

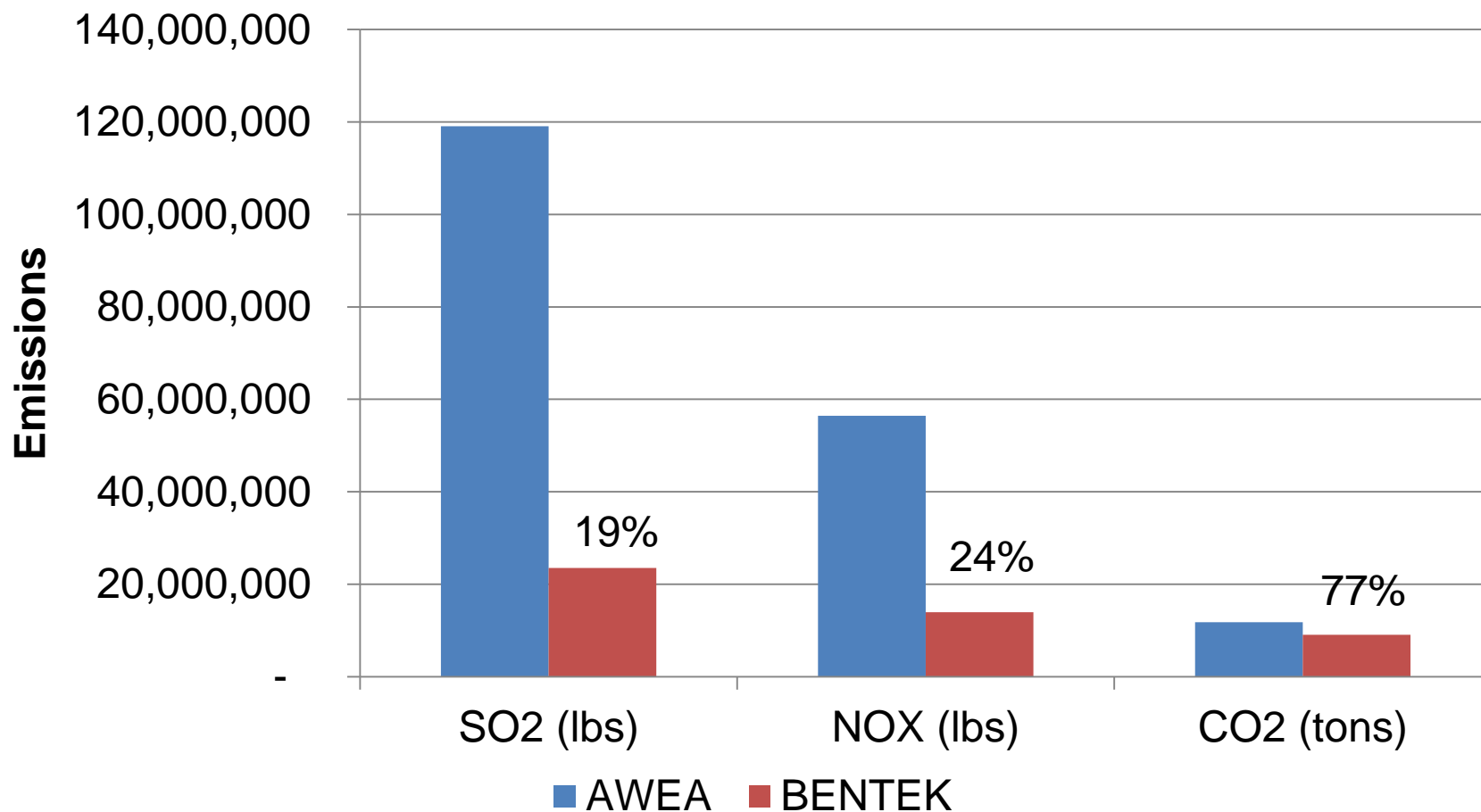


The Unintended Consequences of Wind Generation

Presented to the CEE Renewable Roundtable

December 1, 2010

Emission Savings Is Far Less Than Expected



1,881,081 MWh of Wind Generation During 2009

Agenda

- ❖ Introduction
- ❖ Wind Generation in America
- ❖ Thermal Plants Are Cycled to Accommodate Wind Generation
- ❖ Cycling Reduces Emission Reduction Efficiency
- ❖ The Unintended Consequences of Wind Generation
- ❖ Independent Research
- ❖ Implications

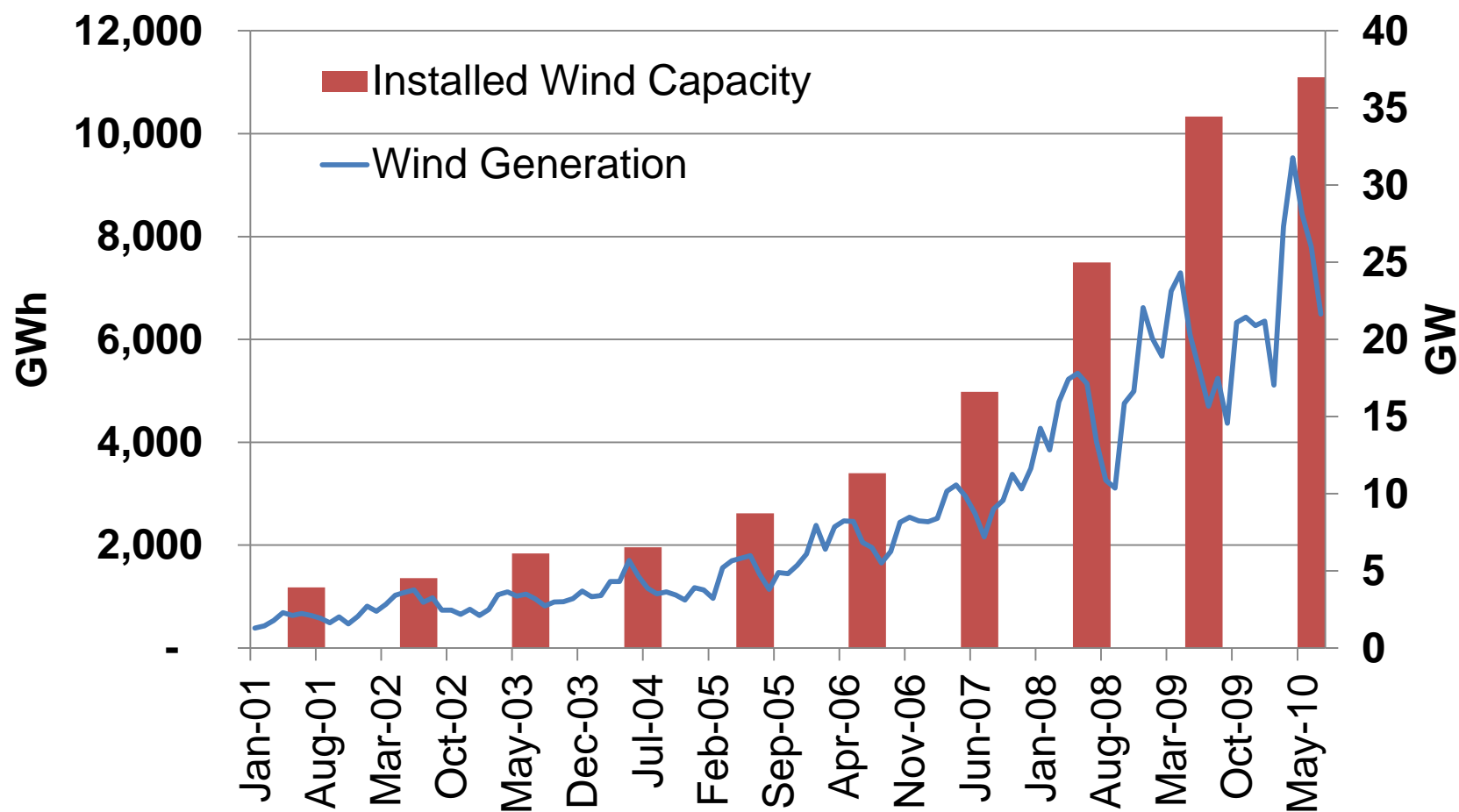
BENTEK Client Mix > 300

BENTEK is an energy market analytics company, focused on the natural gas market and related energy sectors.

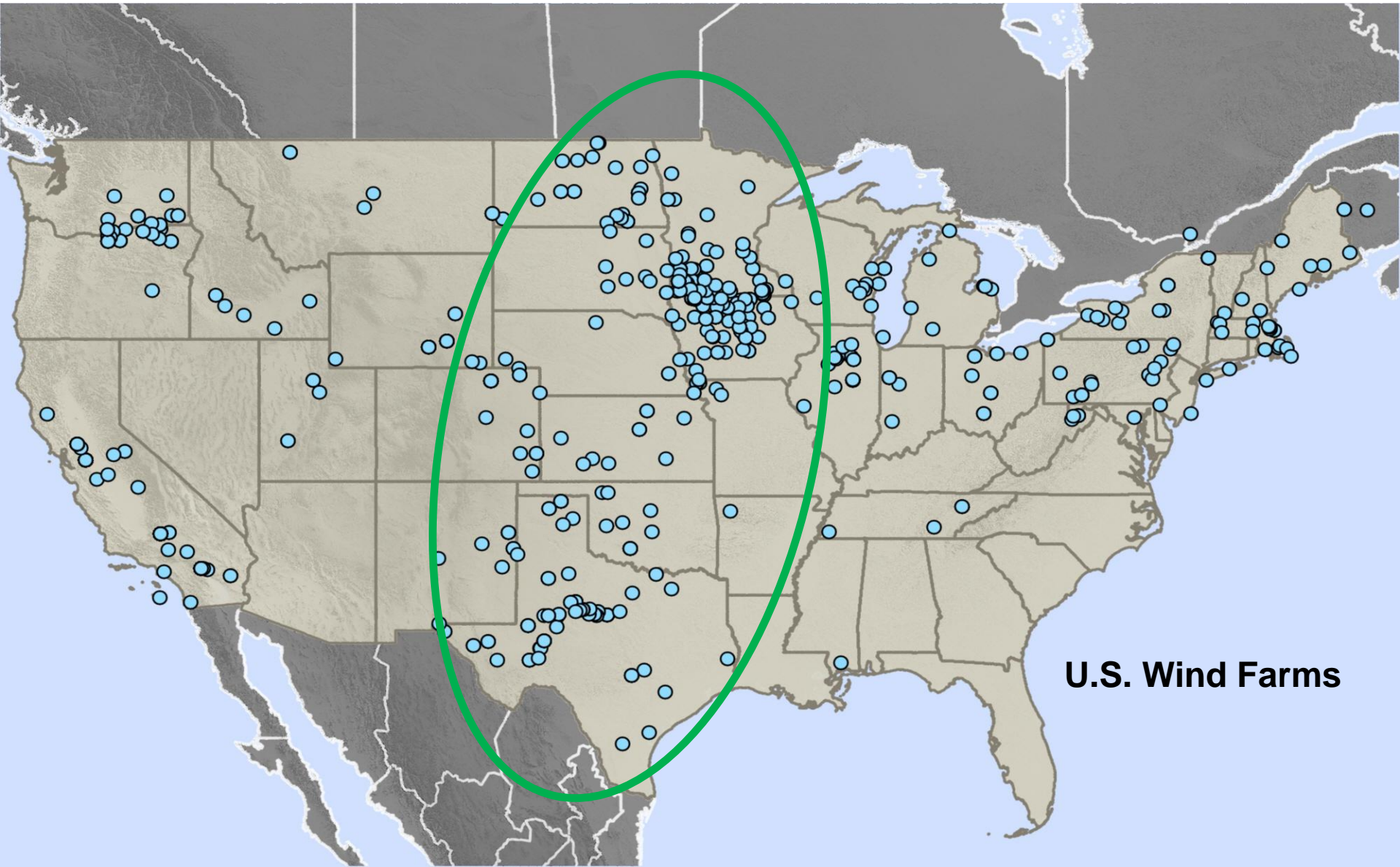


- ❖ >120 Oil and Gas Majors, Producers, Marketers and Industrials
- ❖ >70 Pipelines, Processors and Utilities
- ❖ >100 Financial institutions including most major investment banks and hedge funds
- ❖ 6 Government agencies, Associations and Consultants
 - Federal Energy Regulatory Commission (FERC)
 - Minerals Management Service (MMS)
 - Energy Information Administration (EIA)

844% Increase in Wind Turbine Capacity Since 2001



36,300 MW Installed Capacity, More to Come



U.S. Wind Farms

Politics Are Driving Wind Generation Build-out

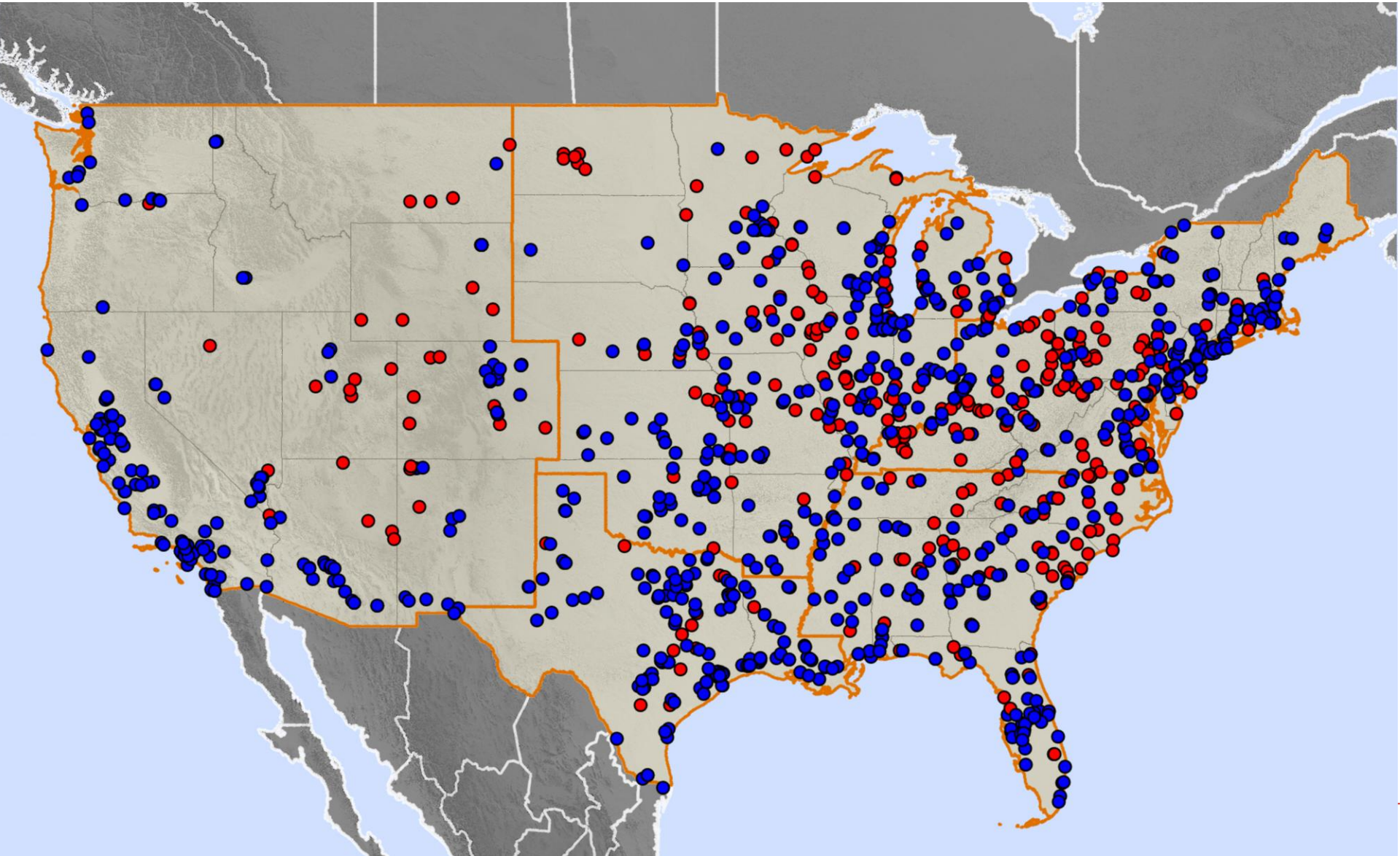
Current

- ❑ State Renewable Portfolio Standards (RPS)
- ❑ Federal Production Tax Credit (PTC)
- ❑ Voter Appeal

Going Forward

- ❑ Increased RPS standards
 - 6,000 MW of capacity currently under construction
- ❑ National Renewable Portfolio Standard

Granular Data, Bottoms-Up Approach



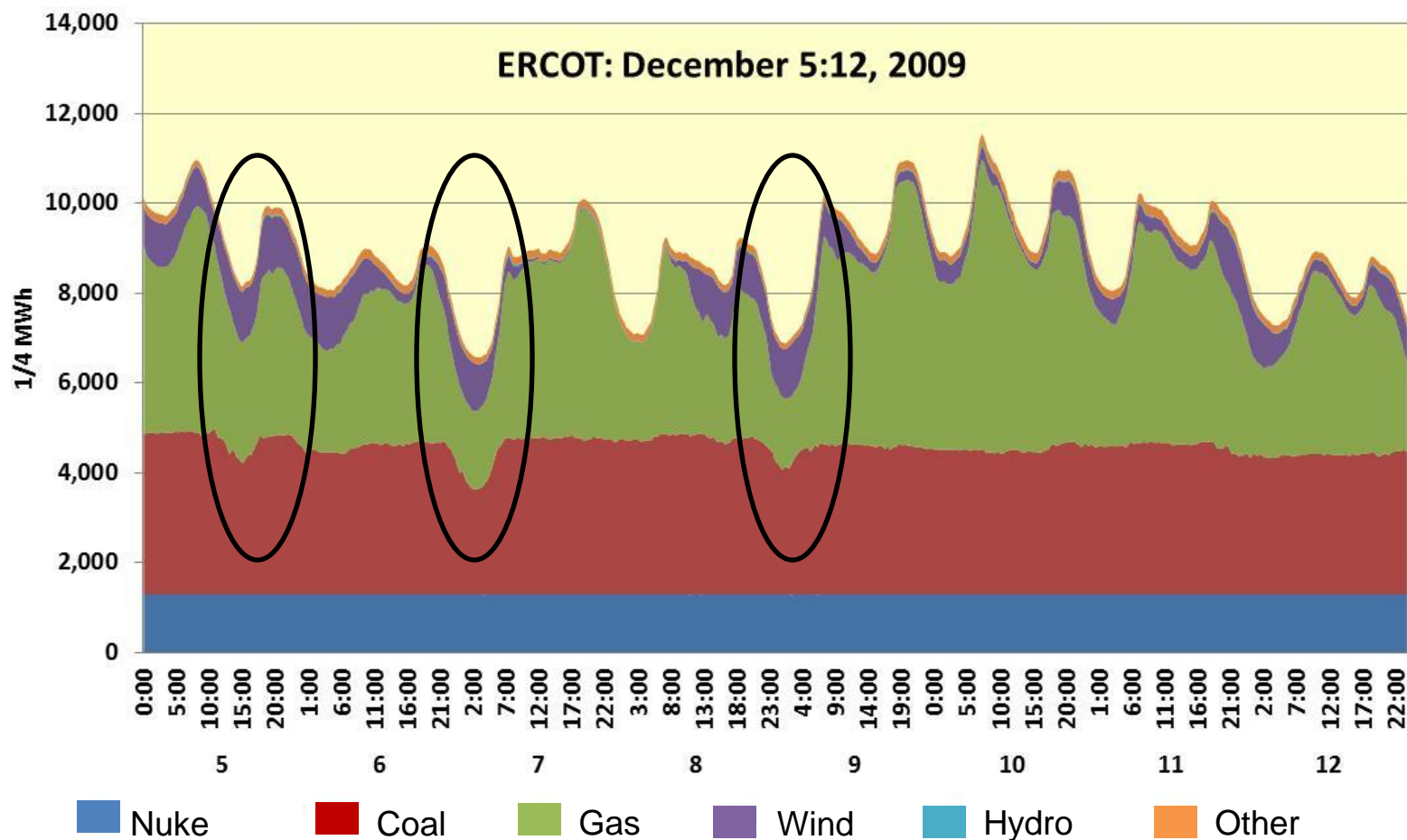
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Cycling Defined

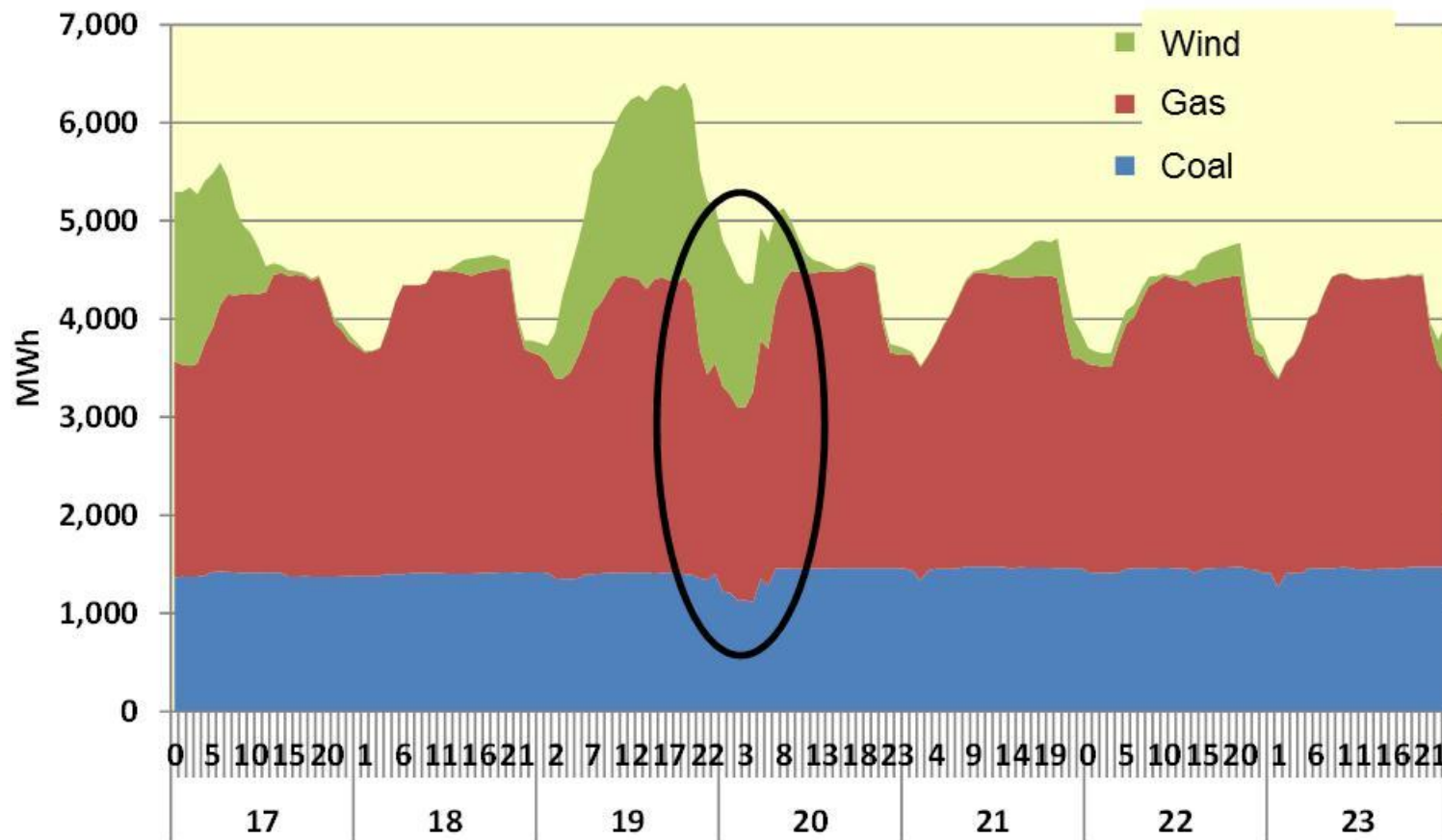
“Integrating intermittent, volatile electricity into the grid can cause a surge or a sag that can lead to brownouts or blackouts. So grid operators, like Xcel Energy, must balance the wind-generated electricity with electricity online, ready and available to the system. In order to do that, plants that are already operating and connected to the grid must suddenly and rapidly increase or decrease their output to maintain balance. In some cases, this means that plants that are offline must be brought online quickly. The rapid starts and stops or increases and decreases in output are called ‘cycling’.” – APTECH Engineering (2008)

Coal Plants Are Cycled to Accommodate for Wind



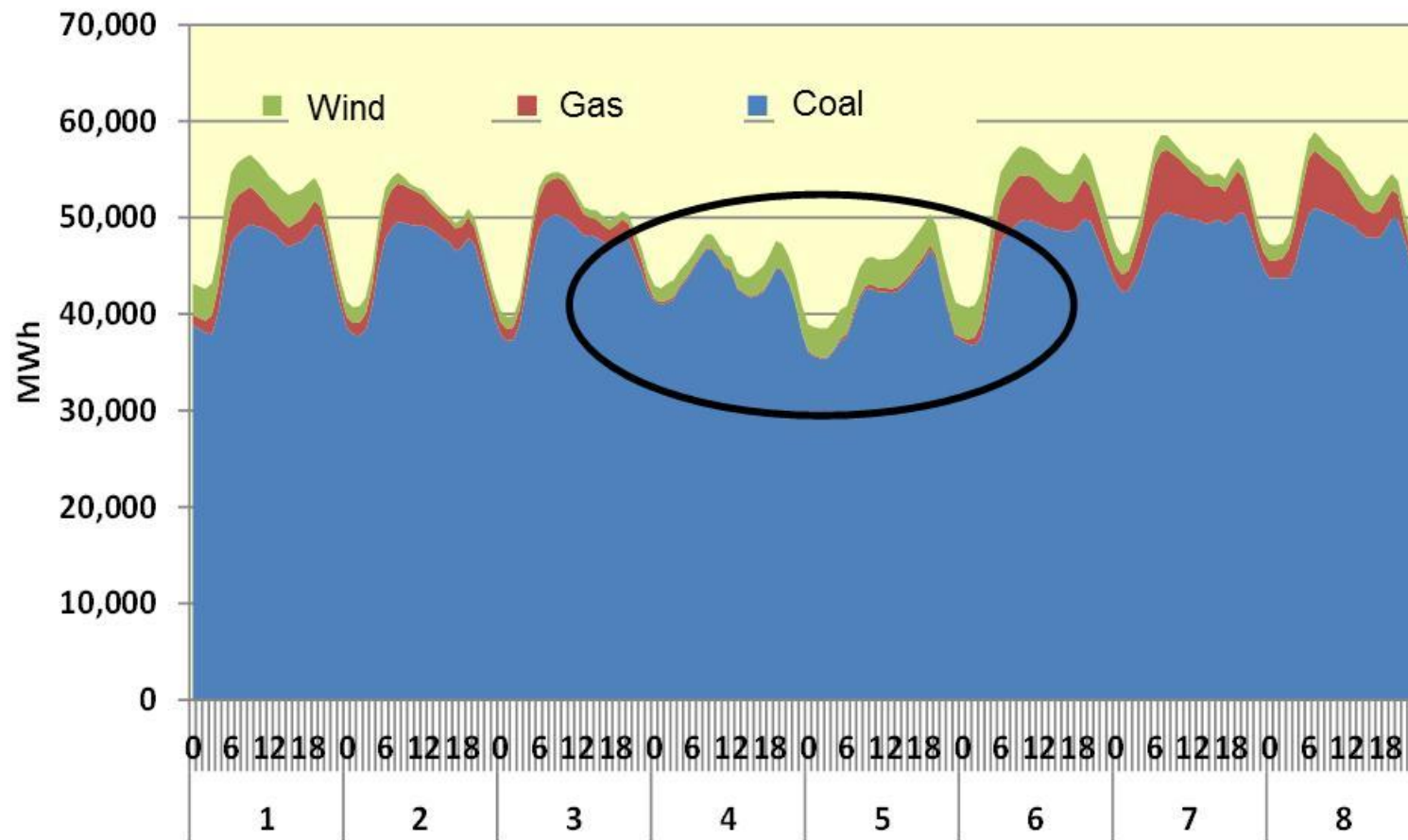
Coal Plants Are Cycled to Accommodate for Wind

BPA September 17:23, 2009

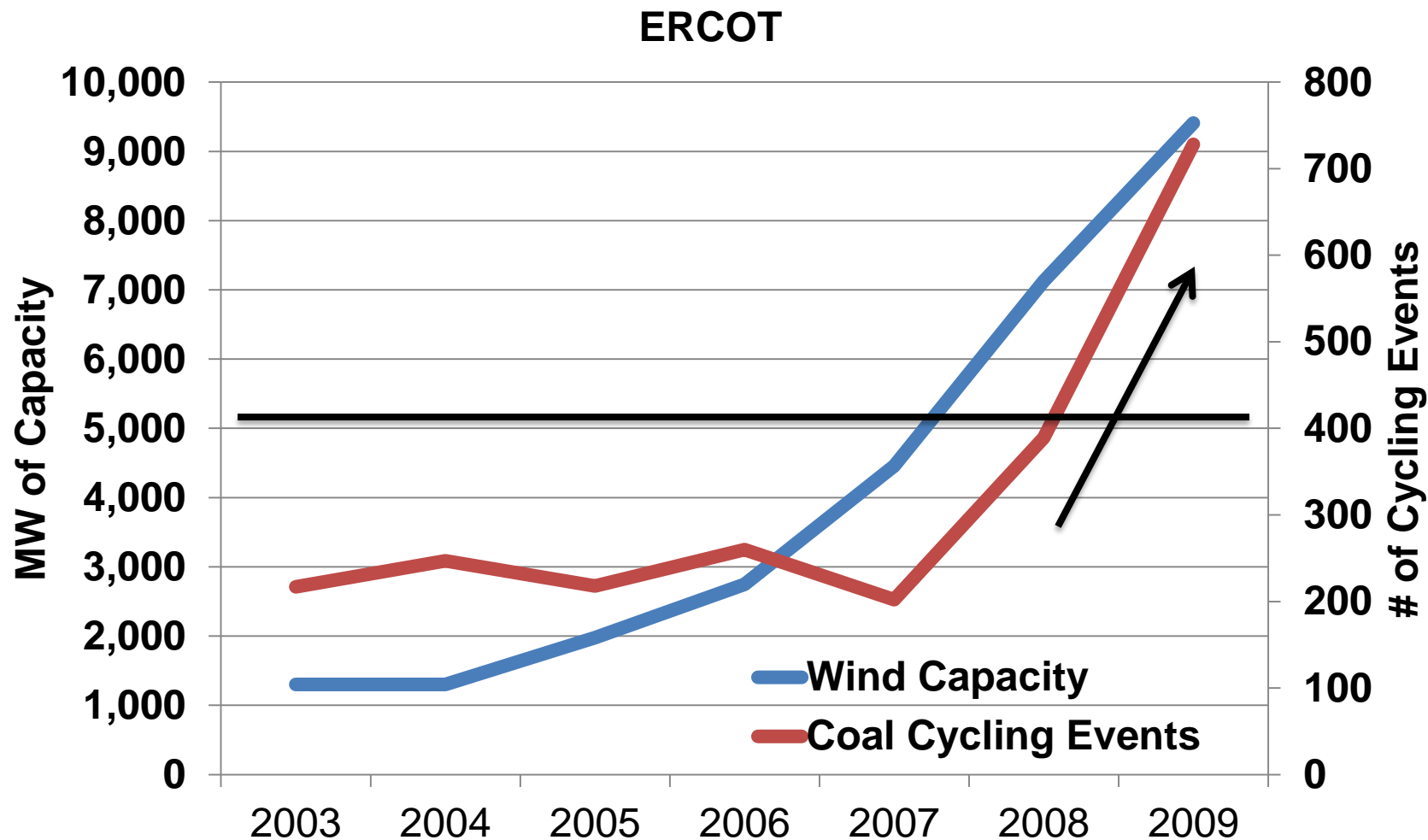


Coal Plants Are Cycled to Accommodate for Wind

MISO April 1:8, 2009



Wind Generation Increased Coal Cycling



Cycling Event: > 5% change in generation output hour over hour

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Cycling Reduces Emission Reduction Efficiency

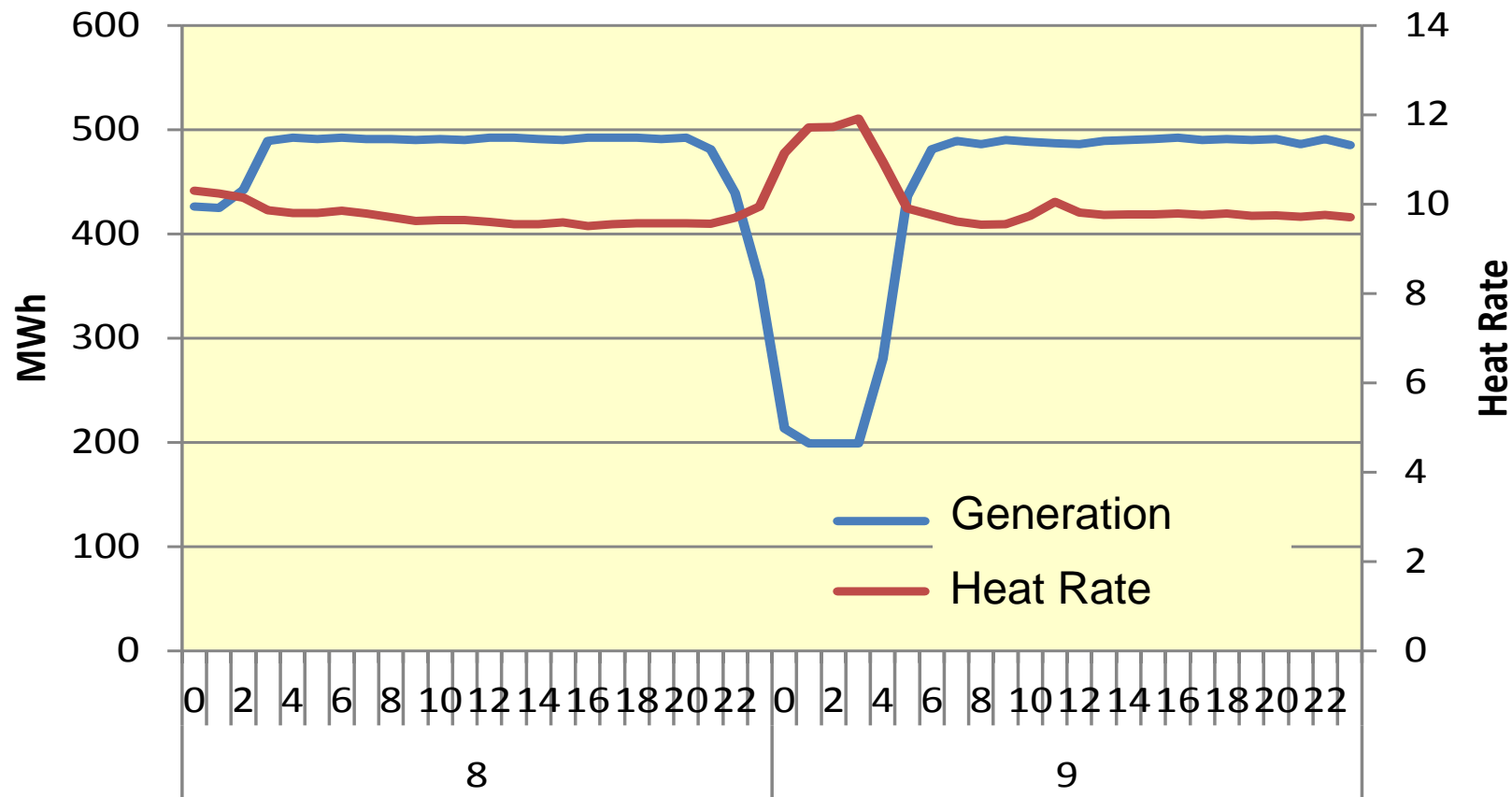
*“The aim [of this study] is to show that the **fuel economy and emissions reduction** in the power systems consisting mainly **of thermal power plants** are not proportional with the electricity production of wind turbines. **Participation of thermal power plants in the compensation of fluctuating production of windmills eliminates major part of the expected positive effect of wind energy.** – Liik, Oidram, Keel (2003): Denmark*

Cycling Decreases Efficiency, Increases Emissions

- ❖ Coal plants are designed to run at steady, efficient rates
- ❖ Deviating from this creates stresses on the facility
 - Increased heat rate
 - Maintenance & part degradation
 - Emission equipment malfunction
 - Decreased reliability
- ❖ These consequences have drastically decreased emissions savings from wind generation

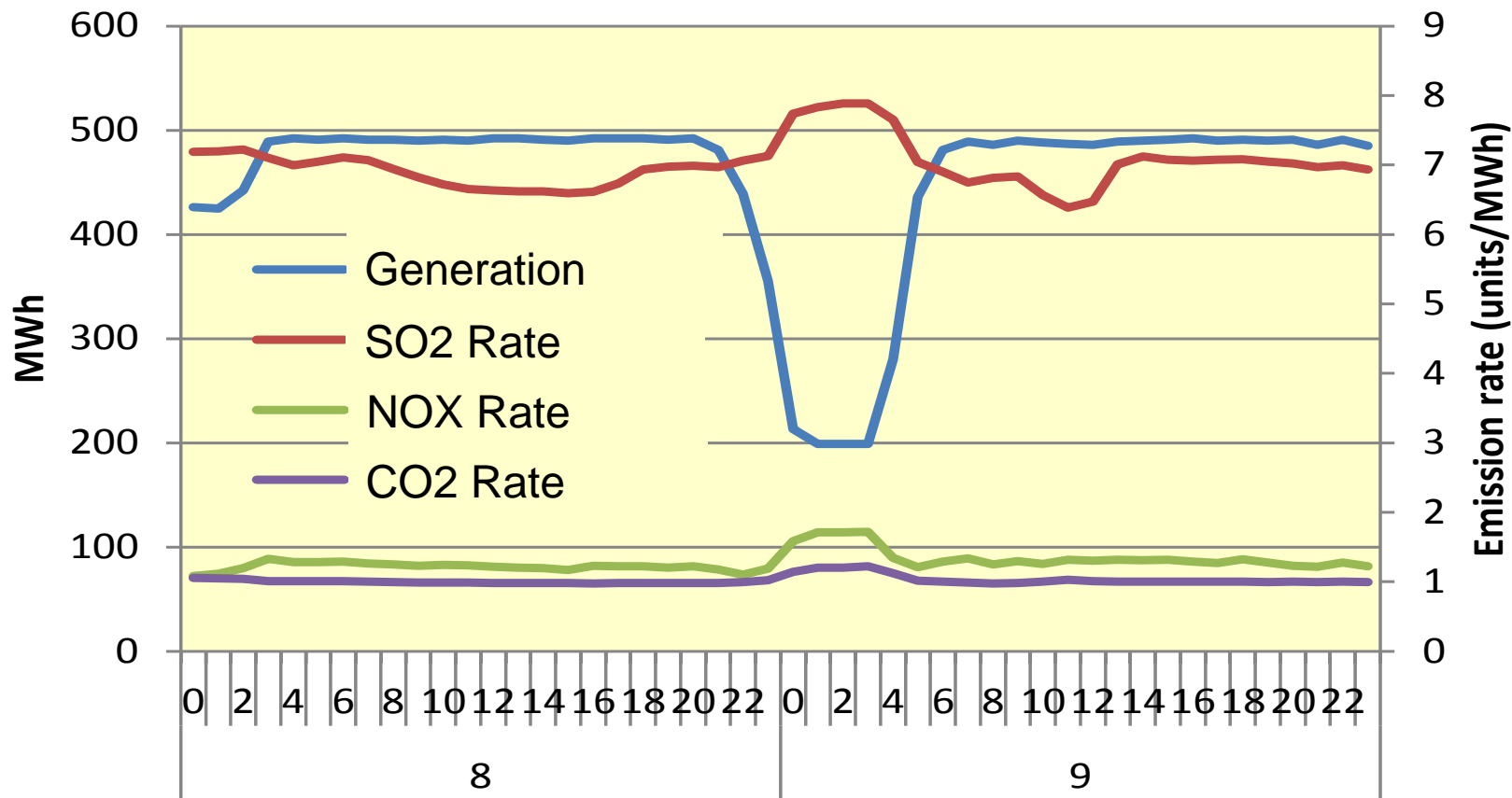
As Thermal Plants are Cycled, Heat Rate Increases

Gibbons Creek Steam Electric Station (ERCOT), January 8:9, 2009

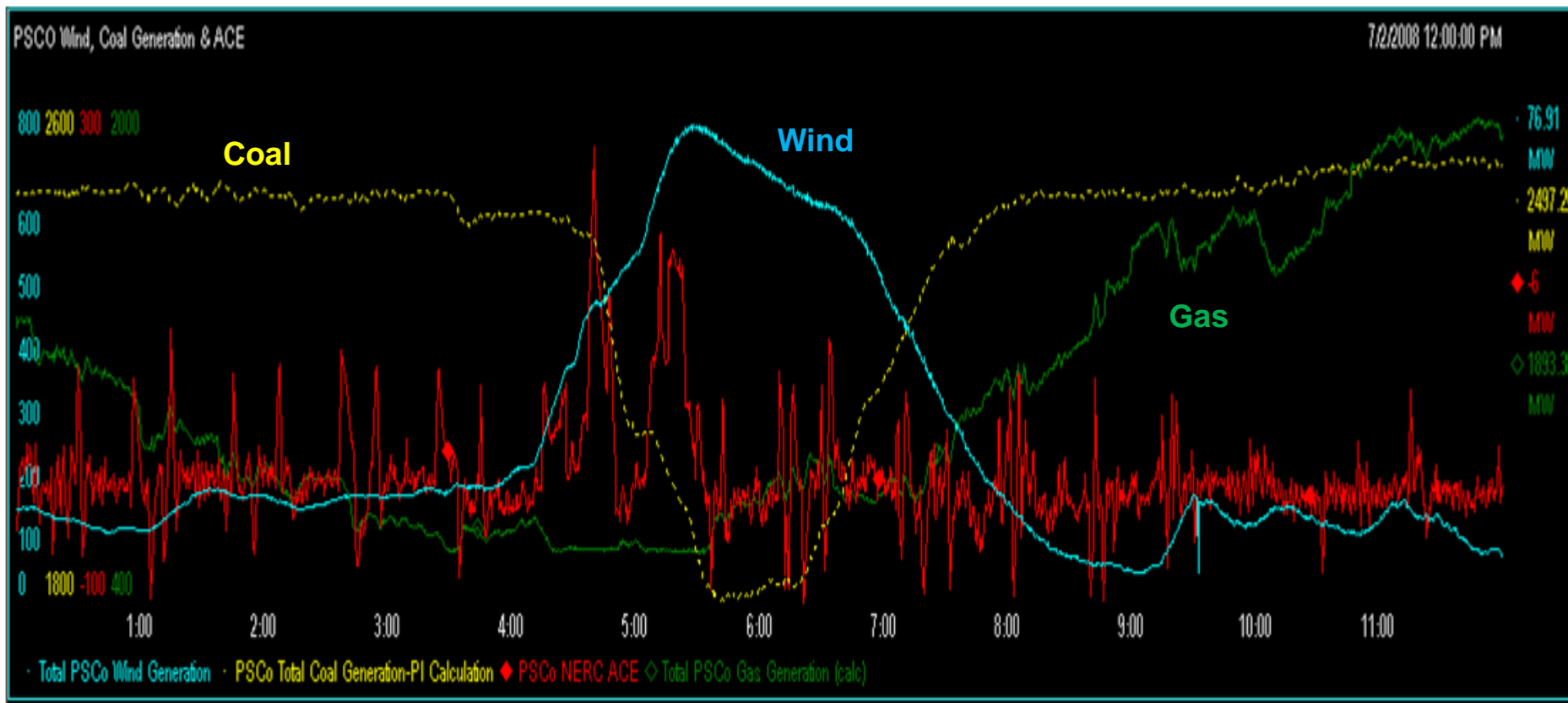


Emission Rates Also Increase

Gibbons Creek Steam Electric Station (ERCOT), January 8:9, 2009



PSCO Wind Event: 7/2/2008

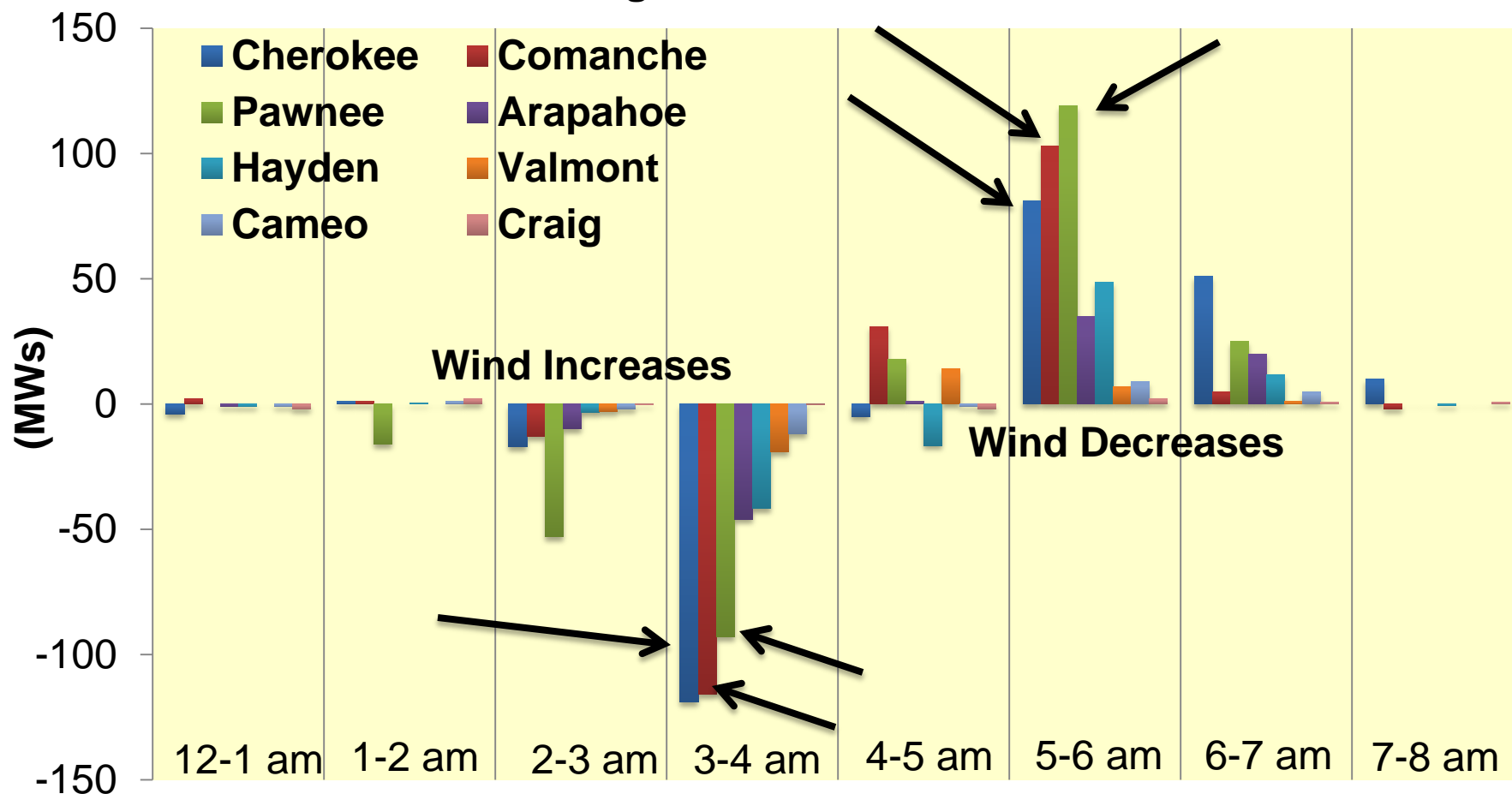


4:00 AM

8:00 AM

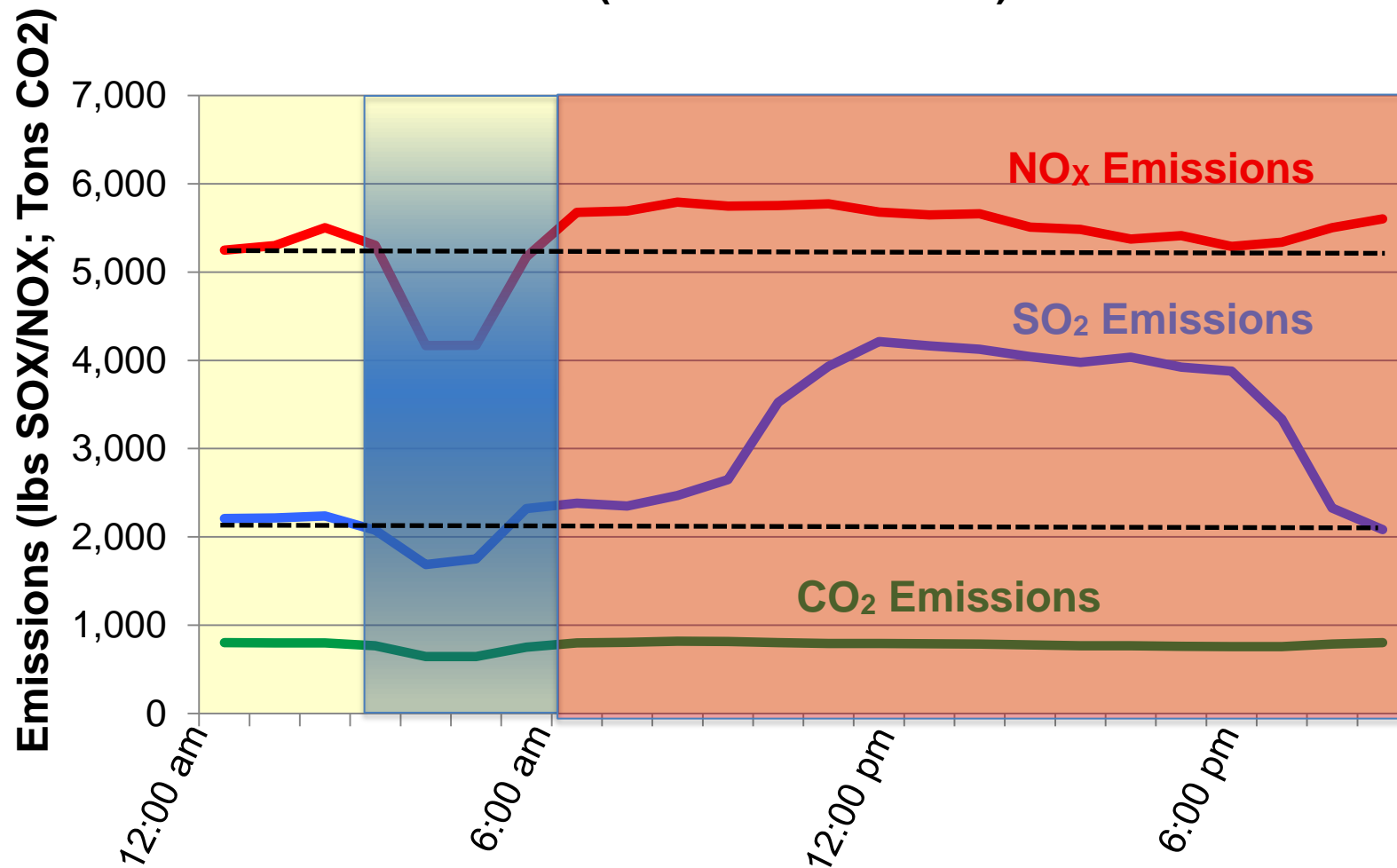
Several Coal Plants Were Forced to Cycle

Hour - to - Hour Change in Generation
Midnight to 8:00 am on 7/2/08



Emissions Increased After the Cycling Event

Emissions At Cherokee (All Units – 7/2/2008)



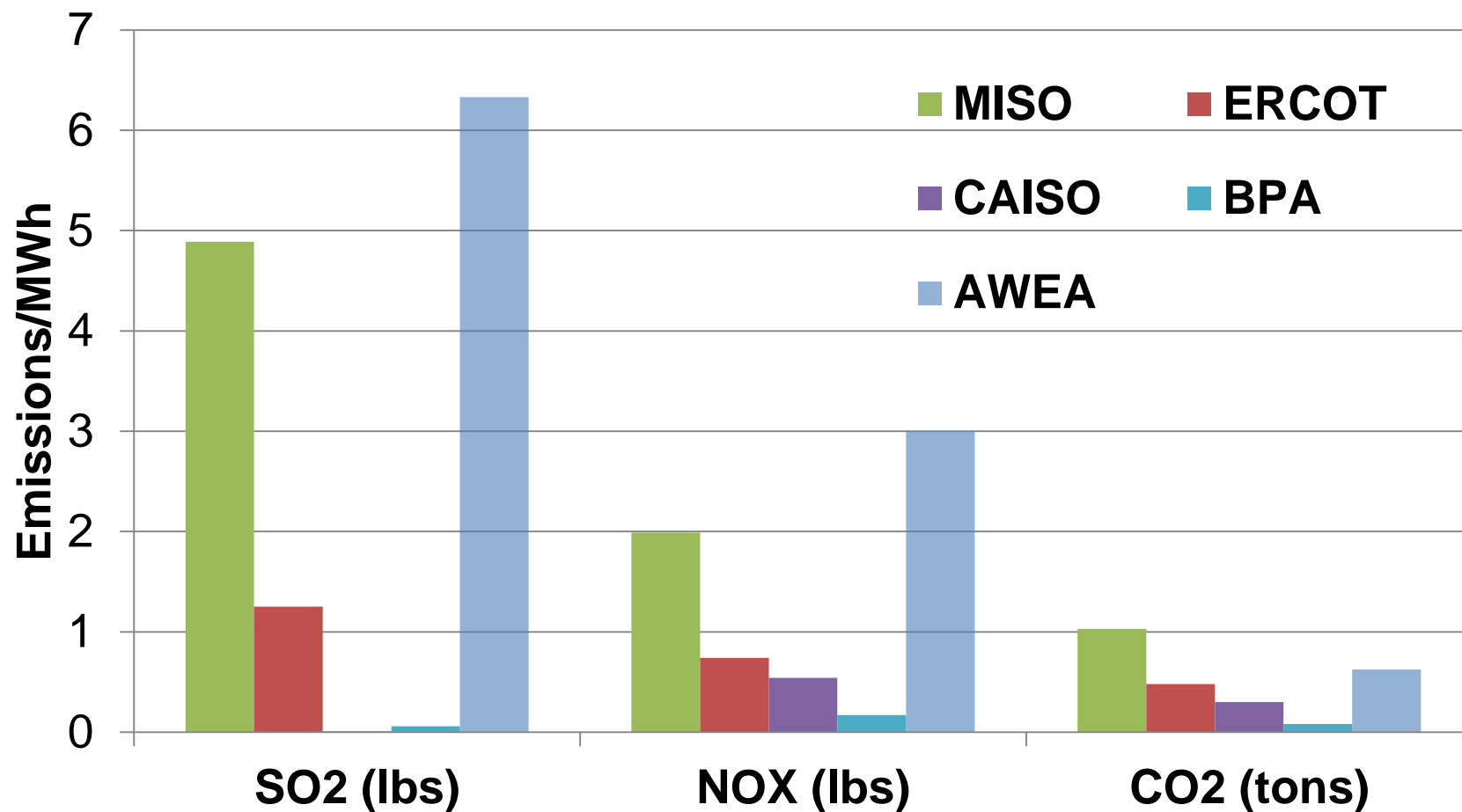
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The Unintended Consequences of Wind Generation

“There is no evidence that industrial wind power is likely to have a significant impact on carbon emissions. The European experience is instructive. Denmark, the world's most wind-intensive nation with more than 6,000 turbines generating 19% of its electricity, has yet to close a single fossil fuel plant. It requires 50% more coal-generated electricity to cover wind power's unpredictability, pollution and carbon dioxide emissions have risen (by 36% in 2006 alone)”. - Trebilcock (2009)

BENTEK Calculated Emission Reductions

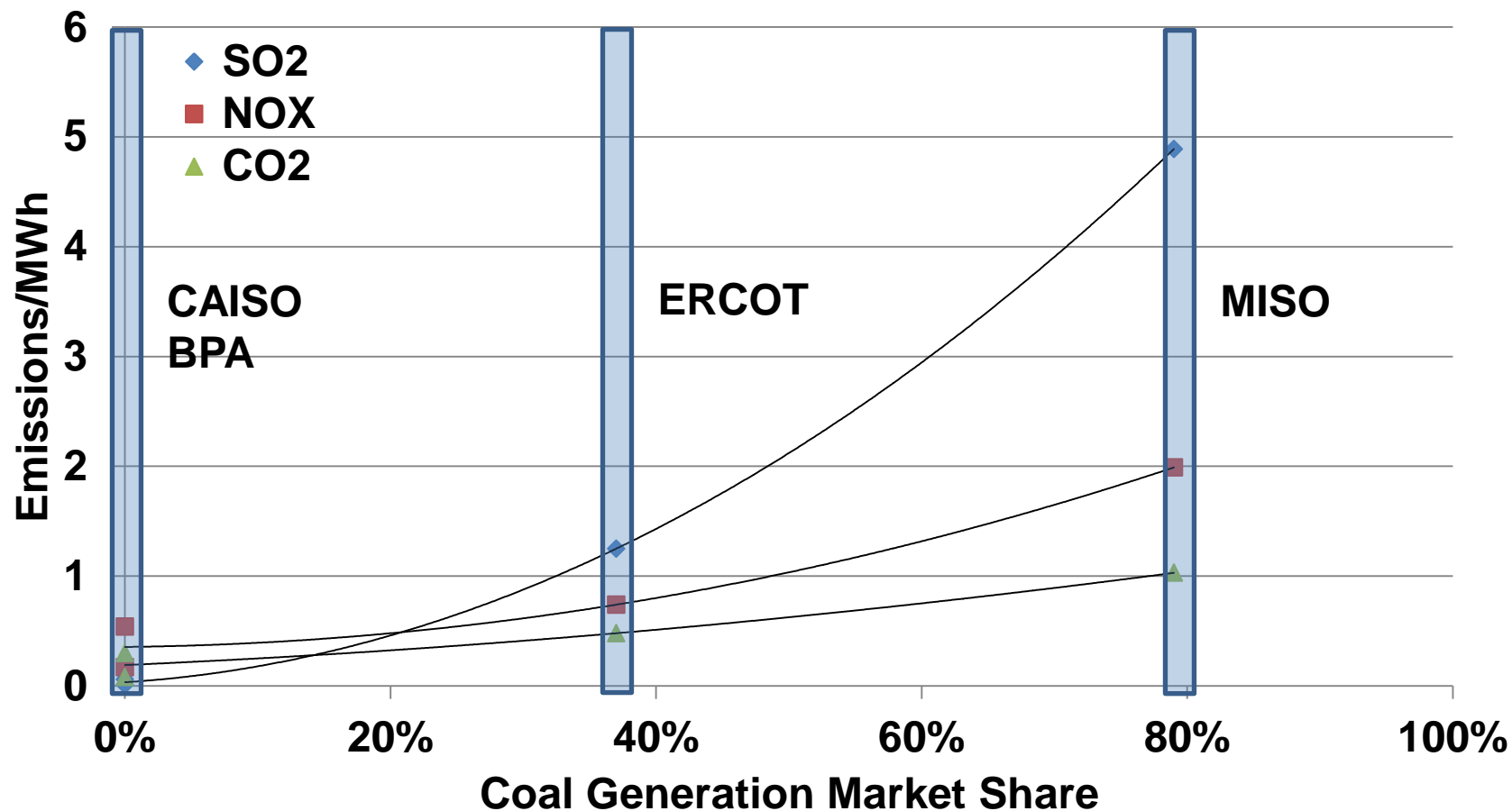


Auto-regressive, non-linear, multivariate reduced form model.

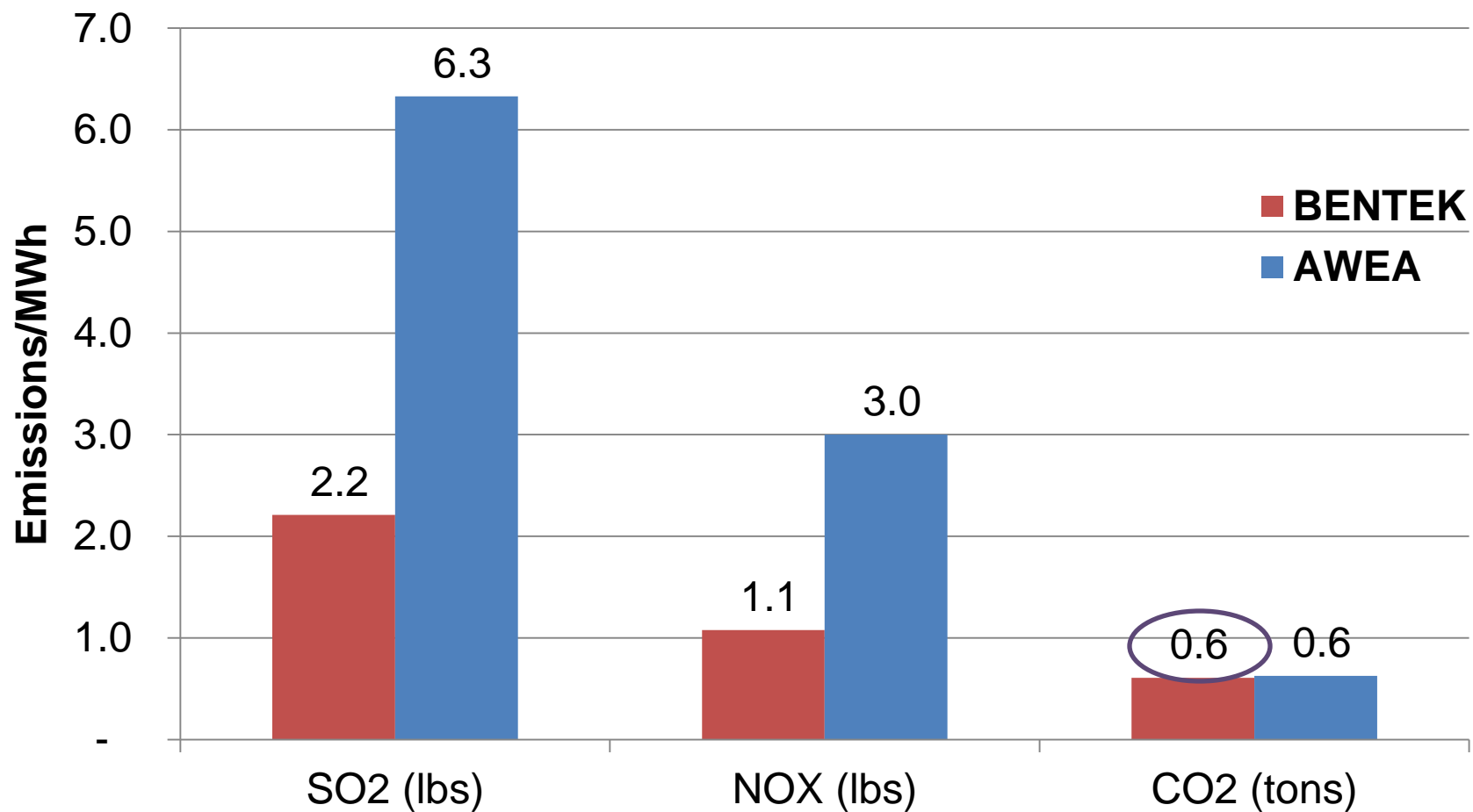
Developed by Dr. Dan Kaffine of the Colorado School of Mines

Emissions Savings Are Dependent on the Generation Mix

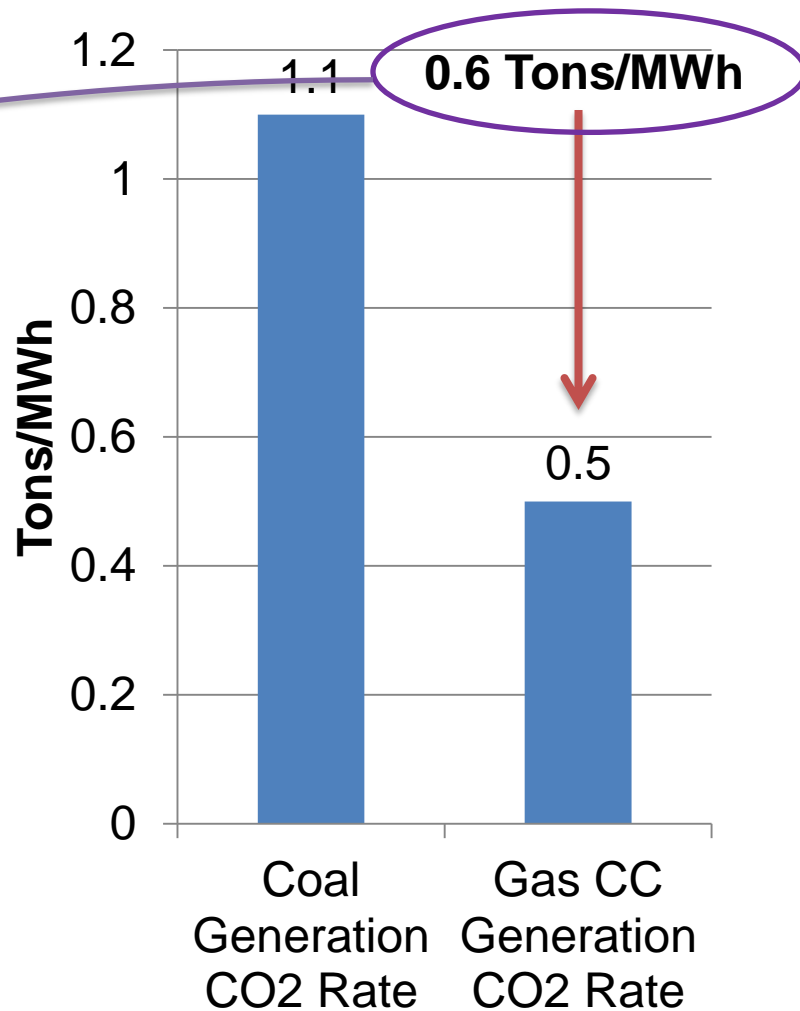
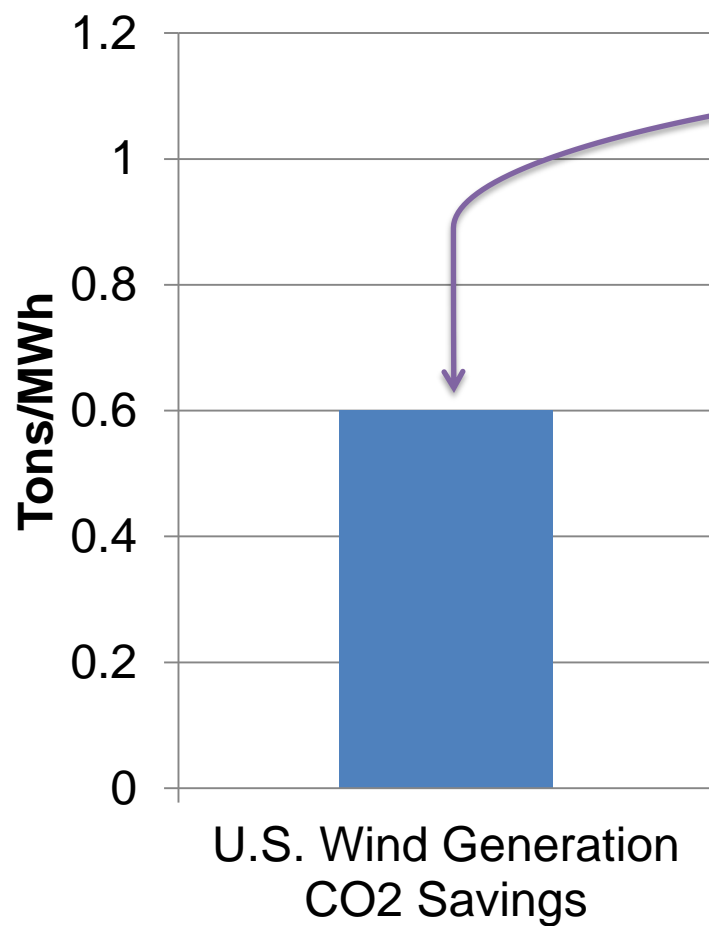
Wind Generation Savings



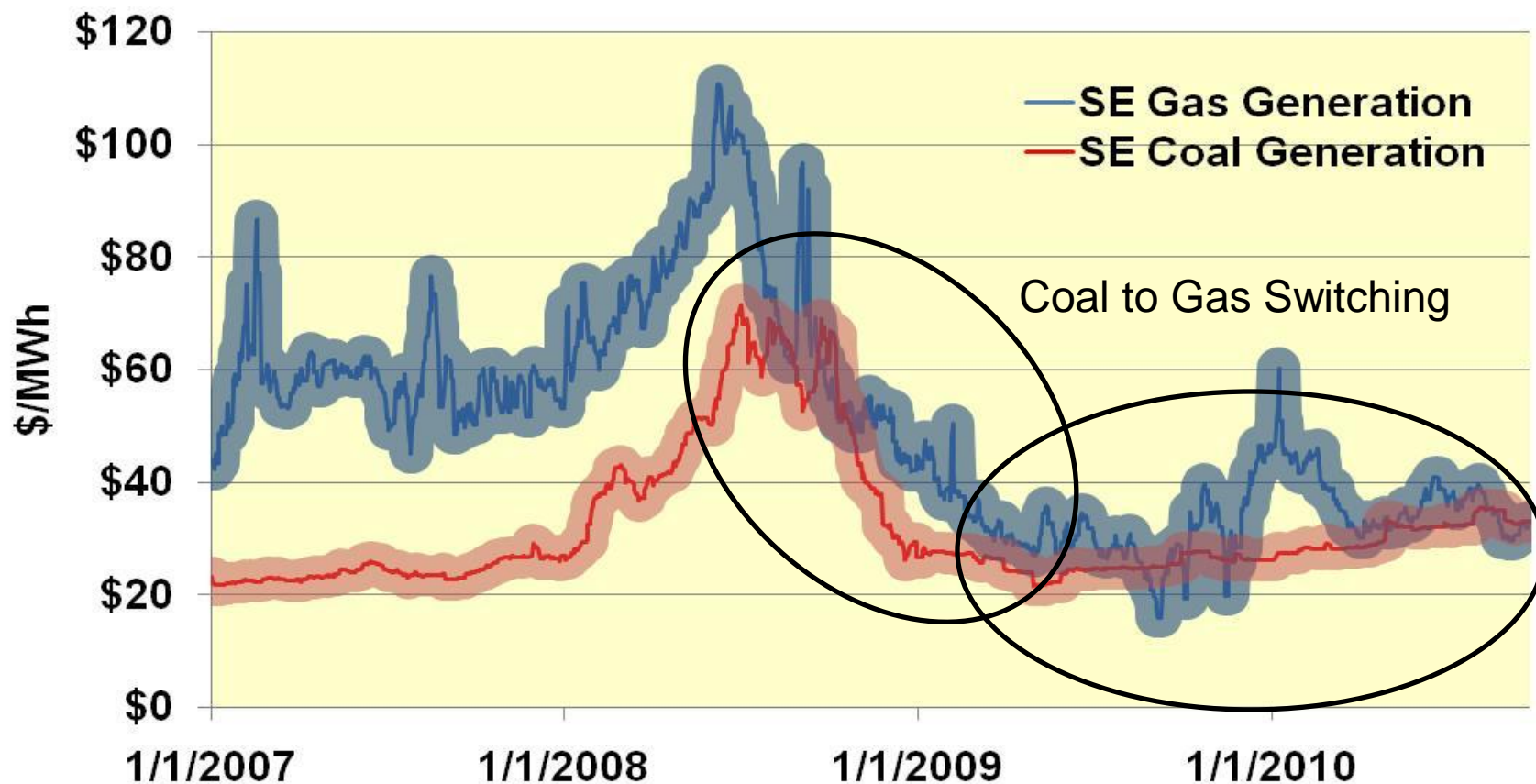
Wind Generation Emission Saving Rates



Makes More Sense to Reduce CO2 Through Natural Gas

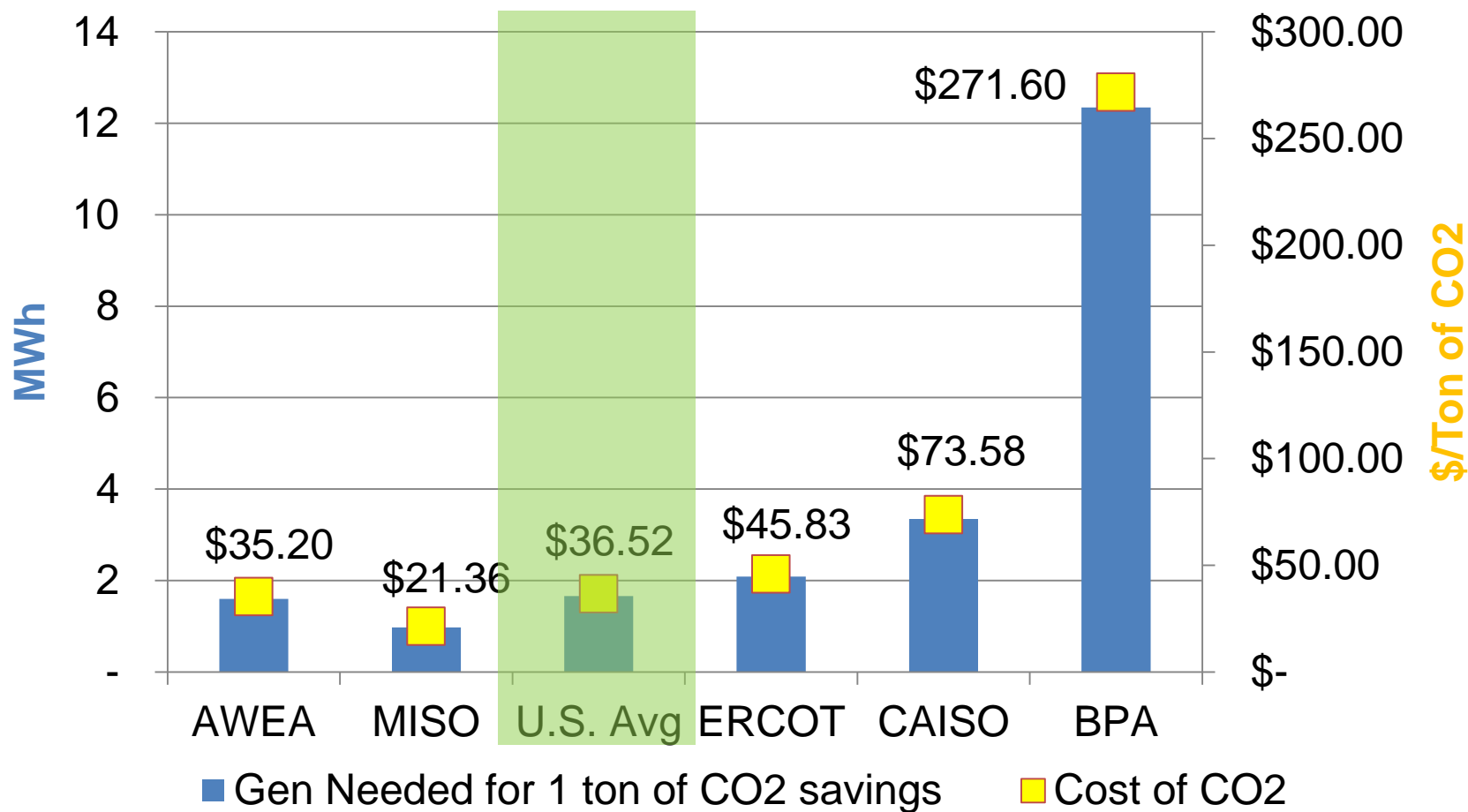


Emission Savings Will Only Decline



Incremental emission limitations will further increase natural gas use

Subsidy Implied Average CO2 Cost: \$36.5/ton



Independent Research

- ❖ Beenstock, M. (1995). The stochastic economics of windpower. *Energy Economics* 17 (1),27-37.
- ❖ Benitez, L., P. Benitez, and G. Van Kooten (2008). The economics of wind power with energy storage. *Energy Economics* 30 (4), 1973-1989.
- ❖ Campbell, A. (2009). Government Support for Intermittent Renewable Generation Technologies. *MIT Department of Economics, Working Paper* 6, 1381-1402.
- ❖ Cullen, J. (2008). Whats powering wind? measuring the environmental attributes of wind generated electricity. *Working Paper* .
- ❖ Decarolis, J. and D. Keith (2006). The economics of large-scale wind power in a carbon constrained world. *Energy Policy* 34 (4), 395-410.
- ❖ Katzenstein, W. and J. Apt (2009). Air emissions due to wind and solar power. *Environmental Science and Technology* 43 (2), 253-258.
- ❖ Lang, P. (2009). Cost and quantity of greenhouse gas emissions avoided by wind generation. *Working Paper*.
- ❖ Liik, O., R. Oidram, and M. Keel (2003). Estimation of real emissions reduction caused by wind generators. In *International Energy Workshop, June 24-26, IIASA*.
- ❖ Moore, M., G. Lewis, and D. Cepela (2010). Markets for renewable energy and pollution emissions: Environmental claims, emission-reduction accounting, and product decoupling. *Energy Policy*.
- ❖ Puga, J. (2010). The Importance of Combined Cycle Generating Plants in Integrating Large Levels of Wind Power Generation. *The Electricity Journal*.
- ❖ Trebilcock, M. (2009). Speaking Truth to Wind Power. *CD Howe Institute* 22, 209.
- ❖ Valor, E., V. Meneu, and V. Caselles (2001). Daily air temperature and electricity load in Spain. *Journal of Applied Meteorology* 40, 1413-1421.

Conclusions

- ❖ Wind generation causes thermal plants to cycle (both coal and gas), which significantly degrades efficiency
- ❖ Wind generation emission savings vary by territory due to different generation stacks
- ❖ As natural gas generation use increases, potential wind generation emission savings will decline
- ❖ Displacing coal-fired generation with natural gas combined cycle generation would reduce CO2 emissions at the same rate that wind generation reduces CO2 emissions
 - SO2 and NOX savings through this process would be greater than the savings achieved through wind generation
- ❖ Further research using empirical, granular emissions data is absolutely paramount before further government mandated integration of wind generation in the U.S.



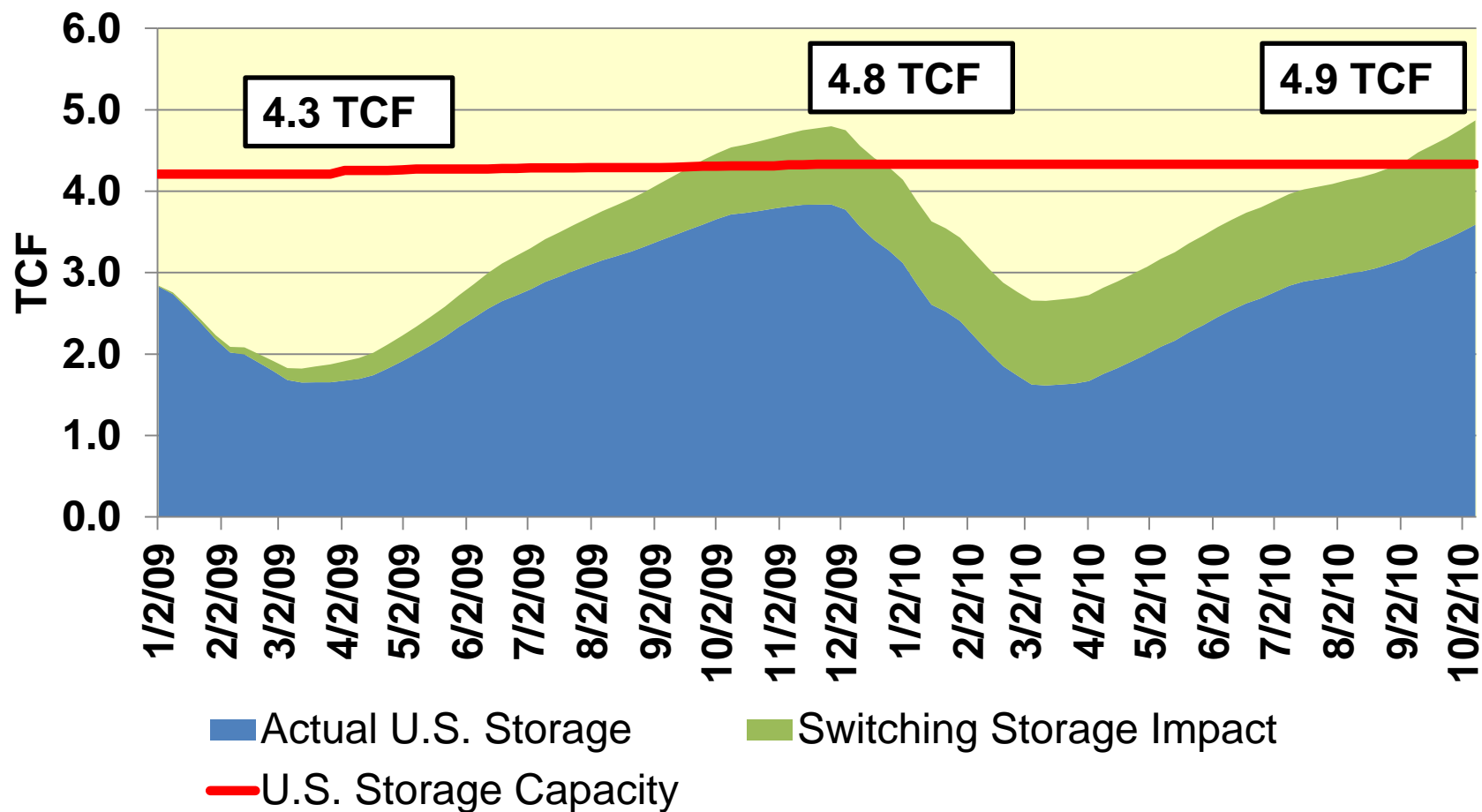
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(303) 988-1320**

Appendix

Without Switching, Producers Would Have to Shut In



Switching Expected to Average >3 Bcf/d Over Winter

