

Integrating Wind Power into the Electric Power System



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(EPRI Renewable Energy Programs, 1976-1998)

Unleashing the Potential: Wind Energy in Michigan
October 21, 2005

Lansing, Michigan



Key Integration Issues



- ❖ Costs (capital, energy, O&M)
- ❖ Variability Impacts (ancillary services costs)
- ❖ Energy (fuel displacement) and Capacity (serving demand growth) Contributions
- ❖ Environmental Considerations

Wind Energy Cost Trend

1979: 40 cents/kWh

**2000:
4 - 6 cents/kWh
(no subsidy)**



NSP 107 MW Lake Benton wind farm
4 cents/kWh (unsubsidized)

- Increased Turbine Size
- R&D Advances
- Manufacturing Improvements
- Operating Experience

**2004:
3 - 5 cents/kWh
(no subsidy)**

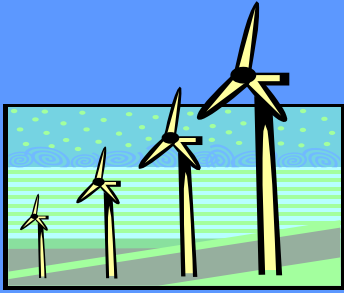
Natural Gas Situation

“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.”

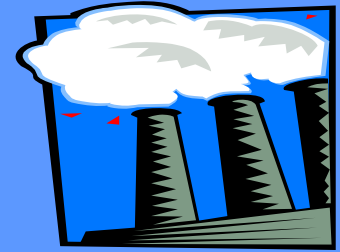
– Alan Greenspan, Federal Reserve Chairman,
Testimony at Senate hearing, July 10, 2003

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

Current prices and projections exceed \$6/MMBTU



Cost Comparison



- ❖ Wind total capital cost: \$1,100 - \$1,200 kW today
- ❖ **Wind energy** cost: about **3.5¢/kWh** (4.5¢ without PTC)
- ❖ Includes 0.5 to 1.0¢/kWh for O&M
- ❖ Wind energy costs are **stable** over plant lifetime

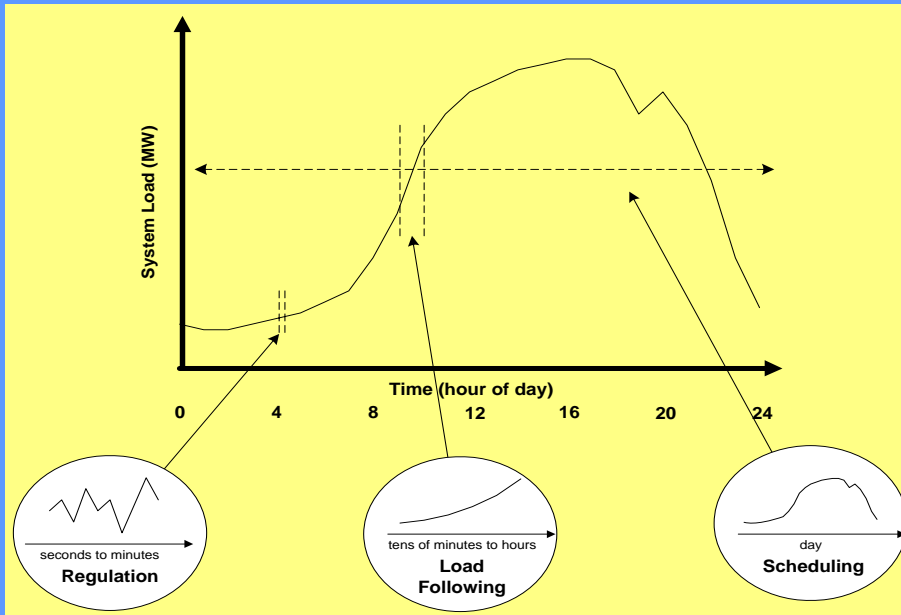
Natural-gas plant fuel cost (HR 7,000 - 10,000)

\$/MMBTU:	2	4	5	6	8	gas cost
¢/kWh:	1.4 - 2	2.8 - 4	3.5 - 5	4.2 - 6	5.6 - 8	fuel only

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



Wind Variability: Power-System Operation Impacts



- Regulation -- seconds to a few minutes -- similar to variations in customer demand
- Load-following -- tens of minutes to a few hours -- demand follows predictable patterns, wind less so



- Scheduling and commitment of generating units -- hours to several days -- wind forecasting capability?

Supply-demand balance maintained instantaneously.

Wind controlled by nature, not power-plant operators!



Wind Variability Can Increase Power System Operating Costs

- Committing unneeded generation
- Allocating extra load-following capability
- Allocating additional regulating capacity
- Increased cycling operation
- **These are reflected in *ancillary services* costs**

Incremental cost added by wind's variability?
Utility Wind Interest Group 2003 case study:
\$1.85/MWh of wind energy (<10% of value)



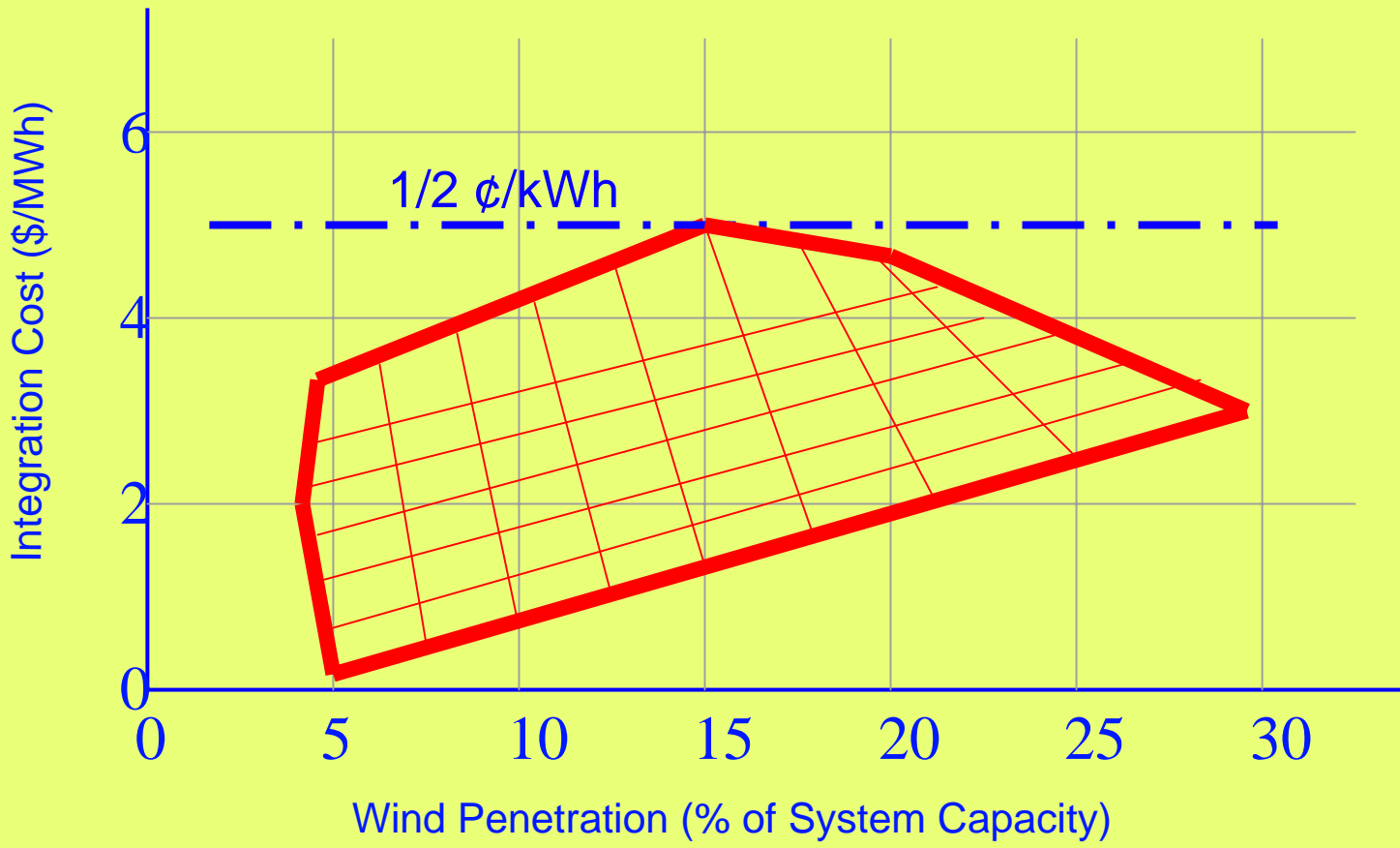
System Operating Costs Impacts: Results from Recent Studies (\$/MWh)

Study	Penetra- tion (%)	Regula- tion	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/MNDOC	15	0.23	0	4.37	4.60
Xcel/PSCO	15	0.20	0	4.77*	4.97

* includes \$1.45 for new gas storage

Range of System Operating Cost Impacts

Studies Conducted To Date



All results to date fall within the crosshatched area



GE Energy/NYISO/NYSERDA

New York Wind Evaluation

- ❖ *Comprehensive study* of wind's impacts on transmission system planning, reliability and operations
 - System stability
 - Regulation, load following, generation scheduling
 - Load growth and reliability
 - System operating costs and emissions reductions
- ❖ 3,300 MW of wind in system serving 34,000 MW of customer load (*10% wind penetration*)
- ❖ Energy prices based on *functioning commercial wholesale markets* -- day-ahead and hour-ahead
 - All previous studies based on operating costs only
- ❖ *Assumes wind is a price-taker*
 - Market (demand-supply balance) sets price; wind generators are paid the market price
 - 11 zones in the state -- transmission constraints included



GE Energy/NYISO/NYSERDA

New York Wind Evaluation

- ❖ *Overall Conclusion: NY State power system can reliably accommodate at least 10% wind (3,300 MW)*
 - Minor adjustments to planning, operation and reliability practices
- ❖ Total NY system (less wind) variable operating costs (fuel, plant startup costs, etc.) reduced by \$350 M
- ❖ State-of-the-art wind forecasting contributed \$125 M of this reduction
- ❖ Electricity costs reduced statewide
- ❖ System transient stability improved



GE Energy/NYISO/NYSERDA

New York Wind Evaluation

- ❖ *Load payment reductions (savings to energy consumers):* \$305 M or about 0.18¢/kWh
- ❖ *Energy displacement:* 65% natural gas, 15% coal, 10% oil, 10% imports
- ❖ *Emissions reductions:*
NOx -- 6,400 tons (10%);
SOx -- 12,000 tons (5%)
- ❖ *Wind revenue:* \$315 M (about 3.5¢/kWh)



Wind's Contributions to Electric Power



Energy: displacement of fossil fuels

- ❖ In most cases, this is the primary motivation. Previously existing power plants run less, but continue to be available to ensure system reliability.
- ❖ Contrary to common lore, addition of a wind plant requires NO new conventional backup generation to maintain system reliability.
- ❖ In many cases, natural gas is saved, reducing total system operating costs. In all cases, overall emissions are reduced.



Wind's Contributions to Electric Power



Capacity: meeting new load growth

- ❖ Because of its variability, wind is less effective in this respect than conventional generation. Winds may be low during peak electricity demand periods.
- ❖ Nonetheless, addition of a wind plant will allow some new load to be served. The amount depends on many factors. Examples:

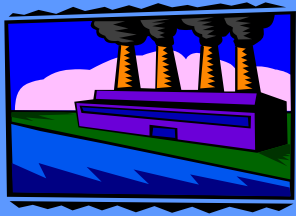
New York	about 10%
Long Island	about 40%
Minnesota	about 25%
- ❖ With experience and over time, operating strategies and generation mix will evolve so that combinations of wind and other plants like hydro and natural gas will serve new load reliably.



Environmental Benefits of Wind



- ❖ *No emissions* of any kind during operation
 - No SO_x, NO_x, particulates or mercury
 - No contributions to regional haze
 - Hedge against environmental regulations
 - No greenhouse gases
- ❖ *No toxic wastes or health impacts*
 - Nuclear waste transport and storage unresolved
 - Respiratory diseases of growing concern
- ❖ *Global climate change* is a serious concern to every major political entity worldwide *except* the current Administration in Washington, DC
 - Avoidance not politically sustainable in the U.S. or worldwide



Environmental Tradeoffs



We need to evaluate environmental impacts on a relative basis.

No energy-generation approach is without impacts.

The choice is wind vs. *something* -- not wind vs. *nothing*.

Clinton Foundation Energy Policy Forum

December 6, 2004, NYU

“The argument that global warming does not exist is now so discredited that it is no longer acceptable in polite society to make that case.”

– Former President Bill Clinton, December 6, 2004

Bush Ally Breaks Ranks on Global Warming - James Baker, March 3, 2005; Houston, TX -

“It may surprise you a little bit, but I think we need to pay a little more attention to what we need to do to protect our environment. When you have energy companies like Shell and British Petroleum saying there is a problem with excess carbon dioxide emission, I think we ought to listen.”

- Former U.S. Secretary of State James Baker, speech to oil industry and other executives, reported March 4 by MSNBC

James Rodgers, CEO of Cinergy (Midwestern Utility, 95% Coal)

2010 Goal: Cut Carbon Dioxide emissions
by 5% voluntarily

“We are in an era where companies are rewarded for postponing action on the issues they will face in the future. This is not an option for us.”

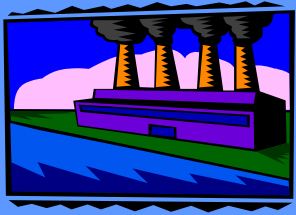
– James Rodgers, interview with Utilipoint’s IssueAlert,
published April 5, 2005

Paul Anderson, CEO of Duke Energy (Southeastern Utility, Coal/Nuclear)

Lobbying for tax on carbon dioxide emissions

“Personally, I feel the time has come to act - to take steps as a nation to reduce the carbon intensity of our economy. And it’s going to take all of us to do it.”

– Paul Anderson, quoted in AP press release, published April 7, 2005



If I Were A Utility CEO or Board Member

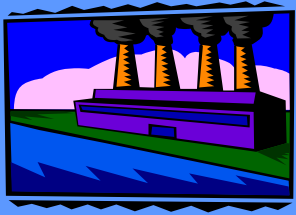


What would keep me awake at night?

Customers want clean energy

Wind energy is economical, environmentally responsible and offers price stability

Ignoring global warming is irresponsible -- too much handwriting on the wall



If I Were A Utility CEO or Board Member



What would keep me awake at night?

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Wind energy is economical, environmentally responsible and offers price stability

Ignoring global warming is irresponsible -- too much handwriting on the wall

Are we doing enough in response? Will society find us liable for future consequences?

Is Wind Power a Prudent Investment?

Affordable costs

Hedge gas price volatility

Operational synergy

Environmentally responsible

Economic development

Strong public support

