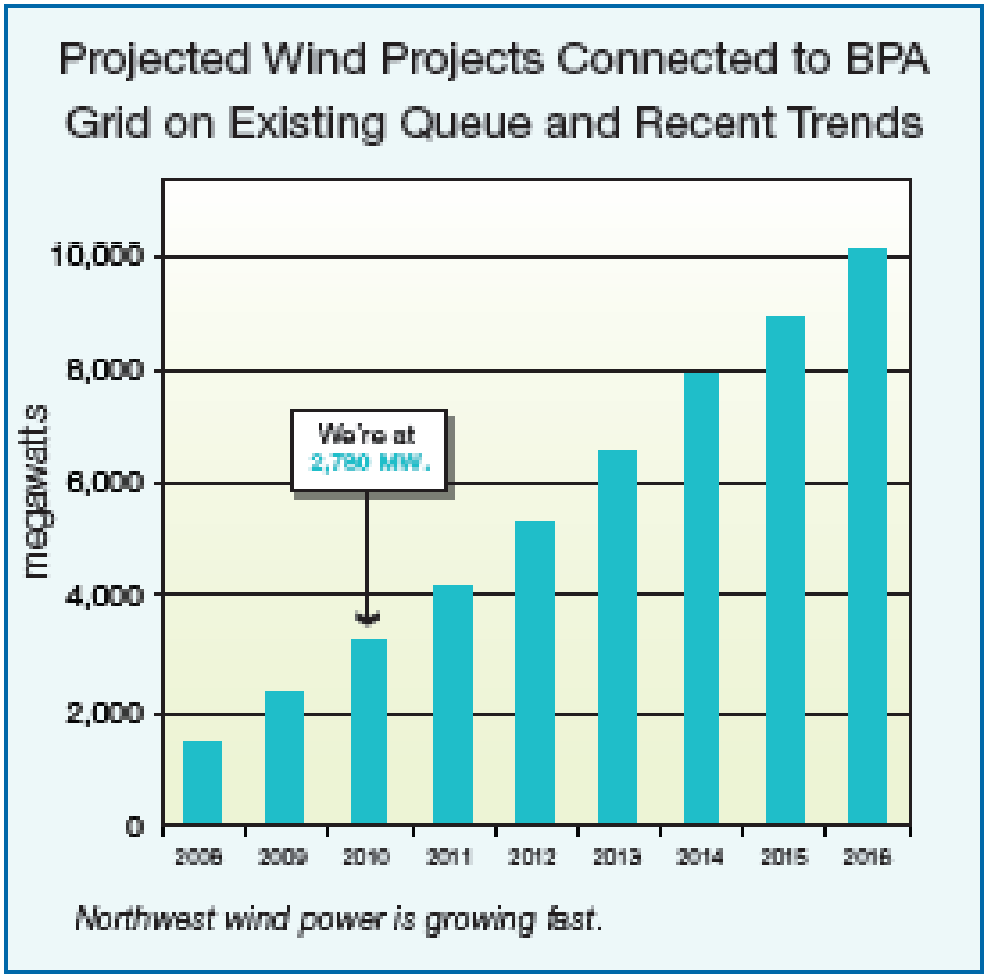


The Bonneville Power Administration

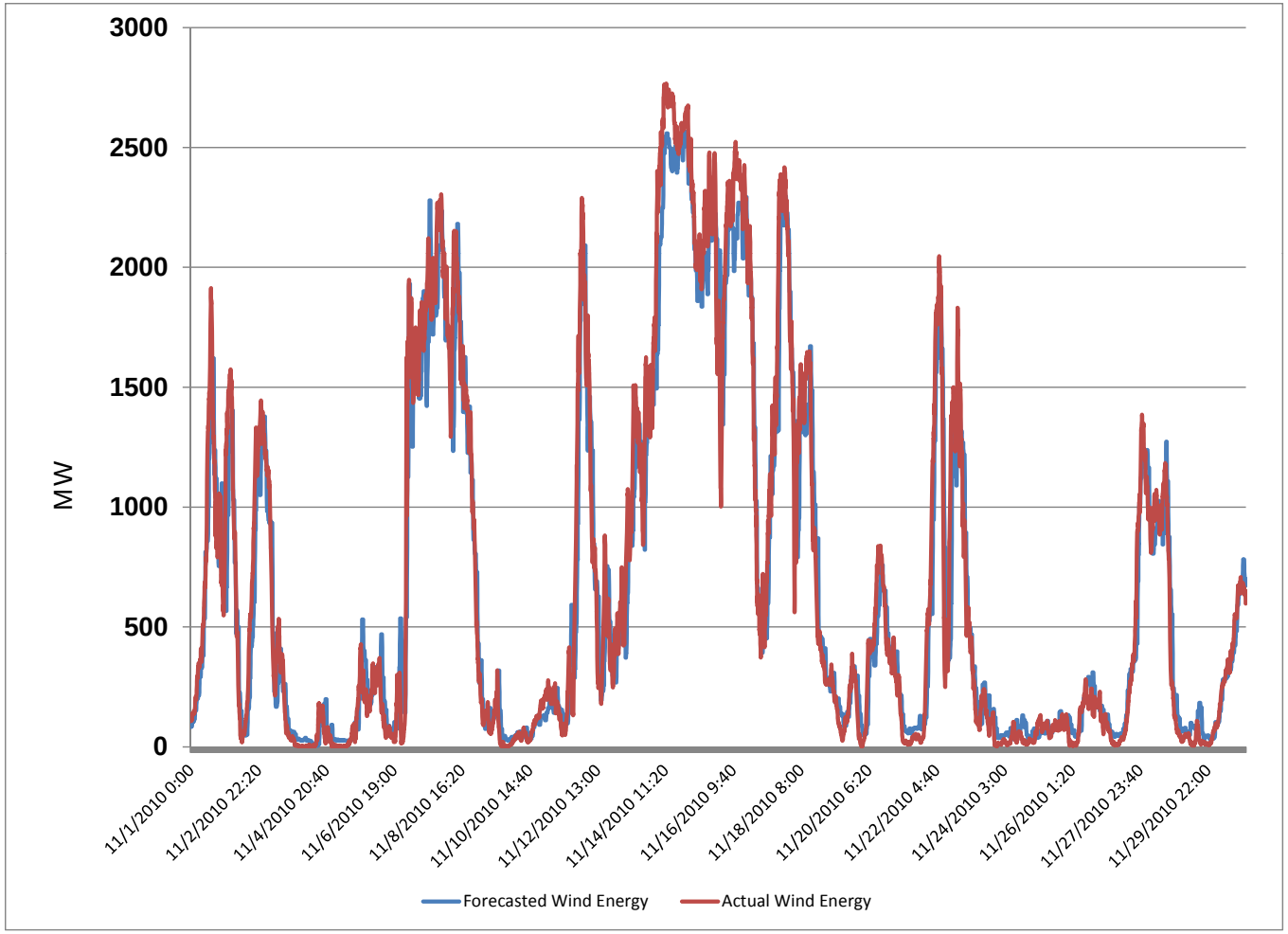


BPA is the balancing authority responsible for maintaining a constant balance between the power load and power generation in the area shown in teal. (A balancing authority is also known as a control area.) Most of the wind power on line and planned for the Pacific Northwest is clustered in BPA's balancing authority at the eastern end of the Columbia River Gorge. However, 80 percent of the wind power in BPA's balancing authority area serves loads in other utilities' balancing authorities.

Projected Growth in Wind Energy in the BPA Control Area



A Rorschach Test:
Forecasted vs. Actual Wind Energy for the BPA Control Areas, November 1-30, 2010



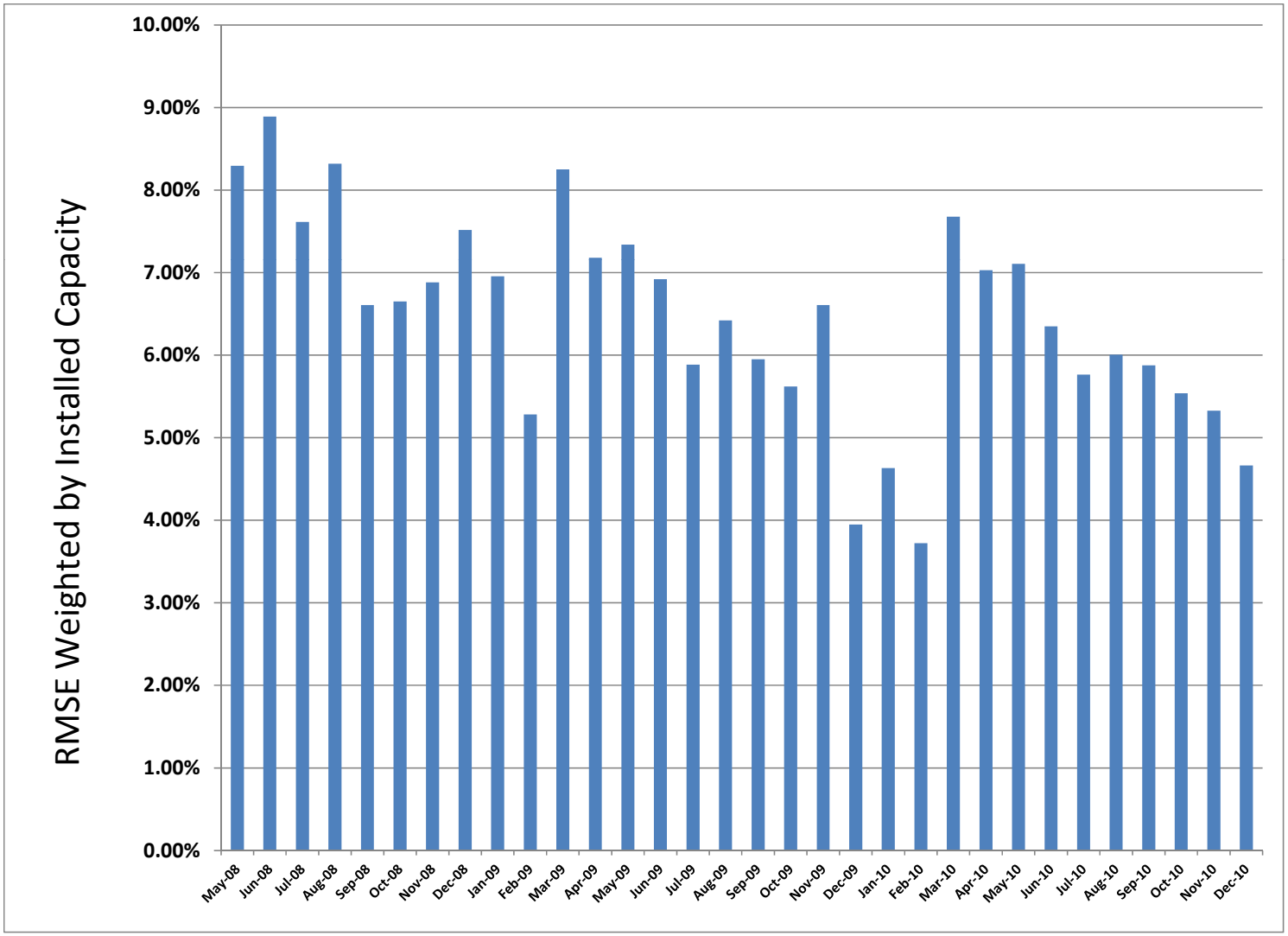
The Wind Forecast Errors for BPA November 1-30, 2010

- The RMSE of the wind forecast for November 2010 (see previous slide) was 24 percent of the average level of wind energy production.

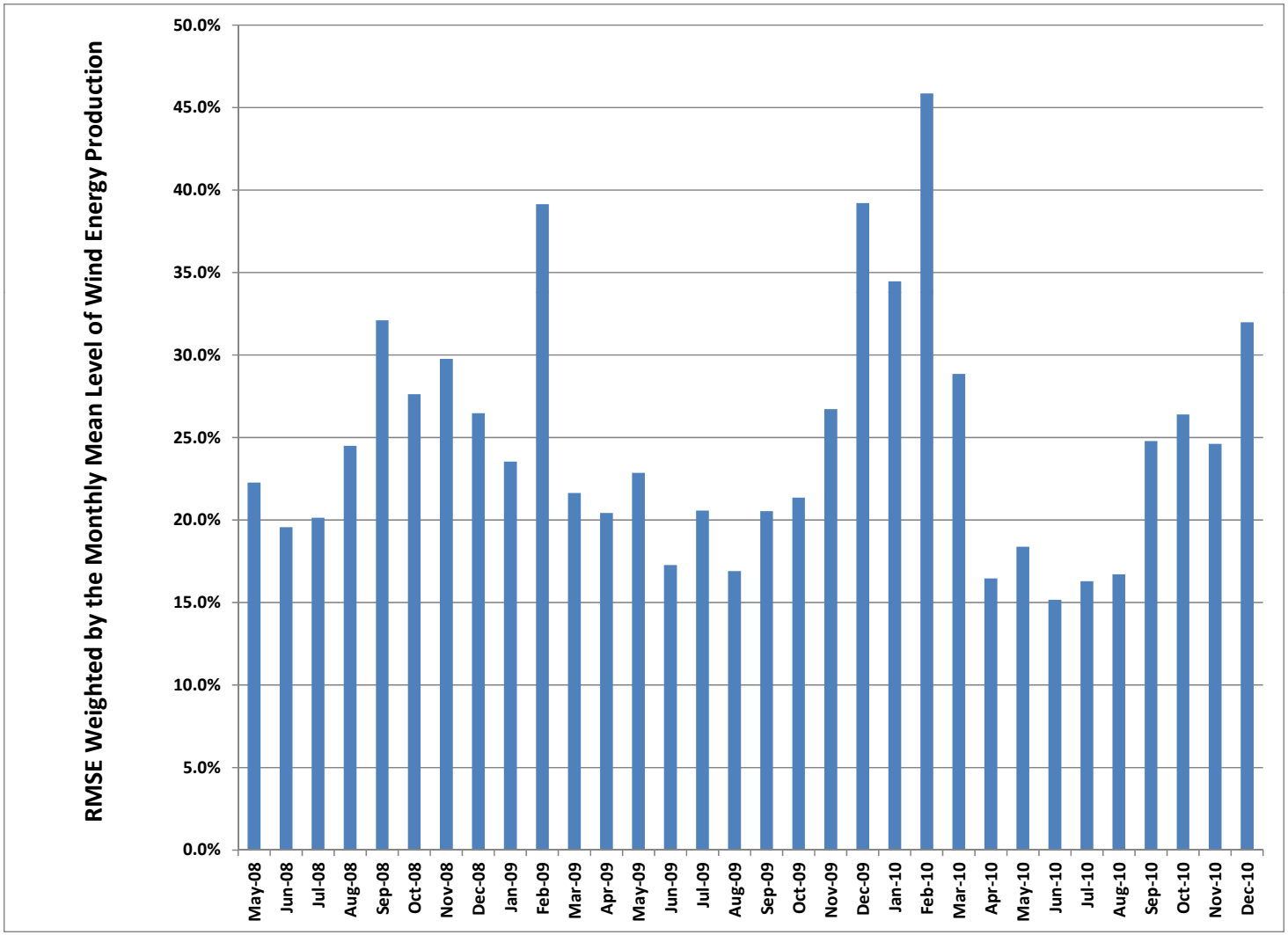
- The largest positive error was 898 MW.

- The largest negative error (in absolute value) was -1084 MW.

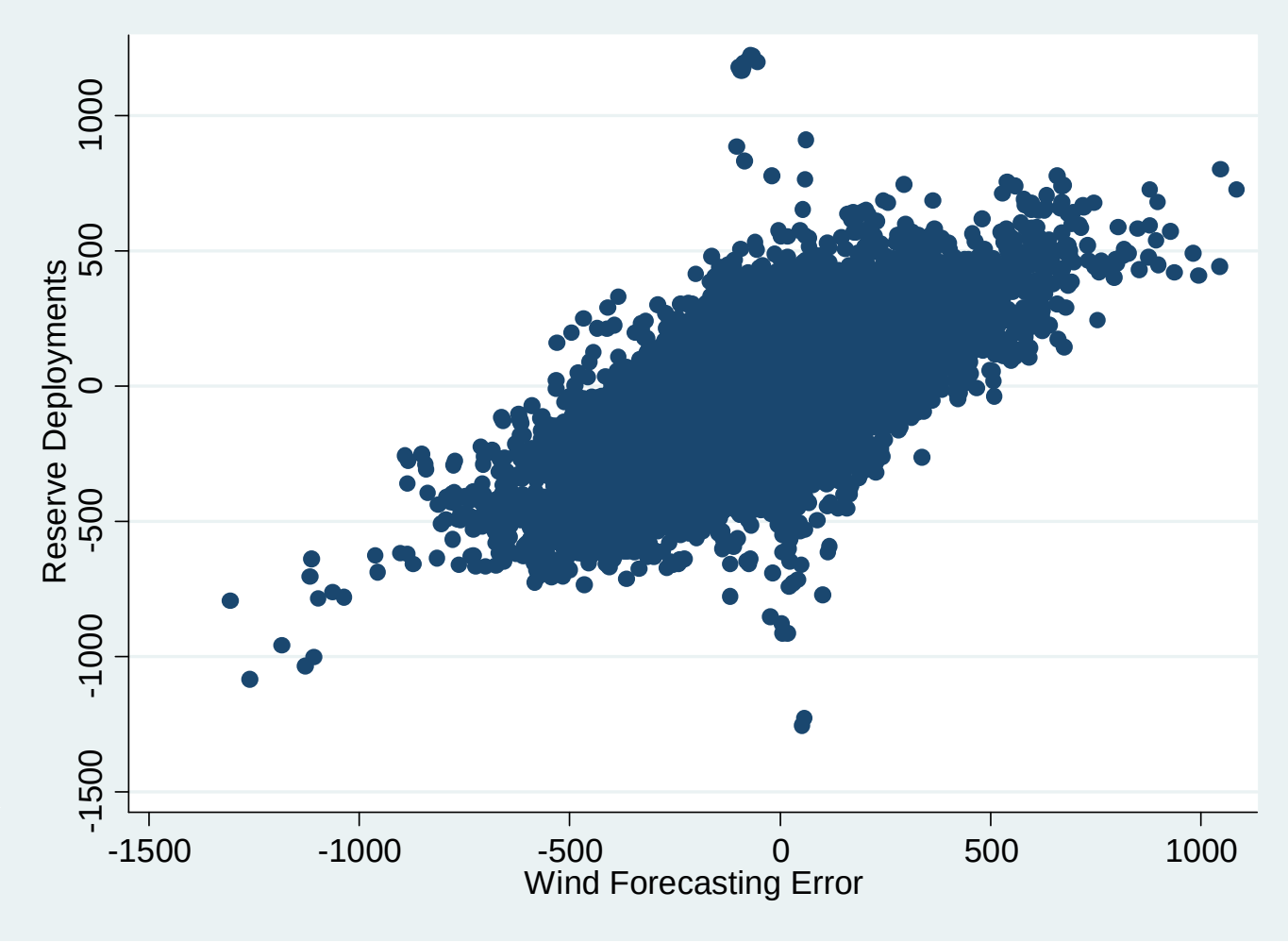
Monthly Capacity-Weighted Wind Forecast Errors for BPA, May 2008 – December 2010



Wind Forecast Errors for BPA Weighted by Mean Monthly Wind Energy, May 2008 – December 2010



Wind Forecast Errors and the Deployment of Reserve Power by BPA : 2 Nov 2010 - 1 March 2011



The Potential Consequences of Large-Scale Wind Energy Penetration for System Operator Uncertainty

- Assume two sources of forecasting error, load and wind.
- Total system error is equal to the sum of unexpected load (ULOAD) and unexpected wind (UWIND).
- Total uncertainty is equal to the variance of (ULOAD + UWIND).

Total Uncertainty per MWH of System Load: A Function of Wind Penetration

$$\text{var}(ULOAD + UWIND) = \text{var}(ULOAD) + \text{var}(UWIND) + 2\,\text{cov}(ULOAD, UWIND)$$

Multiply and divide var(*UWIND*) by mean wind production (*MEANWIND*). Then divide both sides by average load (*MEANLOAD*) to derive uncertainty per MWH of load .

$$\frac{\text{var}(ULOAD + UWIND)}{MEANLOAD} = \frac{\text{var}(ULOAD)}{MEANLOAD} + WINDSHARE\left(\frac{\text{var}(UWIND)}{MEANWIND}\right) + 2\left(\frac{\text{cov}(ULOAD, UWIND)}{MEANLOAD}\right)$$

where $WINDSHARE = \dfrac{MEANWIND}{MEANLOAD}$ and measures the degree of wind penetration.

Using data from control areas on actual and forecasted load and wind energy, the uncertainty impact of increased wind energy penetration on system operators can be estimated.

Total Uncertainty per MWH of System Load: A Function of Wind Penetration: The Case of Western Denmark

- Wind Energy is currently equivalent to about 30 percent of load in Western Denmark

- The Government of Demark wants to achieve 50 % wind integration by 2025.

- Based on the variance of ULOAD and UWIND and their covariance for Western Denmark, achieving the goal of 50% wind would increase the uncertainty per MWh by about 57%

Total Uncertainty per MWH of System Load: A Function of Wind Penetration: The Case of the Midwest ISO

- Wind Energy is currently equivalent to about 3.4 percent of load in the Midwest ISO

- The American Wind Energy Association is promoting legislation that would achieve 20 % wind integration by 2030.

- Based on the variance of ULOAD and UWIND and their covariance for the Midwest ISO, achieving the goal of 20 % wind would increase the uncertainty per MWh by about 62 %

Conclusions

- There is no legitimate reason to weight wind forecast errors by installed wind energy capacity
- The errors in forecasting wind energy are much larger than the errors in forecasting load.
- The data from the BPA makes it clear that the errors have consequences for power grid operations.
- Increases in wind energy penetration increase the operating uncertainty that system operators must confront to keep the lights on.
- Wind energy policies should reflect these realities.