Integrating Wind Power into the Electric Power System

Ed DeMeo
Technical Advisor: Utility Wind Integration Group
Co-Chair, 20% Wind Energy Advisory Group
Renewable Energy Consulting Services, Inc.

NARUC Electric Reliability and Electricity Staff Subcommittees
July 20, 2008 *Portland, Oregon*

Key Integration Issues

- Market competitiveness
- Variability and Uncertainty impacts
- Mitigation of impacts
- Storage: is it needed?
- Energy, Capacity and Carbon Emissions

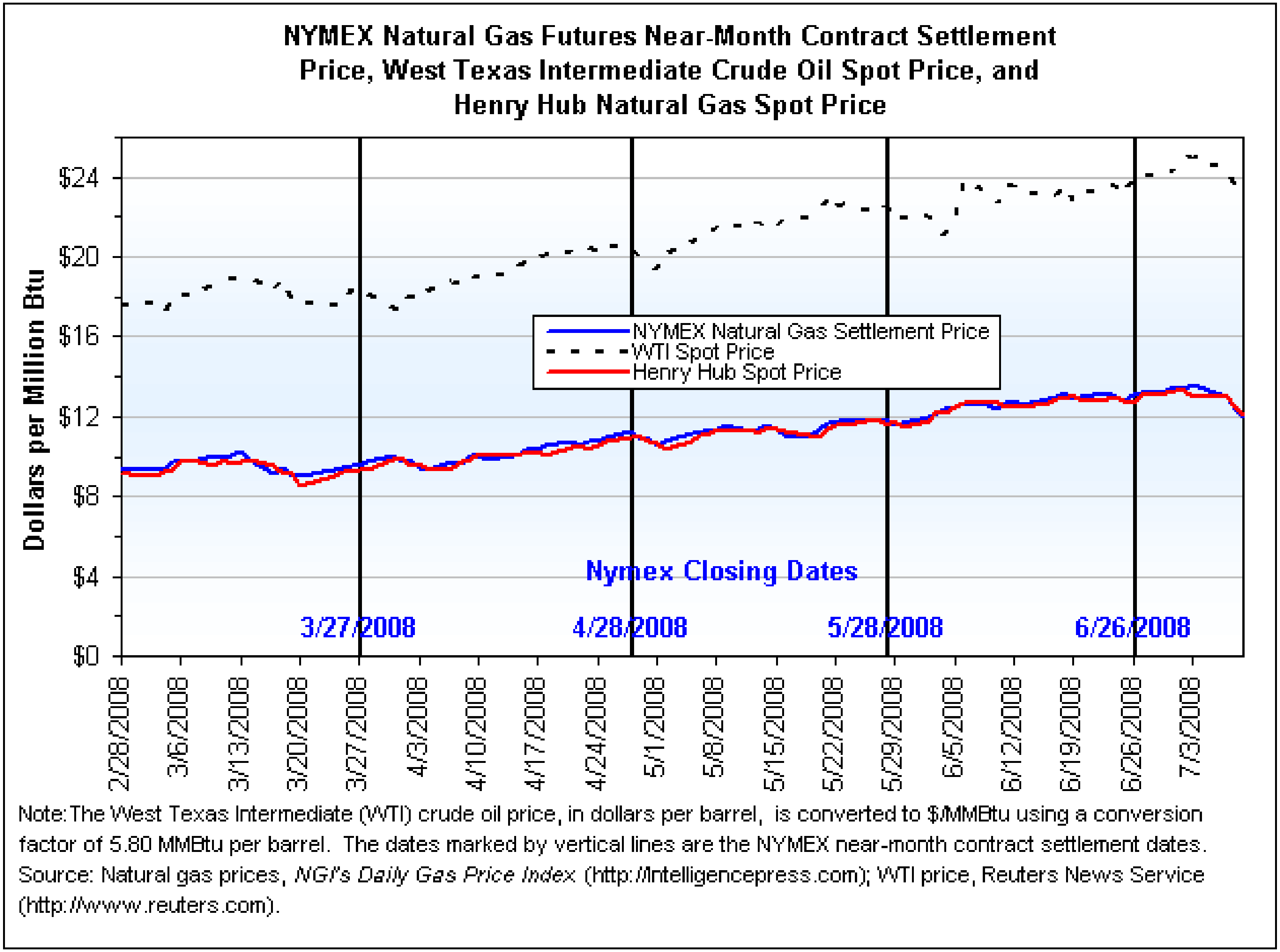
Natural Gas Situation (old news today)

"Today's tight natural gas markets have been a long time in coming, and distant futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon."

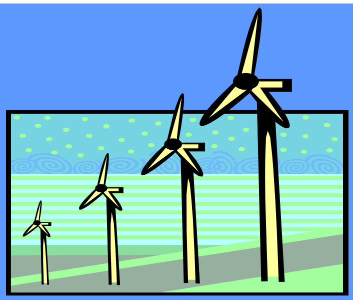
– Alan Greenspan, Federal Reserve Chairman, Testimony at Senate hearing, July 10, 2003

Wellhead gas costs - 2002-2003: $3 - $5/MMBTU

Current prices and projections exceed $10/MMBTU



Source: EIA Natural Gas Weekly Update, 7-10-08



Cost Comparison

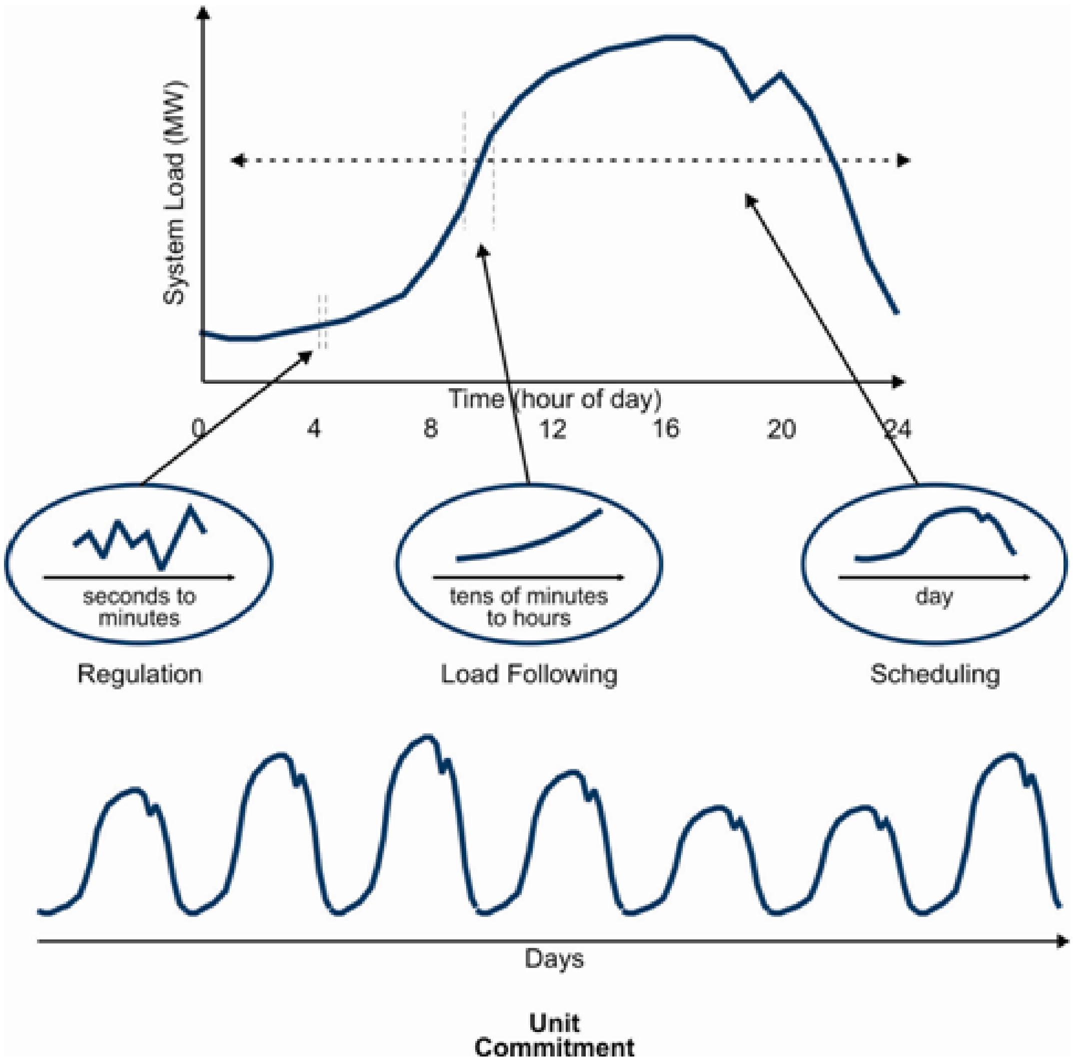
- Wind total capital cost: about $2,200 kW today
- Wind energy cost: about 8¢/kWh (without PTC)
- Includes 0.5 to 1.0¢/kWh for O&M
- Wind energy costs are ***stable*** over plant lifetime

Natural-gas plant fuel cost (HR 8,000 - 10,000)

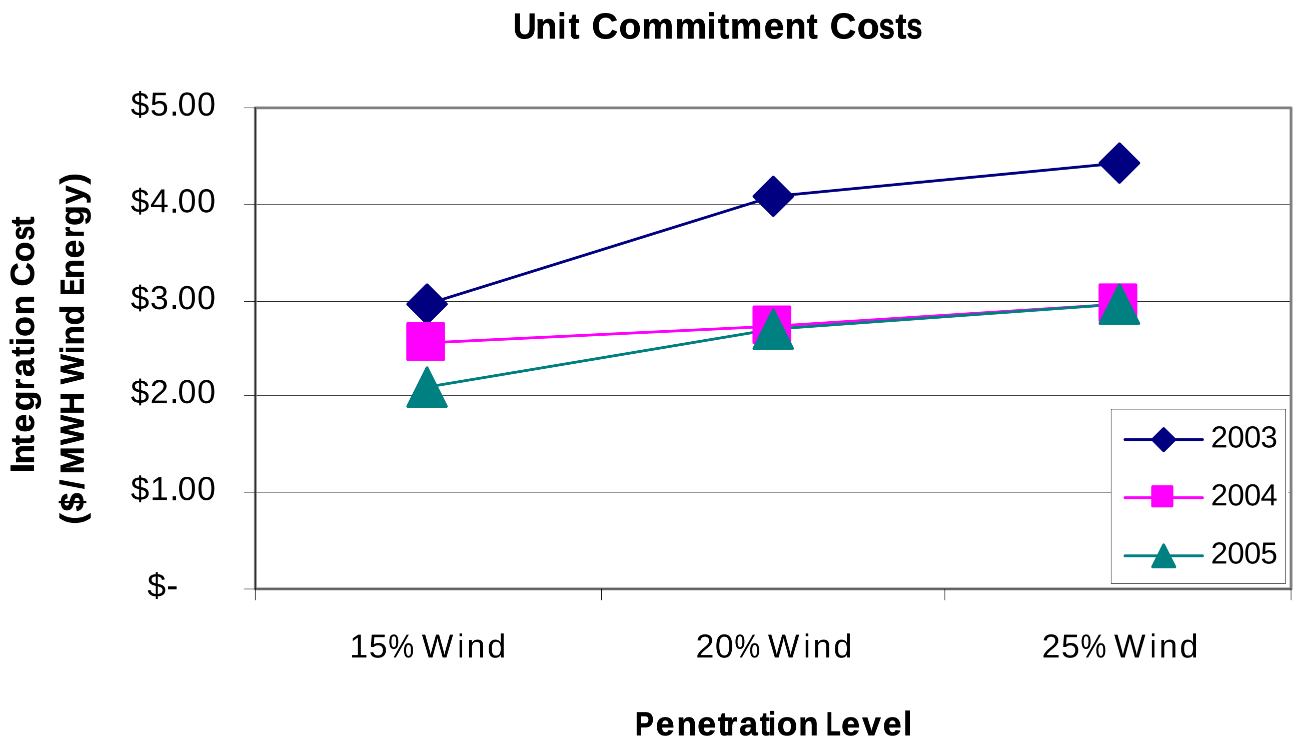
$/MMBTU:	4	6	8	10	12	gas cost
¢/kWh:	3.2 - 4	4.8 - 6	6.4 - 8	8 - 10	9.6 - 12	***fuel only***

- Wind-gas synergy: save gas when wind blows; burn gas to maintain system reliability during low winds

Time scales for grid operations



2006 Minnesota Wind Integration Study
Integration of 20% Wind Energy Can Be Managed



Total integration costs, including load-following and regulation

System Operating Costs Impacts: Results from Recent Studies ($/MWh)

Study	Penetration (%)	Regulation	Load-Follow	Unit-Commit	Total Impact
UWIG/Xcel	3.5	0	0.41	1.44	1.85
Pacificorp	20	0	1.6	3.0	4.6
BPA/Hirst	7	0.19	0.28	1.40	1.87
We Energies	29	1.02	0.15	1.75	2.92
Xcel/PSCO	15	0.20	0	4.77	4.97
Xcel/MNDOC	15	0.23	0	4.37	4.60
MN/MNDOC	20	0.11	0	2.00	2.11
MN/MNDOC	34	0.23	0	4.18	4.41

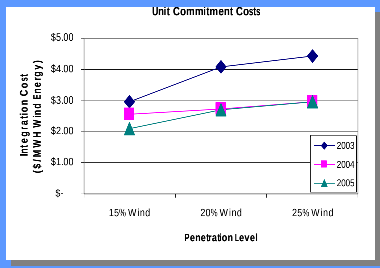
System Operating Costs Impacts: Minnesota DOC Studies ($/MWh)

Study	Penetration (%)	Total Impact
Xcel/MNDOC (2004)	15	4.60
MN/MNDOC (2006)	20	2.11
MN/MNDOC (2006)	34	4.41

Why are the 2006 study impacts lower?

2004: Balancing area -- Xcel NSP MN

2006: Balancing area -- entire state of MN (4 BAs)
Also access to entire MISO footprint

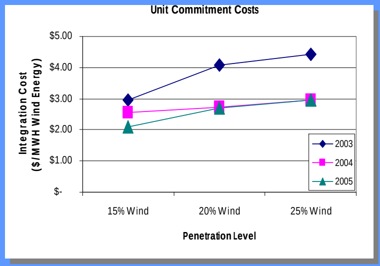


Wind Variability: Impacts on the Electric Power Network

- *Integration costs generally 10% or less of wholesale energy value*
- *Benefit from regional sharing of system-balancing responsibilities*
- *Dedicated "backup generation" or storage not required and not recommended --* remainder of generation fleet compensates for variations in wind
- *Regional sharing requires robust transmission system*
- *Transmission upgrades and expansion required for major wind expansion --* and for any future growth of the nation's electric power capability

European Experience

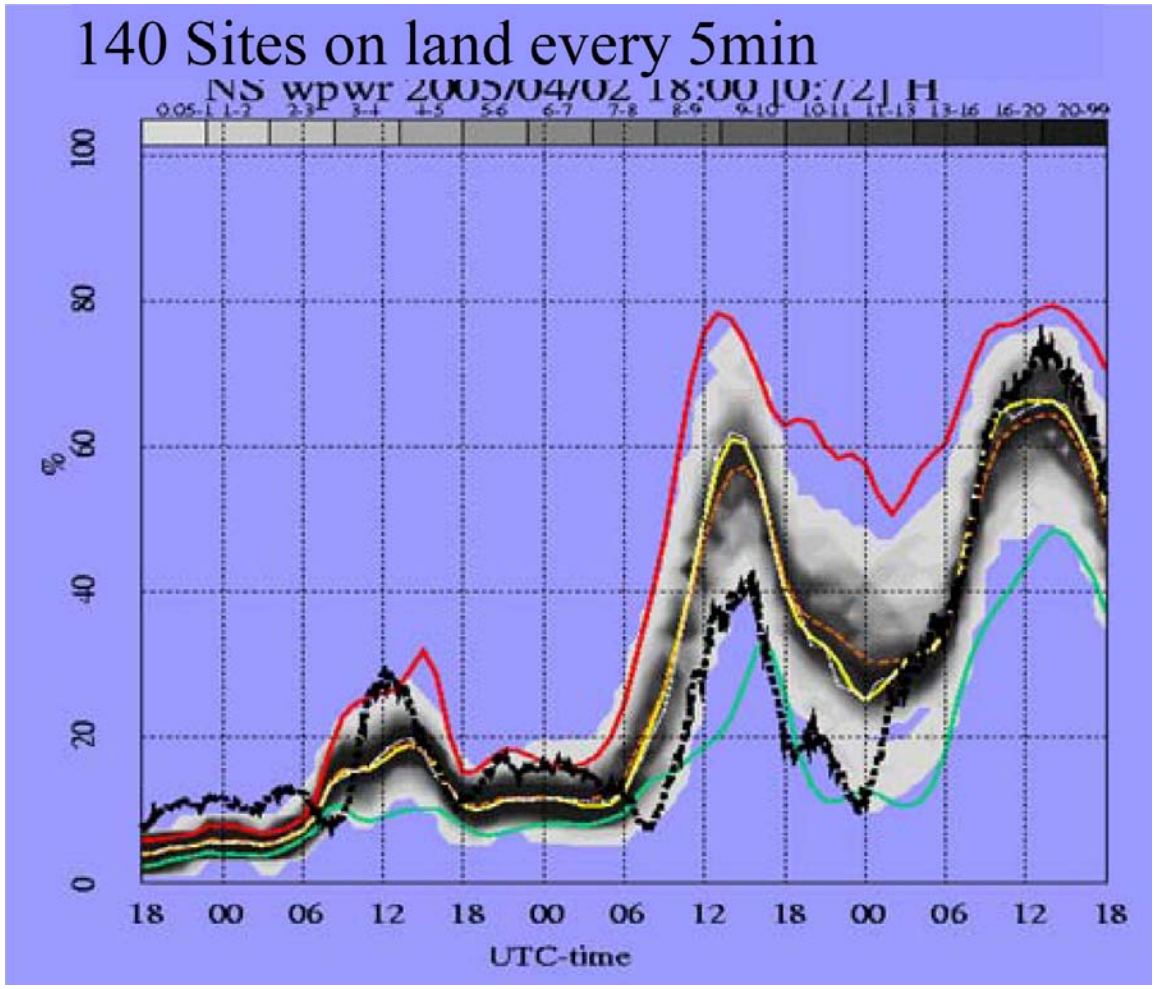
(data for 2005-2006)	Denmark (W)	Spain	Germany	Ireland
Peak Load (MW)	3,700	44,000	78,000	4,800
Minimum Load (MW)	1,200	17,000	38,000	1,800
Wind Capacity (MW)	2,400	10,000	18,000	600
Wind, % Peak Load	65%	23%	23%	12%
Wind, % Minimum Load	200%	59%	50%	33%
Wind, % Total Energy	24%	7%	5.5%	6%
Capacity Goal by 2010 (MW)	3,600	20,000	25,000	1,200



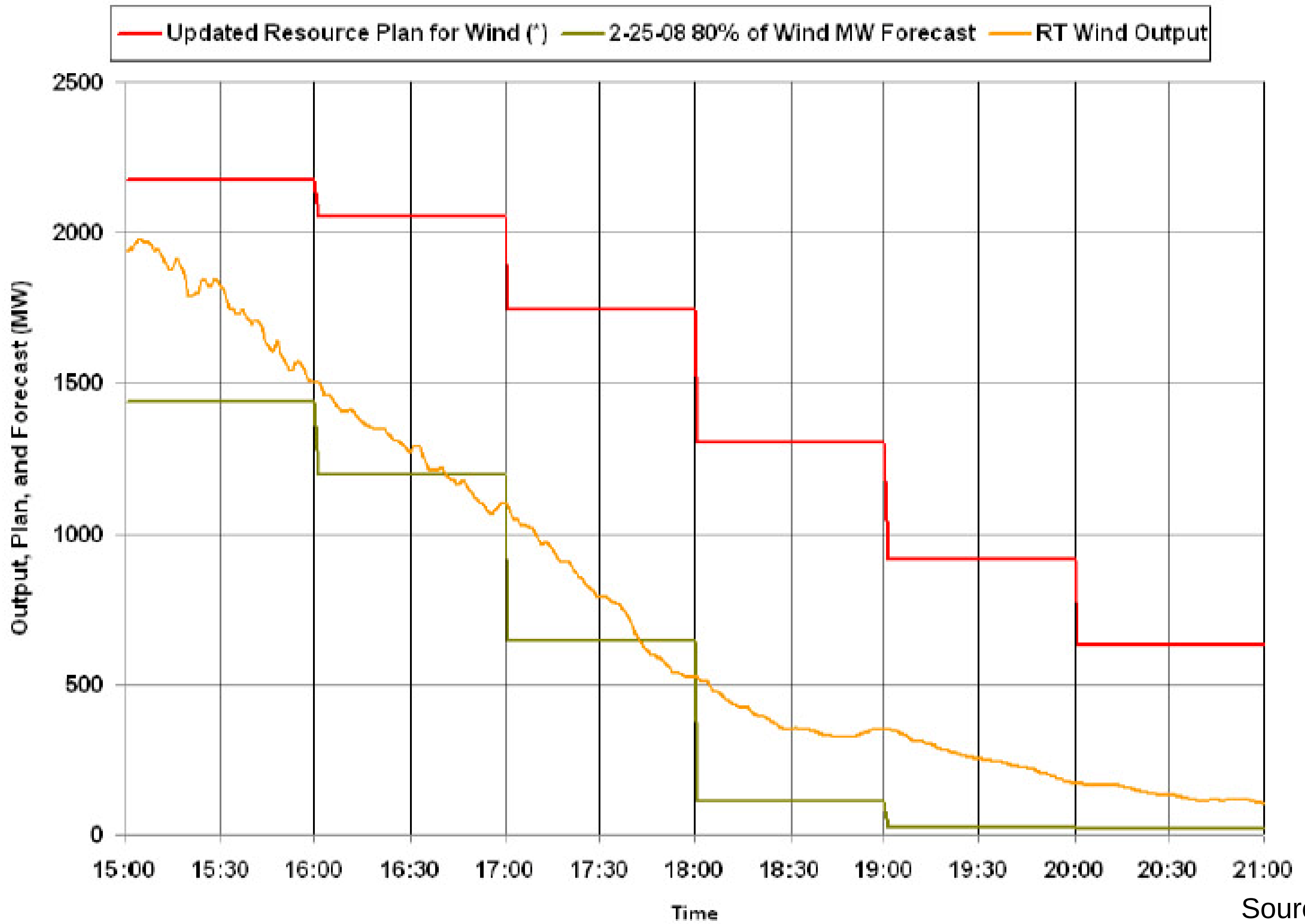
Mitigating Impacts of Wind's Variability and Uncertainty

- *Improve and use wind forecasting tools*
- *Aggregate wind plant output over large regions*
- *Increase balancing area consolidation and sharing of reliability responsibilities*
- *Develop well-functioning real-time, hour-ahead and day-ahead energy and price responsive load markets and expand access to those markets*
- *Add more flexible generation*
- *Develop demand response capability*

Forecasting and Balancing Markets Reduce Impacts



ERCOT Wind Generation – Feb. 26, 2008



Source: ERCOT

UWIG
Utility Wind Integration Group

What About Energy Storage?

- Valuable component of a power system, can provide many benefits
- Greatest value when operated for benefit of entire system, not dedicated to a single resource
- One of many sources of flexibility available to the system
- Integration studies do not show need for storage at 20% wind except possibly on small, isolated systems

Capacity, Energy and Carbon Reduction

Capacity: meeting new load growth and serving peak loads on demand

- ❖ Wind's contribution to capacity is generally a small fraction of it's plant rating
- ❖ Wind generally cannot be relied on as operating reserves on a day-to-day basis
- ❖ Existing non-wind generation maintains balance between demand and generation
- ❖ Hence wind requires no new generation to provide "backup"

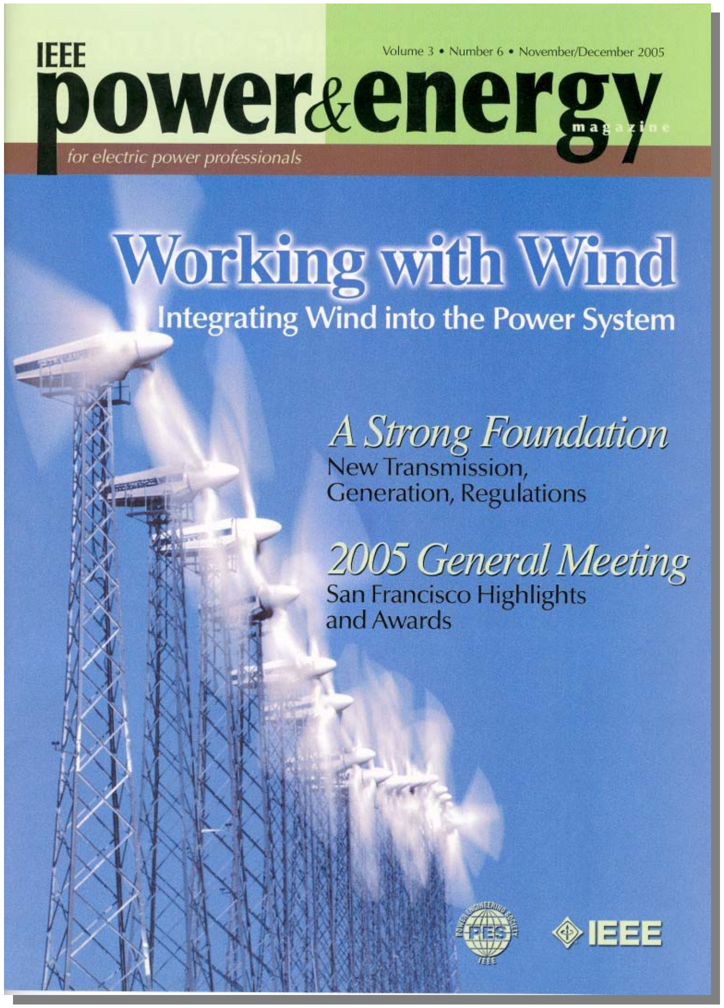
Capacity, Energy and Carbon Reduction

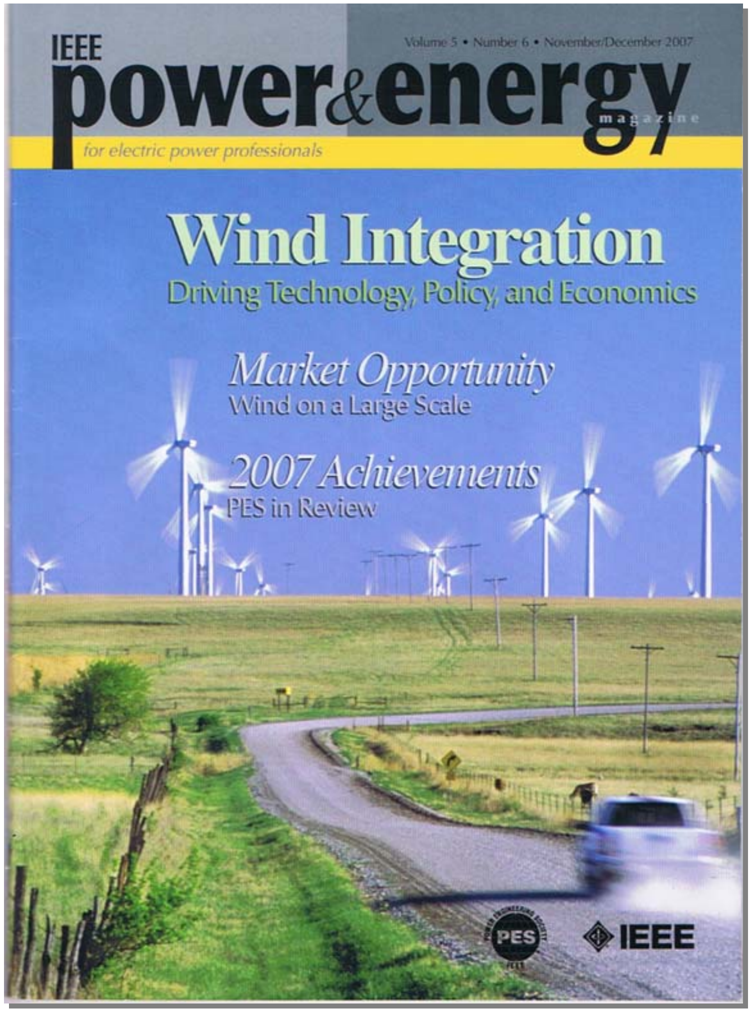
Energy: displacement of fossil fuels

- Wind is primarily an energy source
- System can rely on wind to provide a known amount of energy over some period -- say, a week or a month
- System can't rely on wind to be operating at a prescribed, specific instant
- Wind will displace fuel combustion, and thus greenhouse gases and other emissions
  - Likely primary system planning criterion

UWIG
Utility Wind Integration Group

Wind Integration State of the Art: IEEE Power & Energy Magazines November-December 2005 and 2007





❖ www.uwig.org