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Office of Energy Efficiency & Renewable Energy

Innovation for Our Energy Future

10 FAQ's (Frequently Asked Questions) About Wind Energy…and Answers

Nebraska Public Power
Omaha Public Power
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10 FAQ's about Wind

1) How much wind is currently installed in the US?
2) What are the benefits of wind energy to the power system?
3) How can wind's variability be incorporated into power system operations
4) Does wind plant output start/stop suddenly?
5) Can wind be predicted?

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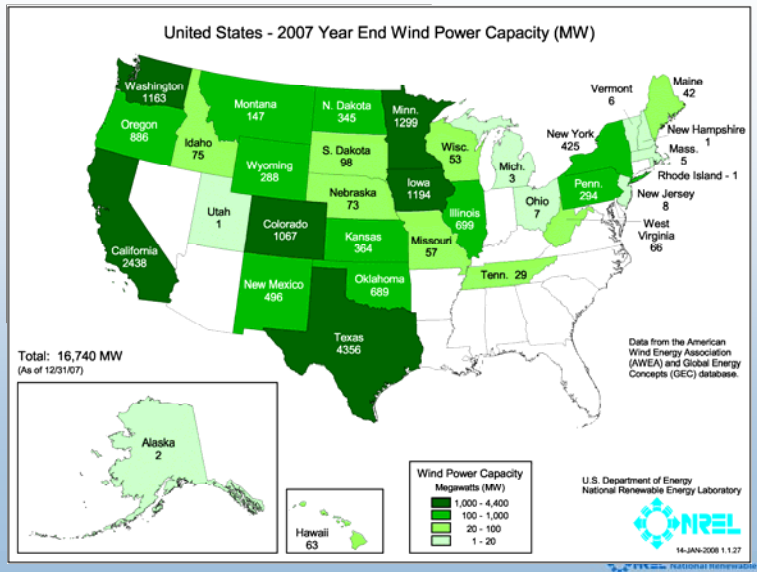
10 FAQ's about Wind

6) Can the power system be reliably operated with wind energy?
7) Does wind need backup or storage?
8) Is there a limit to how much wind can be accommodated on the grid?
9) Can wind power plants be controlled?
10) Can wind energy make effective use of transmission lines?
11) Bonus Question: How can more wind be accommodated on the grid?

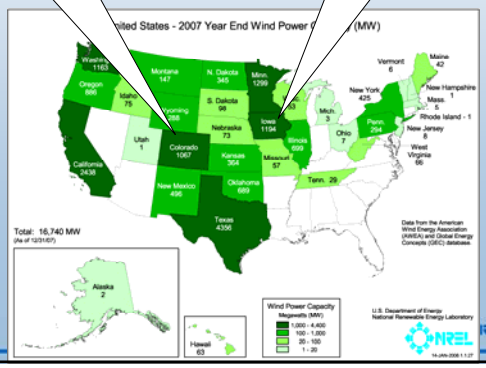
1) How much wind is currently installed in the US?



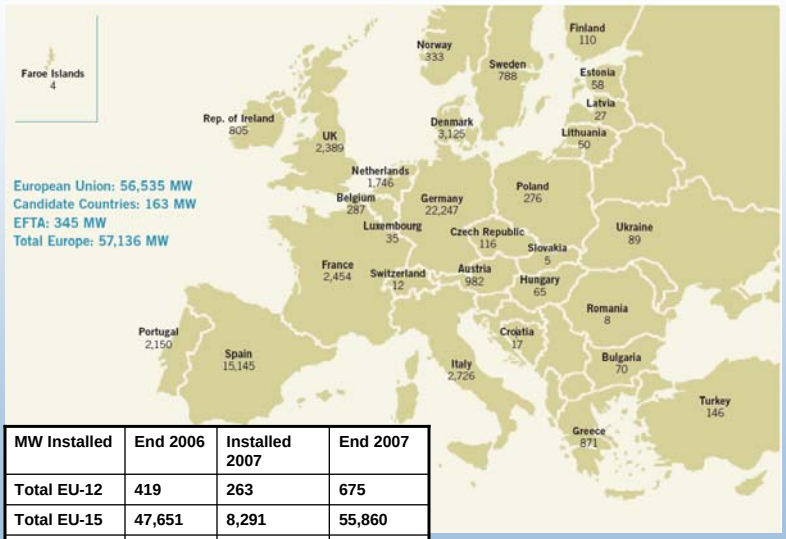
1) How much wind is currently installed in the US?

Colorado/Xcel: Approx 20% wind penetration (wind capacity/system peak)

Iowa: Approx 16% wind penetration (wind capacity/system peak)



1b) How much wind is currently installed in Europe?



MW Installed	End 2006	Installed 2007	End 2007
Total EU-12	419	263	675
Total EU-15	47,651	8,291	55,860
Total EU-27	48,069	8,554	56,535

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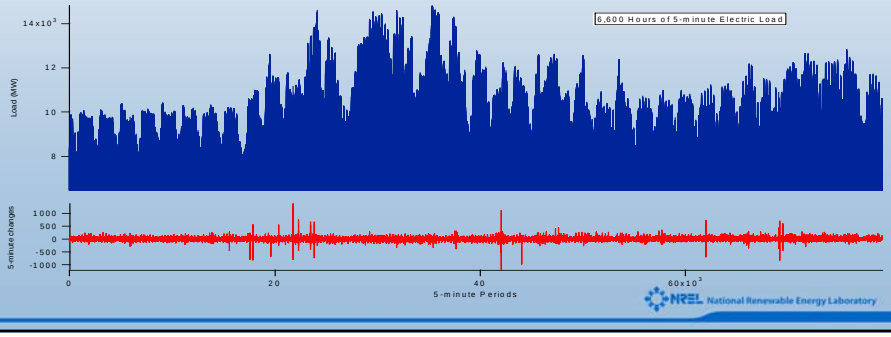
2) What are the benefits of wind energy to the power system?

- Wind energy displaces
  - Fuel
  - Emissions; carbon
- Wind provides a hedge against rising fuel prices (natural gas, coal)
- Wind is an energy source with limited capacity contribution → other generation is also required
- Wind can be cost-competitive with other forms of generation and may reduce electricity cost

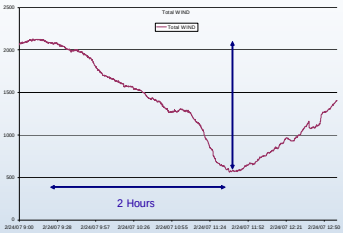
3) How can wind's variability be incorporated into power system operations

- Electric load (without wind) varies considerably
- Power system operating practices are built around meeting the variable load with dispatchable generators that can change their output level
- Wind adds more variability to the system
- Existing operating practice can be used/expanded upon with wind



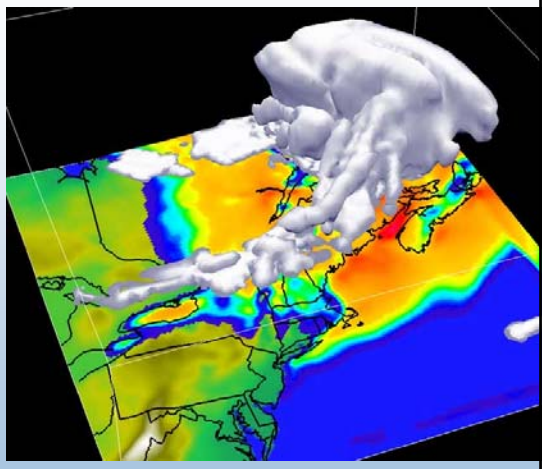
4) Can wind power start and stop suddenly?

- Large wind farms have many individual wind turbines
- The turbines are spread over many miles and do not experience the same wind at the same time
- TX event Feb 24, 2007: drop of 1,500 MW over 2 hours is similar to behavior of load



5) Can wind be predicted?

- Wind forecasts are derived from weather prediction models
- Wind forecast accuracy is improving
- Several wind forecasting firms in U.S.



Courtesy: WindLogics, Inc. St. Paul, MN

6) Can the power system be reliably operated with wind energy?

- Yes – additional flexible generation (operating reserves) may be necessary at higher wind penetrations
- This additional operating reserve has a modest cost, typically about 10% of the cost of the wind energy itself
- Graph shows this level of operating reserve (blue) is a relatively small, varying fraction of wind generation

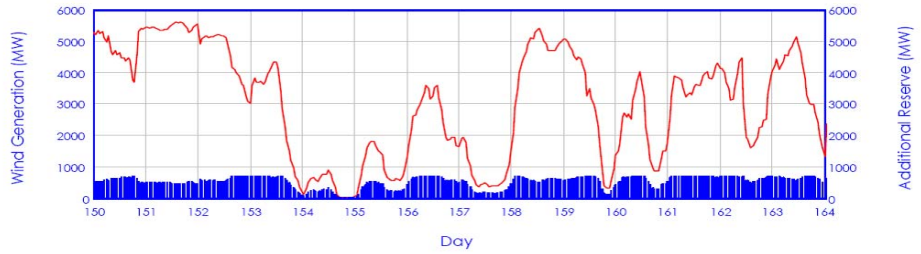
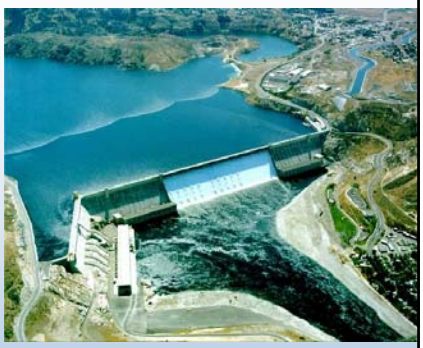


Figure 30: Illustration of time varying "operating reserve margin" developed from statistical analysis of hourly wind generation variations.

7) Does wind need backup or storage?

- Increased operating reserves may be necessary, but not dedicated backup
- Although new storage has value, it may not be cost effective
- There is typically already storage on the system
  - Natural gas in the pipeline or storage facility
  - Controllable hydro
- A recent study by Xcel Energy in Colorado found
  - existing pumped storage provided $1.30/MWh offset to wind integration cost
  - Enlarging existing gas storage facility was economic at large wind penetration



Wind Penetration	10%	15%
$/ MWH Gas Impact No Storage Benefits	$2.17	$2.52
$ / MWH Gas Impact With Storage Benefits	$1.26	$1.45

8) Is there a limit to how much wind can be accommodated on the grid?

- Current studies in the U.S. have analyzed *up to* 25% of all electric energy from wind
- Based on work done so far, the question is not *whether* wind can be accommodated at high penetrations, the question is *how* and at *what cost of integration*

8) Is there a limit to how much wind can be accommodated on the grid?

- Recent International Energy Agency Report:

Design and operation of power systems with large amounts of wind power

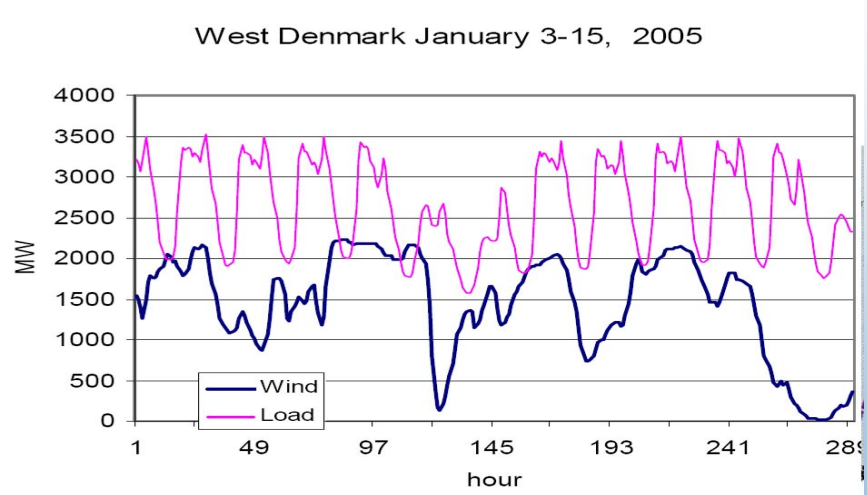
Table 4. Power system size and wind power penetration studied in national cases.

	Load			Inter-connect. capacity	Wind power					
					2006	Highest studied		Highest penetration level		
Region / case study	Peak MW	Min MW	TWh/a	MW	MW	MW	TWh /a	% of peak load	% of gross demand	% of (min load + intercon)
West Denmark	3700	1400	26	2570*	2350		26		100%	
Nordic 2004	67 000	24 000	385	3000*	4108	18 000	46	27%	12%	67%
Nordic+Germany / Greennet	155 500	65 600	977	6600	24730	57 500	115	37%	12%	80%
Finland 2004	14000	3600	90	1850*	86	4000	8	29%	9%	73%
Germany 2015 / dena	77 955	41 000	552,3	10000*	20622	36 000	77.2	46%	14%	71%
Ireland / ESBNG	5000	1800	29	0	754	2000	4,6	40%	16%	111%
Ireland / ESBNG	6500	2500	38,5	0	754	3500	10,5	54%	27%	140%
Ireland / SEI	6127	2192	35,5	500	754	1950	5,1	32%	14%	72%
Ireland / SEI	6900	2455	39,7	900	754	1950	5,1	28%	13%	58%
Netherlands	15 500		100	12 930*	1560	6000	20	39%	20%	46%
Mid Norway / Sintef	3780		21			1062	3,2	28%	15%	
Portugal	8800	4560	49,2	1000	1697	5100	12,8	58%	26%	92%
Spain 2011	53 400	21 500	246,2	2400*	11 615	17 500		33%	19%	73%
Sweden	26 000	13 000	140	9730*	572	8000	20	31%	14%	35%
UK	76 000	24 000	427	2000*	1963	38 000	115	50%	27%	146%
US Minnesota 2004	9933	3400	48,1	1500*	895	1500	5,8	15%	12%	31%
US Minnesota 2006	20 000	8800	85	5000	895	5700	21	30%	25%	41%
US New York	33 000	12 000	170	7000	430	3300	9,9	10%	6%	17%
US Colorado	7000		36,3			1400	3,6	20%	10%	

** The use of interconnection capacity is not taken into account in these studies. In Nordic 2004 study the interconnection capacity between the Nordic countries is taken into account.*

http://www.uwig.org/IEA_Annex25-State_of_the_Art_Report.pdf

8) Is there a limit to how much wind can be accommodated on the grid?



Denmark has access to large export markets

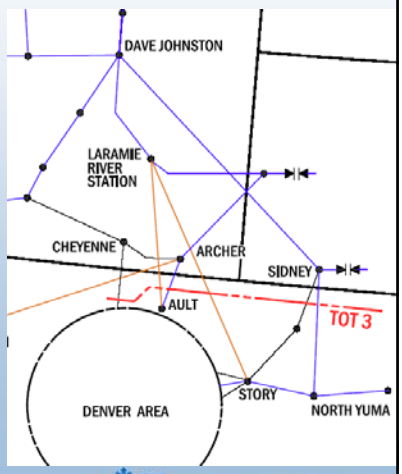
Lennart Söder,KTH, Sweden, presented at UWIG, Oct 23-25, 2006

9) Can wind power plants be controlled?

- New low-voltage ride-through (LVRT) grid codes in the U.S. will help wind turbines contribute to grid reliability
- Wind turbines can be controlled but not to the extent that conventional generation can be controlled
  - Ramp rate limits
  - Up-regulation (operate below potential so that wind output can be increased if needed)
  - Curtailment, if necessary and economic, at low-load/high-wind conditions

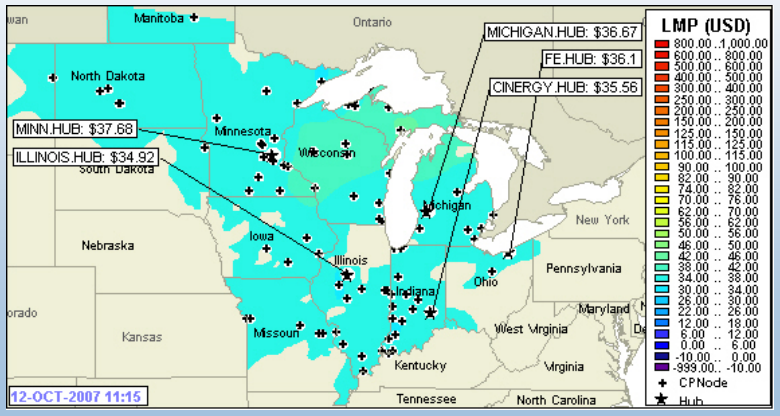
10) Can wind energy make effective use of transmission lines?

- Conditional-firm transmission tariff (recent FERC ruling)
- Wind does not need transmission all of the time
- Most transmission paths have some open capacity most of the time
- Adding wind can result in more efficient usage of existing transmission



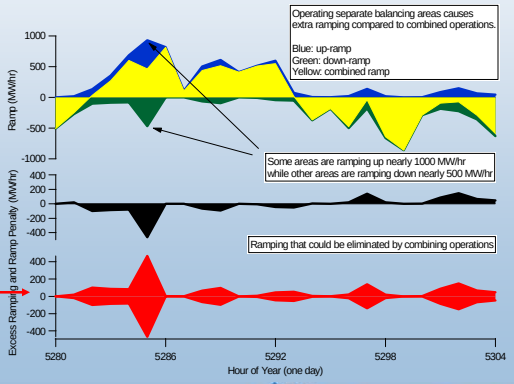
11 Bonus) How can more wind be accommodated on the grid?

- Utility balancing areas can combine or cooperate – large electricity markets (example: Denmark/Europe)



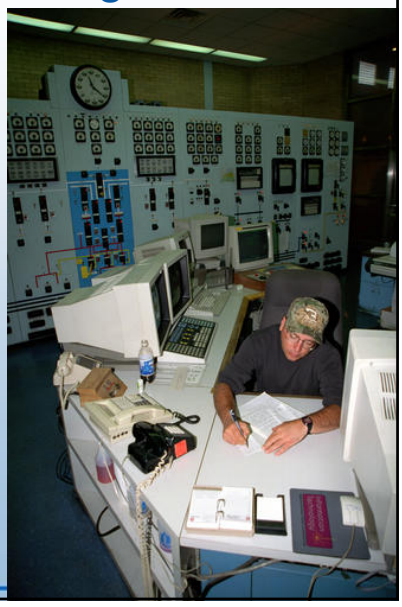
11 Bonus) How can more wind be accommodated on the grid?

- Utility balancing areas can combine or cooperate – large electricity markets
- Example: *Ramping, or changing output of generators that can be eliminated with larger balancing areas*



11 Bonus) How can more wind be accommodated on the grid?

- Power system operations practices and wind farm control/curtailment
- Integration of wind forecasting and real time measurements into control room operations (WindLogics/EnerNex/UWIG / Xcel study underway in Minnesota)
- Hydro dispatch, pumped hydro
- Longer term: other storage and markets (plug-hybrid electric vehicles, hydrogen)

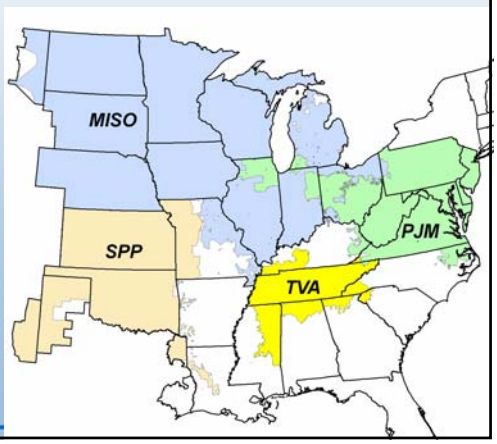


11 Bonus) How can more wind be accommodated on the grid? What about Storage?

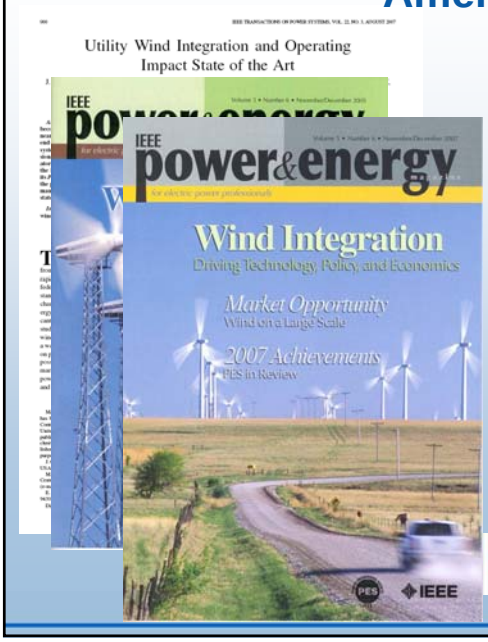
- Storage can have significant benefits to the power system
- Storage may help integrate wind, *but storage is not necessary or economic based on results in the U.S. at low-moderate penetrations*

Large-Scale Studies in Process

- Western Wind & Solar Integration Study
  - 30% Wind in footprint, 20% in WECC
- Eastern Wind Integration Study



Increasing Attention in North America



- IEEE Transactions on Power Systems (2007)
- IEEE Power Engineering Society Magazine, November/December 2005
- Updated in 2007
- Wind Power Coordinating Committee Wind Super-Session, Summer 2008
- Utility Wind Integration Group (UWIG): Operating Impacts and Integration Studies User Group

  www.uwig.org

UWIG Utility Wind Integration Group — *Accelerating the Integration of Wind Generation into Utility Power Systems*

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Texas Event Feb 26, 2008

- 15:00 – Wind generation output at 2000 MW and begins a 3.5 hour ramp down to 360 MW at 18:30. The down ramp was 2 hours sooner and somewhat faster (8 MW/minute vs 5 MW/minute) than forecast the day ahead
- 17:10 – Evening load ramp begins, increasing 3800 MW in 90 minutes, (42 MW/minute). The evening load ramp-up began 25 minutes earlier than the short-term hour-ahead load forecast predicted

Texas Event Feb 26, 2008

- 17:44 – 150 MW conventional unit trips offline
- 18:28 – ERCOT calls on non-spin service to come on-line
- 18:33 – 328 MW of Responsive (spinning) Reserve deployed
- 18:41 – ERCOT calls for EECP step 2
- 18:49 – ERCOT instructs all available LaaRs to reduce consumption

Texas Event Feb 26, 2008

- 18:59 – 1108 MW of LaaR was reduced within 10 minutes (1200 MW within 12 minutes)
- 18:56 – Spinning reserve deployment ends
- 20:08 – ERCOT ends step 2 and enters step 1
- 21:40 – EECP terminated

Lessons Learned

- Load forecast failed to predict the large ramp up in demand
- The accurate wind energy forecast was not used in scheduling (this has been rectified)
- Laar was very effective in economically reducing demand
- Wind event was a ramp event, not a contingency event (similar to 2007 event)