National Renewable Energy Laboratory
Innovation for Our Energy Future

Wind Energy Integration: FAQs and Key Results

NEWEEP Webinar Oct 26, 2010

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Outline

- Power system basics
- Wind in the US today
- Integration studies: what are they?
- Overview of large study results.
- North American Electric Reliability Corporation
- Frequently asked questions…and answers from detailed power system studies and actual operating experience around the world

Thanks to Organizations Sponsoring this Webinar

- National Renewable Energy Laboratory
- NWEEP

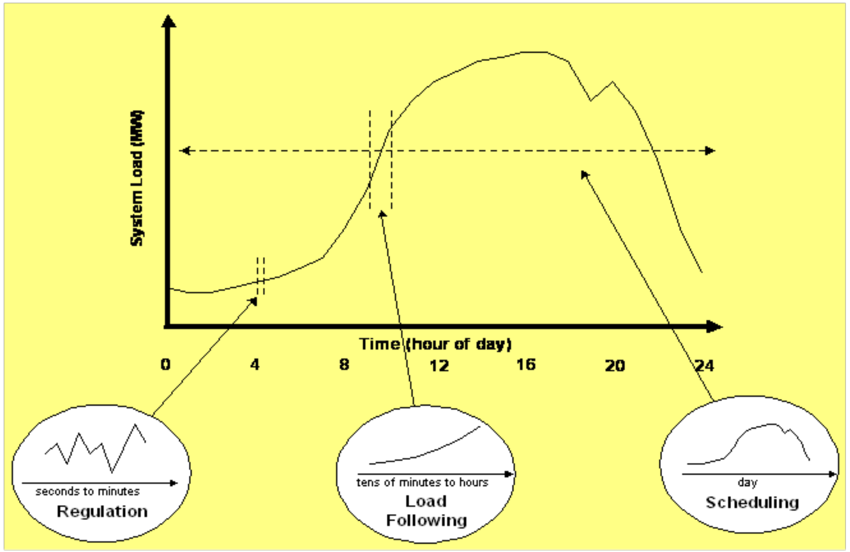
Large-Scale Wind Integration Studies

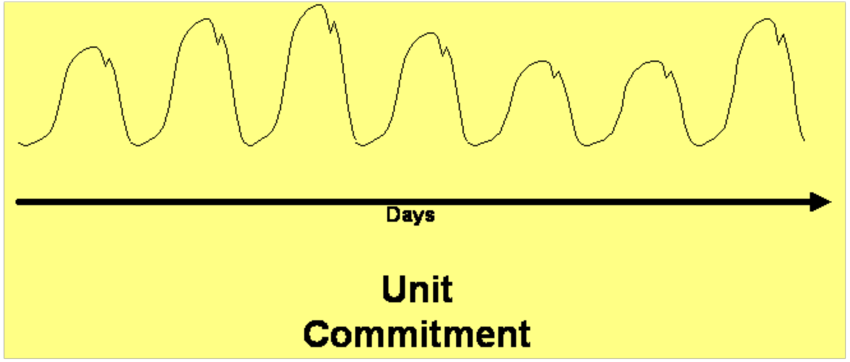
- Sponsored by US DOE, managed by NREL
- Eastern Wind Integration and Transmission Study, released Jan 20, 2010. www.nrel.gov/ewits
- Western Wind and Solar Integration Study, released in Mar 2010. www.nrel.gov/wwsis

- These studies show that up to 30% (and 5% solar in the west) can be integrated reliability and economically if operational practices can provide additional flexibility thru institutional changes

Power System Basics

- Portfolio of different type of generators are managed so that the sum of all output = load at each moment
- Base-load generators run at constant output
- Intermediate/cycling units pick up daily load swings
- Peaking units are seldom run but provide peak capacity when needed

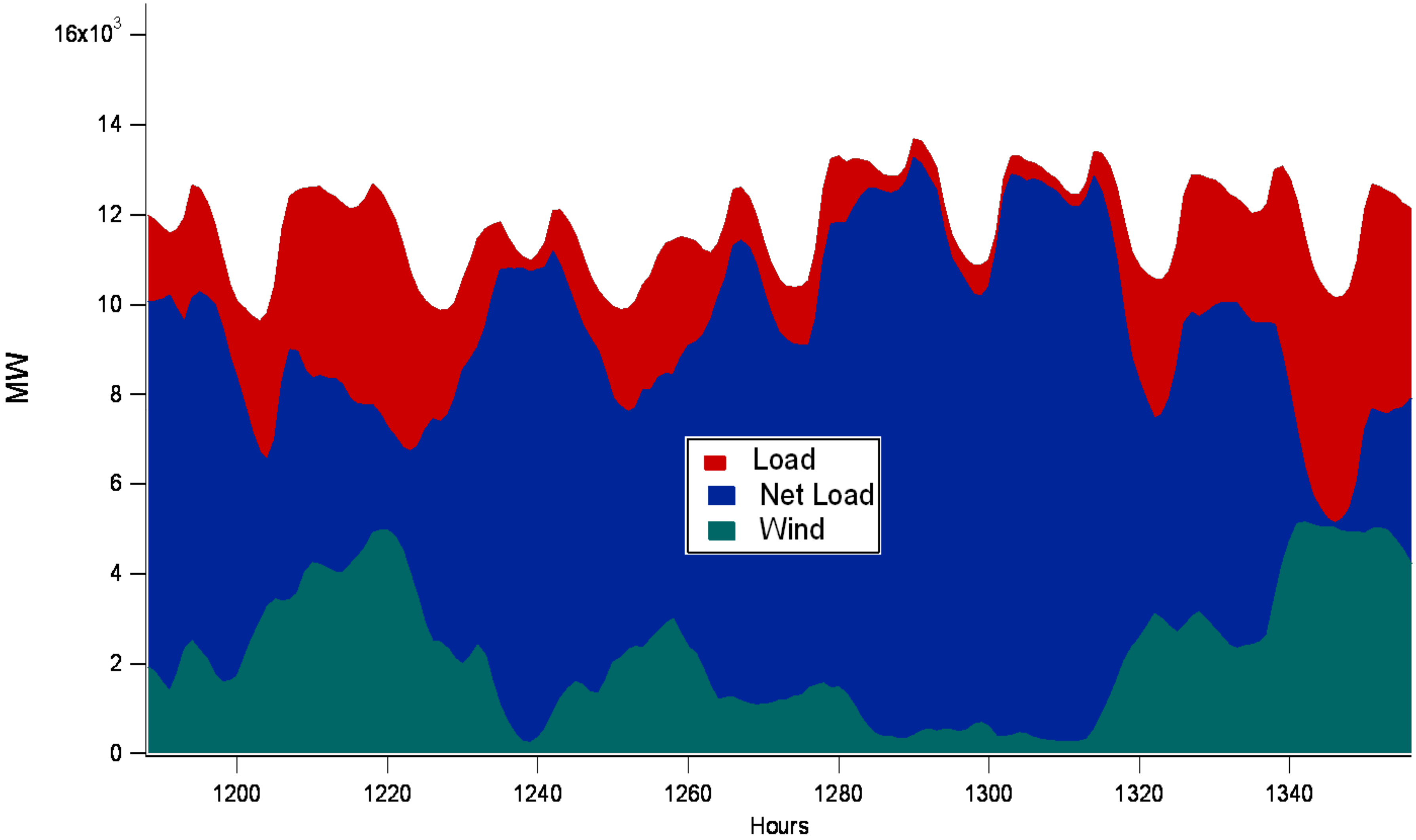




Power System Basics (cont)

- Extra generation – reserves – available in case of generator or transmission outage: *Contingency reserves*
- Some generators can change output and are used to manage ***variability*** in load (demand)
- The demand for power is not known with certainty so may influence the level of reserves for managing this ***uncertainty***
- Wind increases the level of ***variability*** and ***uncertainty*** that the power system operator must manage

Load-less-wind = net load



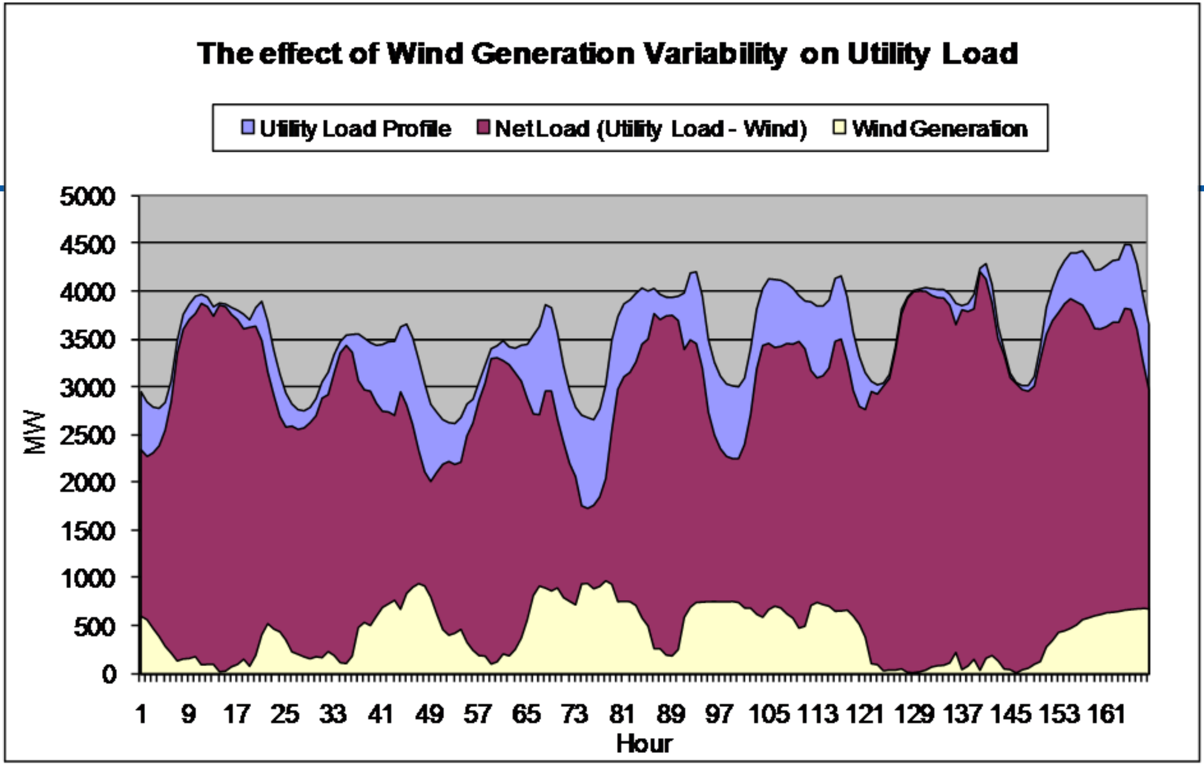
Wind in the US Today

Total Wind Capacity (end of 2009, MW)			Estimated Percentage of Retail Sales (for utilities with > 100 MW of wind)	
Xcel Energy	3,176		Minnkota Power Cooperative	38.0%
MidAmerican Energy	2,923		Empire District Electric Company	18.1%
Southern California Edison	1,772		Turlock Irrigation District	18.0%
American Electric Power	1,196		Otter Tail Power	14.0%
Pacific Gas & Electric	1,131		Sunflower Electric Power Corp.	13.2%
Luminant	913		Xcel Energy	11.1%
Alliant Energy	645		Austin Energy	10.3%
City Public Service of San Antonio	579		Great River Energy	10.1%
Puget Sound Energy	479		Westar	10.1%
Austin Energy	439		Western Farmers' Electric Cooperative	9.8%
First Energy	376		MidAmerican Energy	9.6%
Portland General Electric	375		Snohomish PUD	8.5%
Minnkota Power Cooperative	357		MSR Public Power Agency	8.4%
Basin Electric	352		City Public Service of San Antonio	8.4%
SDG&E	342		Public Service New Mexico	6.8%
Great River Energy	319		Cowlitz PUD	6.5%
Westar	295		WPPI Energy	6.4%
Oklahoma Gas & Electric	272		Alliant Energy	5.9%
Empire District Electric Company	255		Puget Sound Energy	5.4%
SCPPA (not including LADWP)	233		Northwestern Energy	5.3%

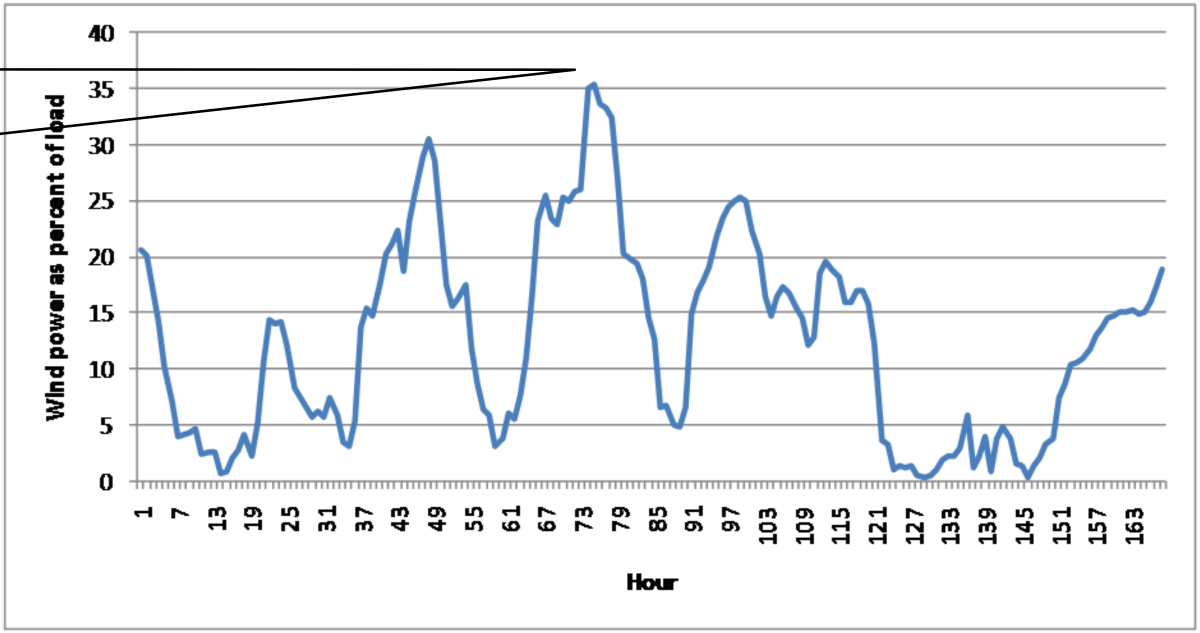
Source: AWEA, EIA, Berkeley Lab estimates

From LBL 2009 Wind Technologies Market Report

Example week, utility in the Western US.



35% instantaneous penetration



Integration Studies

Detailed power system simulations

Data from power system industry

Wind data

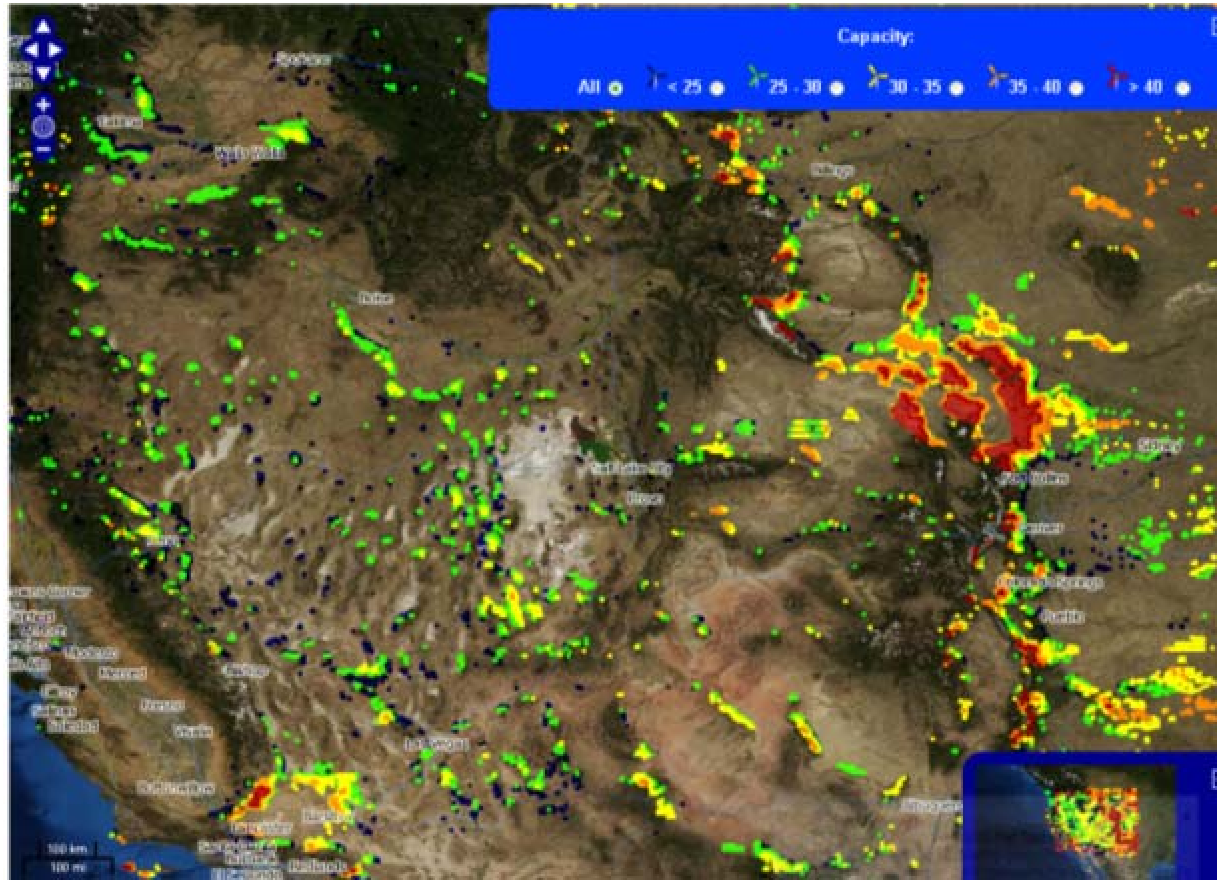
- Actual wind plant data
- Simulated wind data for future wind build-out

Data requirements are stringent so that the variability of wind plants is accurately represented in the power system operations modeling

Other power system data must be consistent, robust, accurate

Atmospheric models

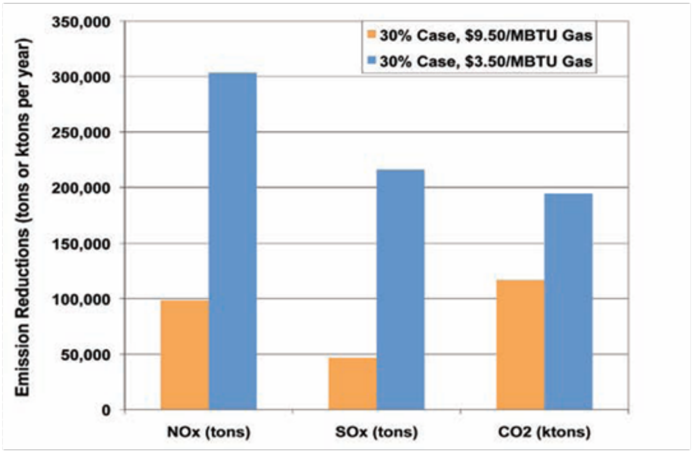
- Meso-scale meteorological modeling that can “re-create” the weather at any space and time
- Maximum wind power at a single point ~ 30 MW to capture geographic smoothing
- Model is run for the period of study and must match load time period
- Wind plant output simulation and fit to actual production of existing plants
- See www.nrel.gov/wwsis for details and validation



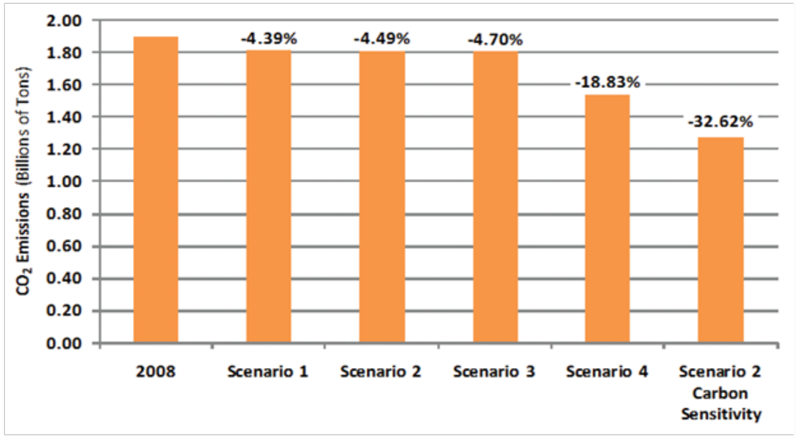
Integration Study Results

- Study results show that wind energy can be integrated into power systems reliably and economically; in some cases operational practice must change
- Most studies have rigorous technical review teams, comprised of power system industry experts
- Utility Wind Integration Group: Industry Exchange for wind integration challenges and solutions
- www.uwig.org contains most integration study results

Wind reduces emissions, including carbon



At high prices natural gas is displaced by renewable generation, leaving coal plants to handle variability at lower emissions reductions. When coal is displaced instead, greater emission reductions are observed.



Scenarios 1-3 are for 20% wind power penetration, with various combinations of new transmission and offshore wind farms, while Scenario 4 is for 30% wind power penetration. Scenario 2 Carbon Sensitivity includes the results if a $100/ metric ton carbon tax were imposed.

Western Wind and Solar Integration Study, www.nrel.gov/wwsis.
Every 3 wind-generated MW reduces thermal commitment by 2 MW.

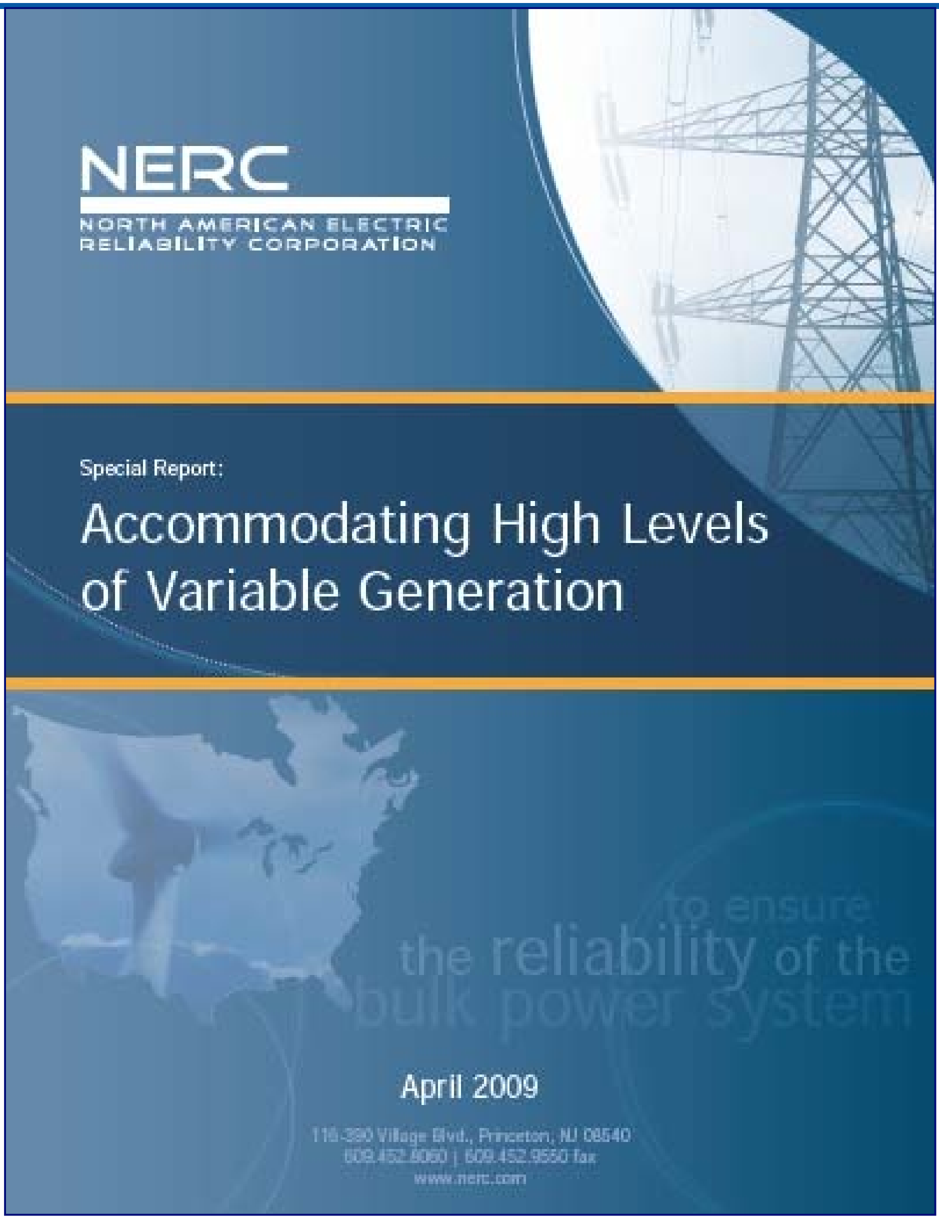
Also see *Impact of Frequency Responsive Wind Plant Controls on Grid Performance*, Miller, Clark, and Shao. 9th International Workshop on Integration of Wind Power into Power Systems, Quebec, Canada, October 2010.

Results show decline from 2008, also eliminating any increase in carbon from 2008-2024. www.nrel.gov/ewits. Overall reduction in emissions in study year is estimated to be approximately 33-47%, depending on wind energy penetration scenario.

Reliability Organization Task Force

Not a question of "if"

It is a question of "how"



Wind Myths Debunked: Frequently Asked Questions

- Michael Milligan, NREL
- Kevin Porter, Exeter Associates
- Edgar DeMeo, Renewable Energy Consulting Services
- Paul Denholm, NREL
- Hannele Holttinen, VTT Technical Research Center, Finland and chair of IEA Task 25: Large-Scale Integration
- Brendan Kirby, Consultant, NREL
- Nicholas Miller, GE Energy
- Andrew Mills, Lawrence Berkeley Laboratory
- Mark O'Malley, University College, Dublin, Ireland
- Matthew Schuerger, Energy Systems Consulting
- Lennart Soder, Royal Institute of Technology, Stockholm,Sweden

Questions addressed

1) Can grid operators deal with the continually changing output of wind generation?
2) Does wind have capacity credit?
3) Does the wind stop blowing everywhere at the same time?
4) To what extent can wind power be predicted?
5) Isn’t it very expensive to integrate wind?

Questions addressed

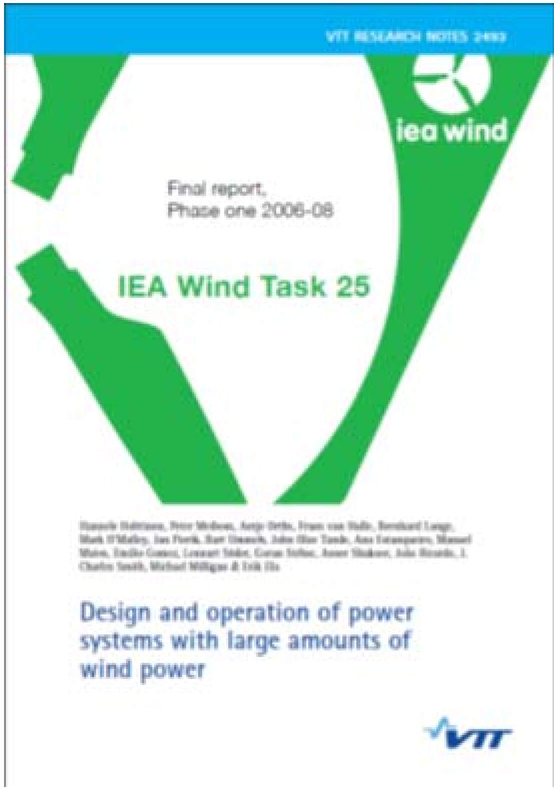
6) Doesn't wind power need new transmission, and won't that make wind expensive?
7) Does wind power need back-up generation? Isn't more fossil fuel burned with wind than without, due to back-up requirements?
8) Does wind need storage?
9) Isn't all the existing flexibility already used up?
10) Is wind power is as good as coal or nuclear even though the capacity factor of wind power is so much less?
11) Is there a limit to how much wind can be accommodated by the grid?

Where did the questions come from?

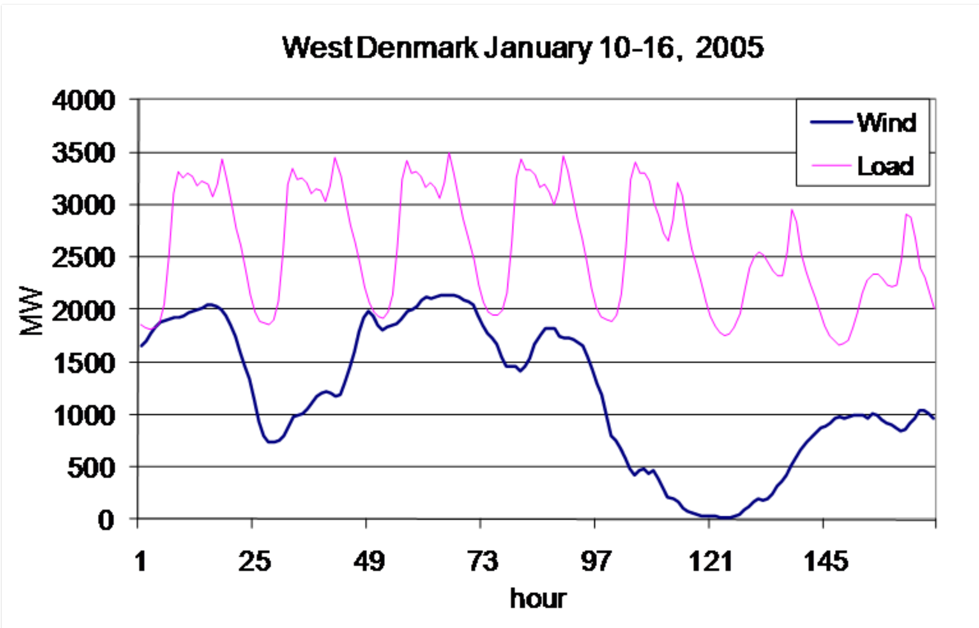
- International experience with wind integration
- Common questions

Where do the Answers Come From?

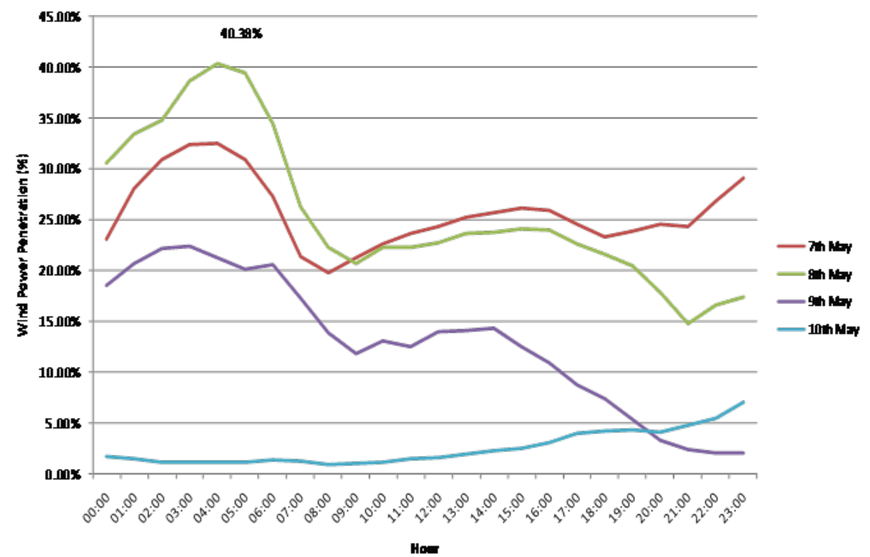
- Extensive scientific and engineering analysis
  - Power system simulations that mimic real-time operations using detailed data
  - Statistical analysis of wind and load data
  - Experience operating power systems with wind
- *International Energy Agency Task 25 Report: Design and operation of power systems with large amounts of wind power State of the art report*.
  - http://www.vtt.fi/inf/pdf/tiedotteet/2009/T2493.pdf
- Utility Wind Integration Group www.uwig.org
- NREL Systems Integration
  - http://www.nrel.gov/wind/systemsintegration
  - http://www.nrel.gov/publications



1) Can grid operators deal with the continually changing output of wind generation?

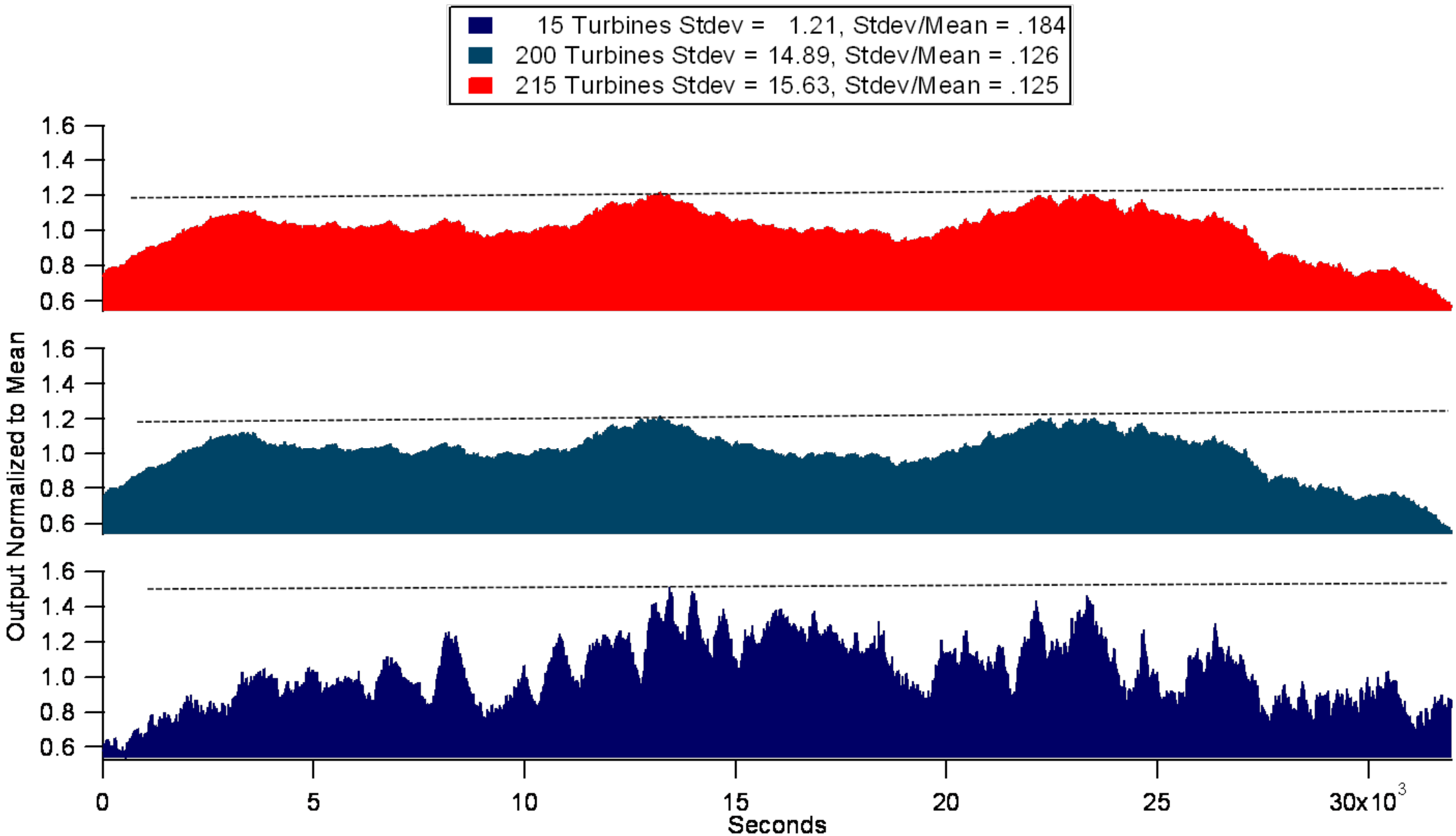


Source: Soder, Royal Institute of Technology, Sweden



Source: EIR Grid, Ireland

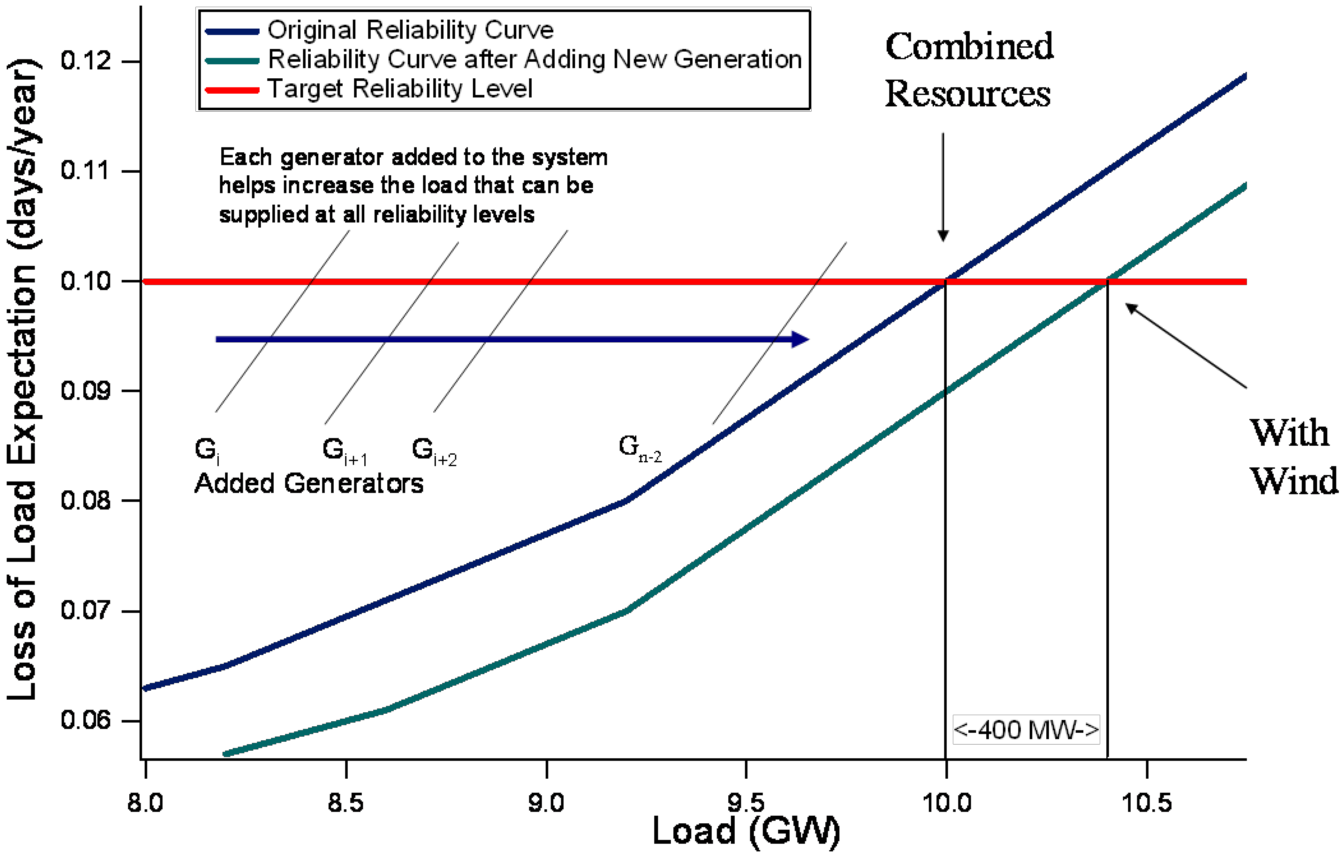
1) Can grid operators deal with the continually changing output of wind generation?



Source: NREL Wind Plant Data

(Approximately 8 hours)

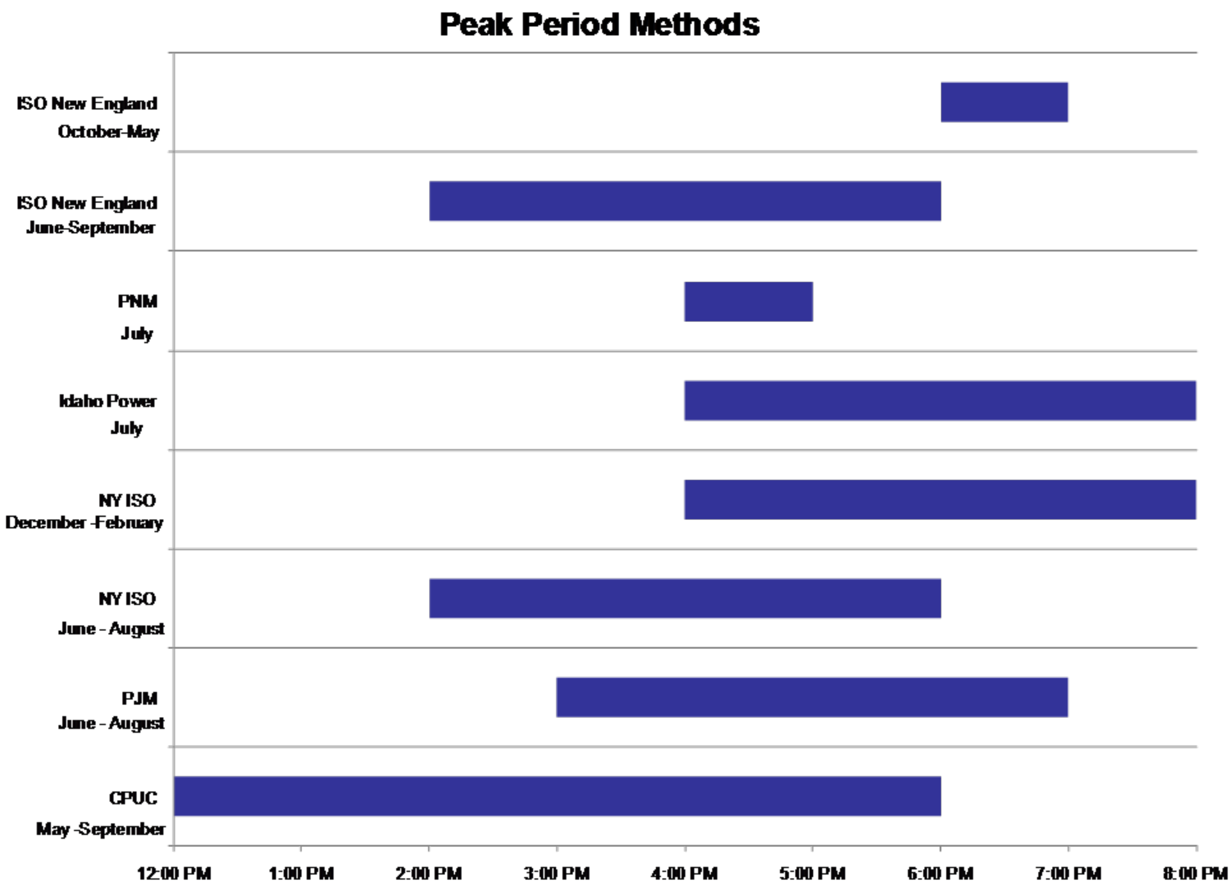
2) Does wind have capacity credit?



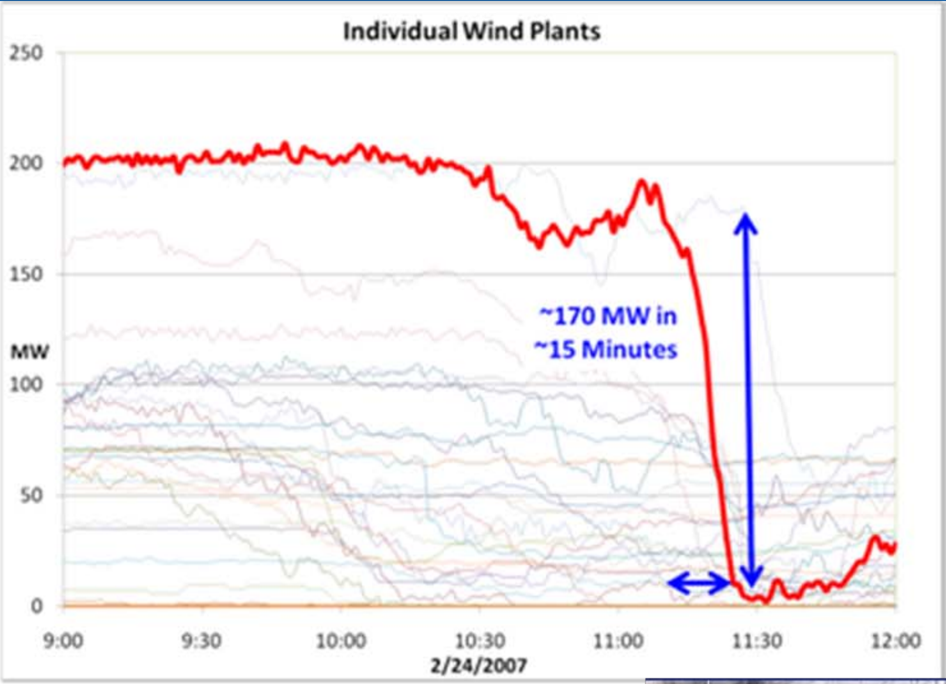
IEEE Task Force Paper, Transactions on Power Systems. In press.

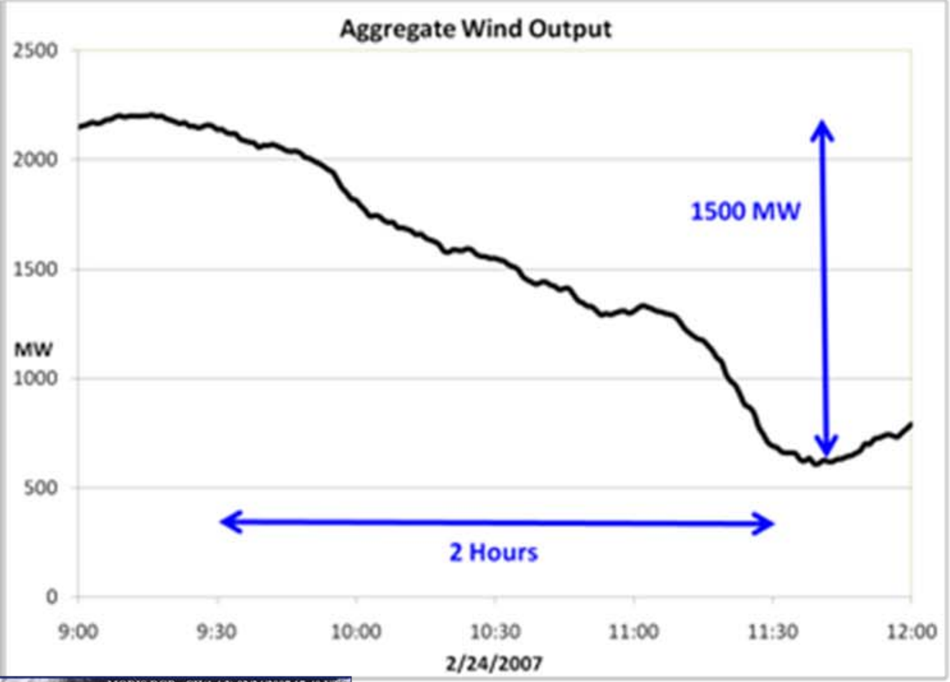
2) Does wind have capacity credit?

- Wind is primarily an energy resource, but can make a small contribution to planning reserves
- Depends on timing of wind energy vs. load characteristics
- Range in the U.S. approximately 5%-40% of rated capacity

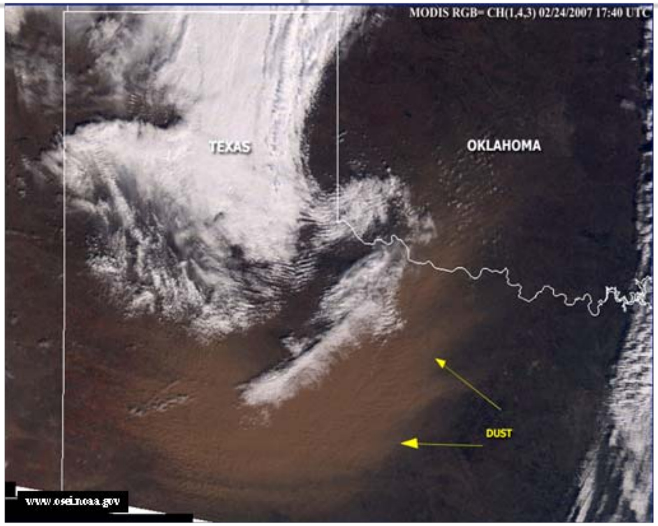


3) How often does the wind stop blowing everywhere at the same time?



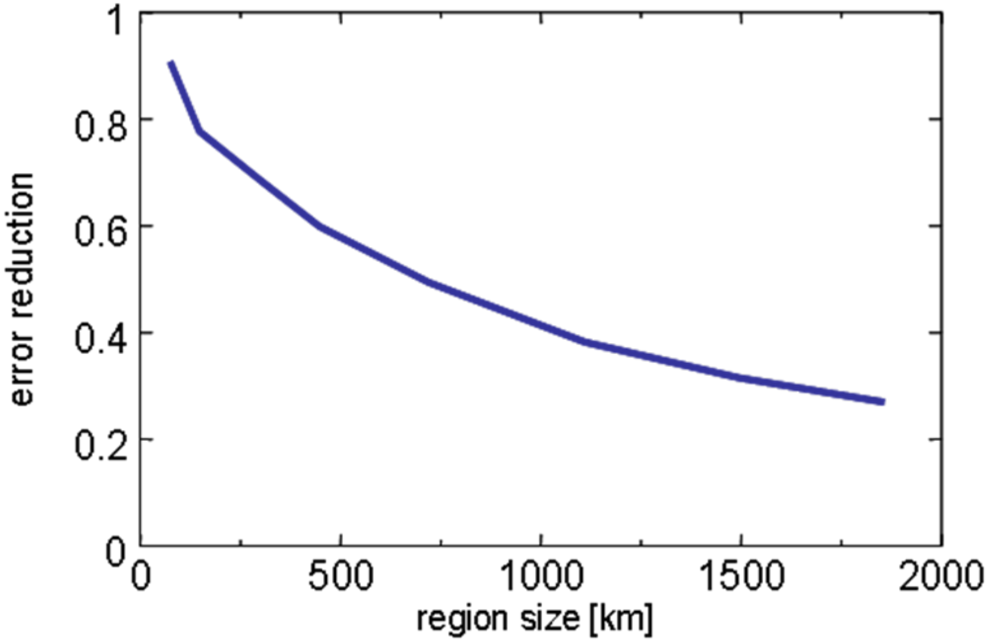


Source: ERCOT, WindLogics



4) To what extent can wind power be predicted?

- Easier to predict wind for short time steps
  - Errors ~5-7% MAE based on rated wind capacity
- More difficult day-ahead
  - Errors ~20% MAE
- Relative forecast errors are reduced for large geographic footprints (energy & meteo)



5) Isn't it very expensive to integrate wind?

Year	Study	Wind Capacity Penetration	Integration Cost ($/MWh) Regulation	Load Following	Unit Commit.	Gas Supply	TOTAL
2003	Xcel-UWIG	3.5%	0	0.41	1.44	-	1.85
2003	We Energies	29%	1.02	0.15	1.75	-	2.92
2004	Xcel-MNDOC	15%	0.23	-	4.37	-	4.60
2005	PacifiCorp-2004	11%	0	1.48	3.16	-	4.64
2006	Calif. (multi-year)*	4%	0.45	trace	trace	-	0.45
2006	Xcel-PSCo	15%	0.20	-	3.32	1.45	4.97
2006	MN-MISO**	31%	-	-	-	-	4.41
2007	Puget Sound Energy	12%	-	-	-	-	6.94
2007	Arizona Pub. Service	15%	0.37	2.65	1.06	-	4.08
2007	Avista Utilities	30%	1.43	4.40	3.00	-	8.84
2007	Idaho Power	20%	-	-	-	-	7.92
2007	PacifiCorp-2007	18%	-	1.10	4.00	-	5.10
2008	Xcel-PSCo***	20%	-	-	-	-	8.56
2009	Bonneville (BPA)+	36%	0.22	1.14	-	-	5.70
2010	EWITS++	48%	-	-	1.61	-	4.54
2010	Nebraska+++	63%	-	-	-	-	1.75

* Regulation costs represent 3-year average.
** Highest over 3-year evaluation period.
*** This integration cost reflects a $10/MMBtu natural gas price scenario. This cost is much higher than the integration cost calculated for Xcel-PSCo in 2006, in large measure due to the higher natural gas price: had the gas price from the 2006 study been used in the 2008 study, the integration cost would drop to $5.13/MWh.
+ Costs in $/MWh assume 31% capacity factor. Aside from regulation and following reserves, the costs of BPA's imbalance reserves are $4.33/MWh.
++ The unit commitment costs listed in EWITS are the cost of day-ahead wind forecast error; the remaining integration costs included in the total are for shorter term variable reserves that account for regulation and short-term forecast errors (energy imbalance).
+++ These integration costs only capture regulating reserves and day-ahead forecast error. A sensitivity case in this study shows that integration costs increase if the differences between the actual hourly deliveries of wind energy are compared to daily flat block of power. The increased costs are shown in Figure 39.

LBL Wind Market Report

5) Isn’t it very expensive to integrate wind?

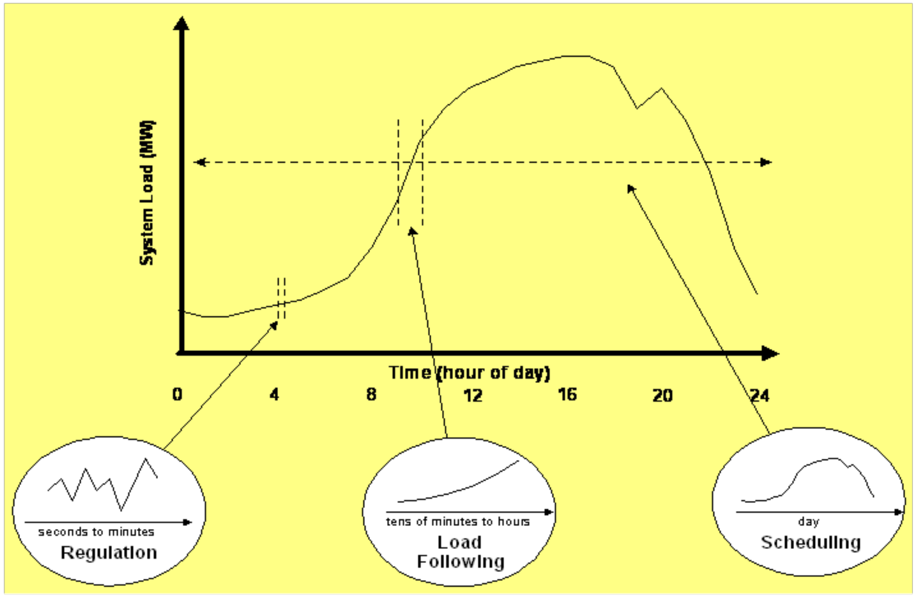
- Primary cost comes from additional operating reserve and impacts on non-wind generation operations
- Additional reserve is not constant throughout the year: it depends on what the wind and load are doing
- Wind’s variability combines with the variability of load
- Small balancing areas will normally find it more difficult and costly to integrate wind than larger balancing areas
- Sub-hourly energy markets can help manage variability

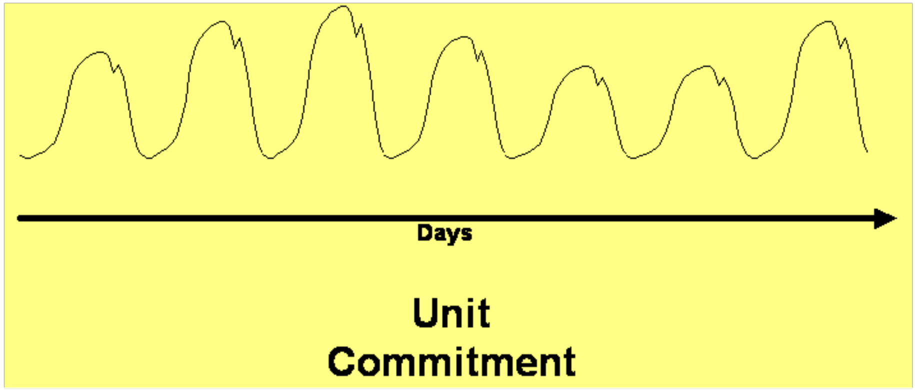
6) Doesn't wind power need new transmission, and won't that make wind expensive?

- Transmission is needed for most new generation sources
- Joint Coordinated System Plan found benefit/cost ratio of 1.7/1 for transmission that would support a 20% wind energy penetration. Transmission was 2% of the wholesale energy cost.
- Consumers often will benefit by lower energy costs
- Transmission build-out can reduce the need for new generation

7) Does wind power need back-up generation? Isn't more fossil fuel burned with wind than without, due to back-up requirements?

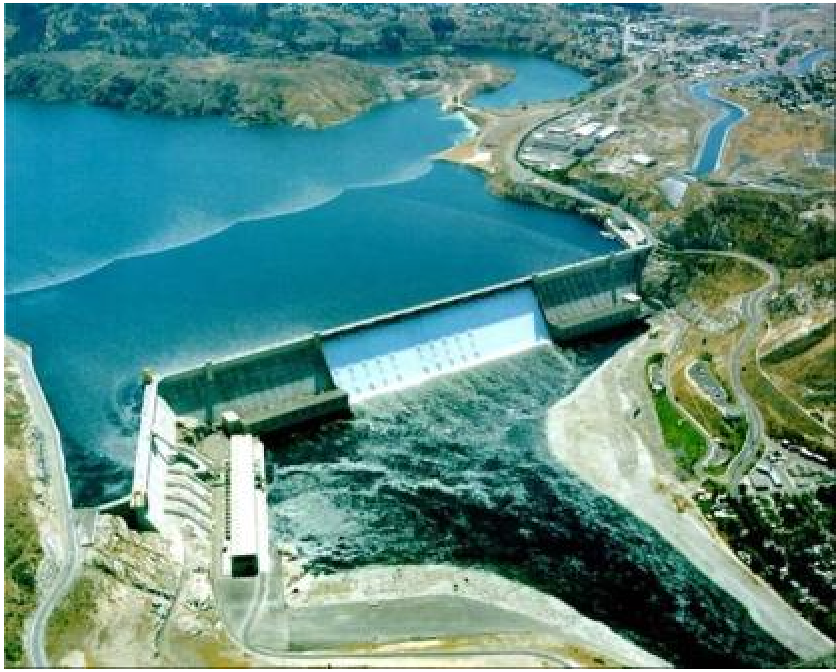
- Total load must be met by a combination of generation
- Individual generators are not backed up: but reserves are provided on a system basis
- Wind will displace generation, freeing up that generation to provide reserves (if economic)
- Generators that change dispatch as a result of wind may have reduced efficiency, but total fuel burn and emissions will decrease





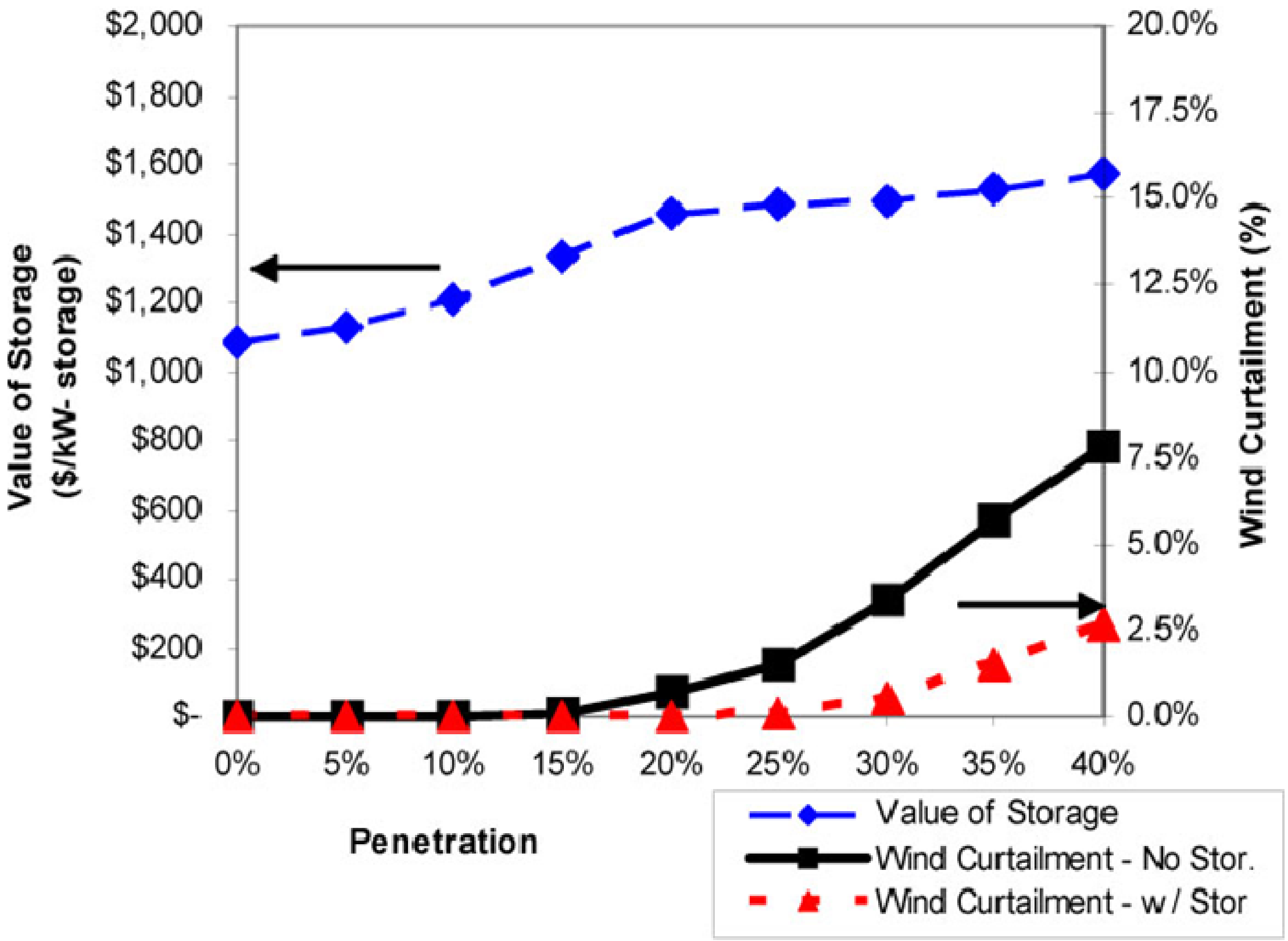
8) Does wind need storage?

- Storage is always useful, but may not be economic
- Detailed simulation of power system operation find no *need* for storage up to 30% penetration
- Experience with more than 31,000 MW of installed wind in the US shows no *need* for storage
- However: storage is very beneficial with and without wind
- Depends on cost-benefit

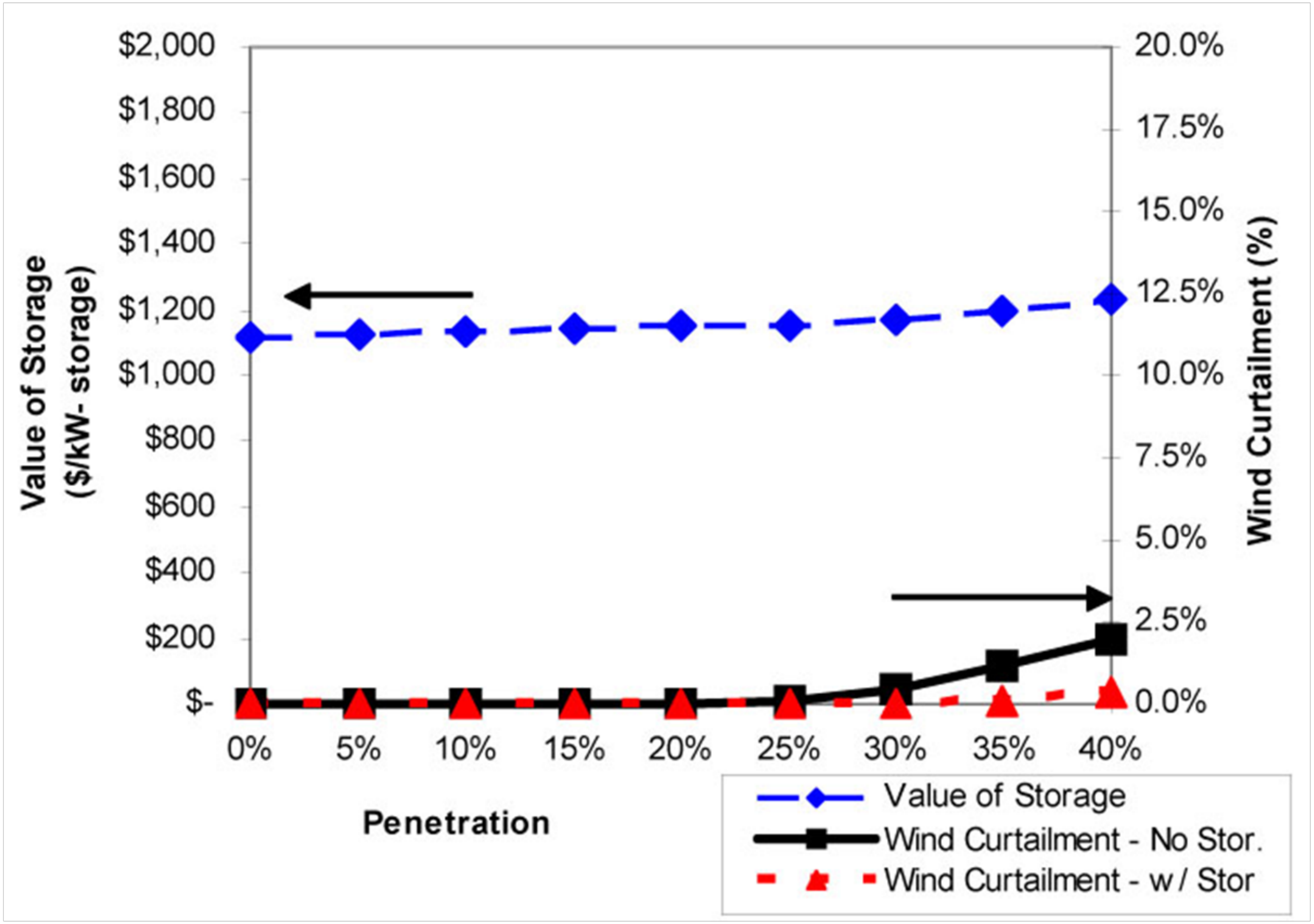


Large-scale studies (EWITS and WWSIS) do not find a need for storage at wind penetrations up to 30% of all electricity, although storage does have value

8) Does wind need storage?



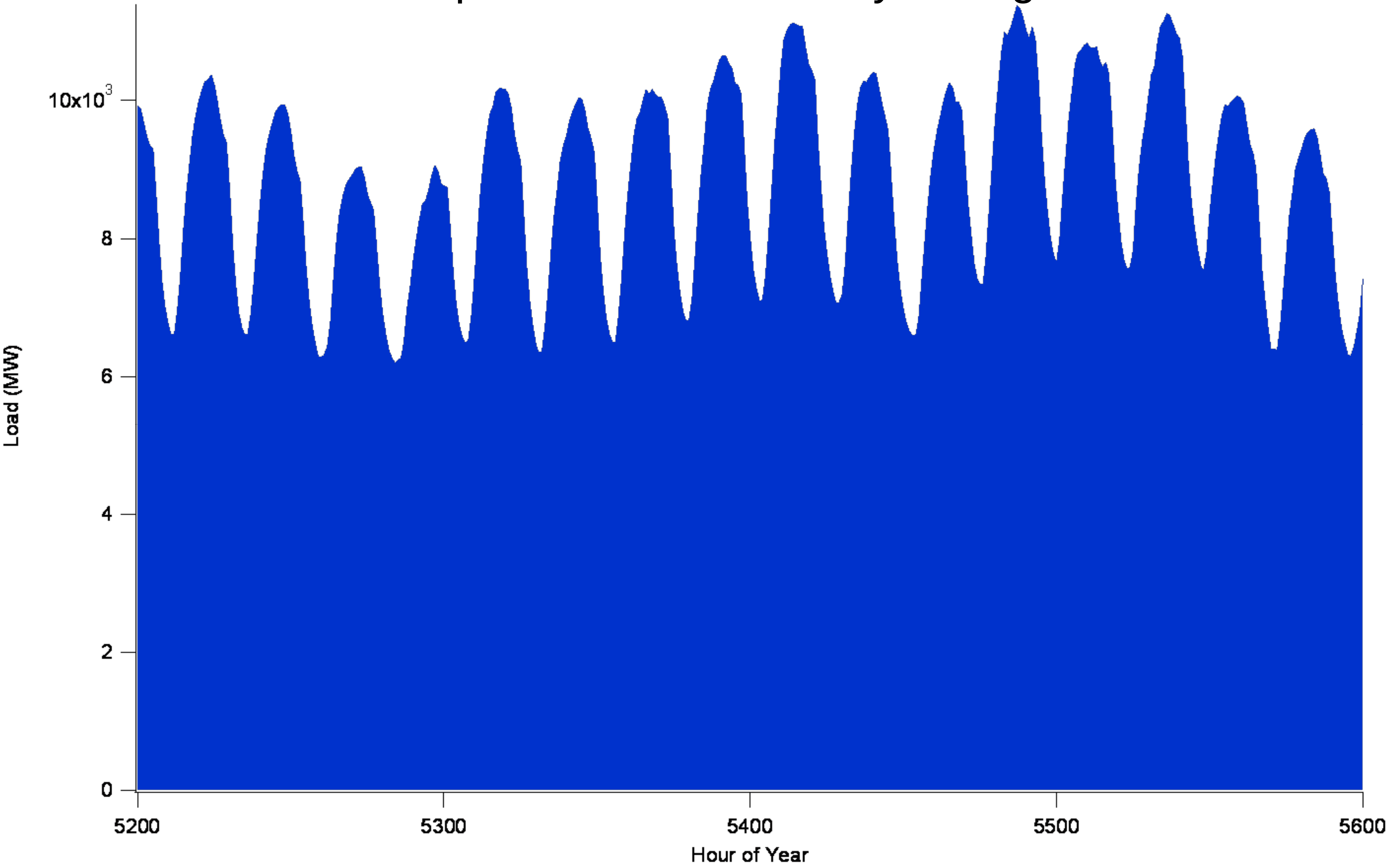
Value of storage with current resource mix.



Value of storage with new flexible resource mix.

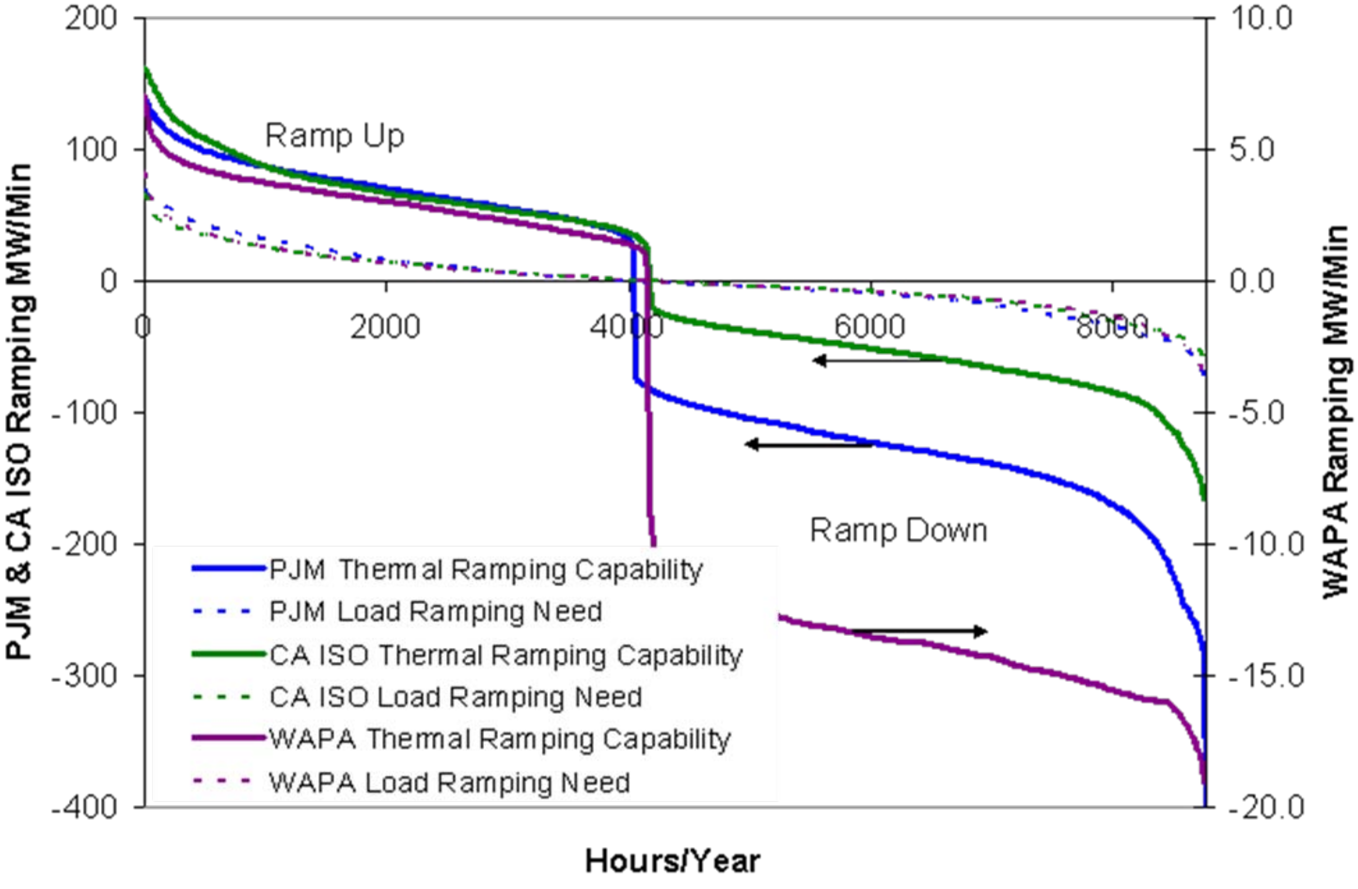
9) Isn’t all the existing flexibility already used up?

Load requires a lot of flexibility from generators



9) Isn't all the existing flexibility already used up?

Analysis of 3 different balancing areas showed that all 3 have excess load-following capability inherent in the conventional thermal generation mix

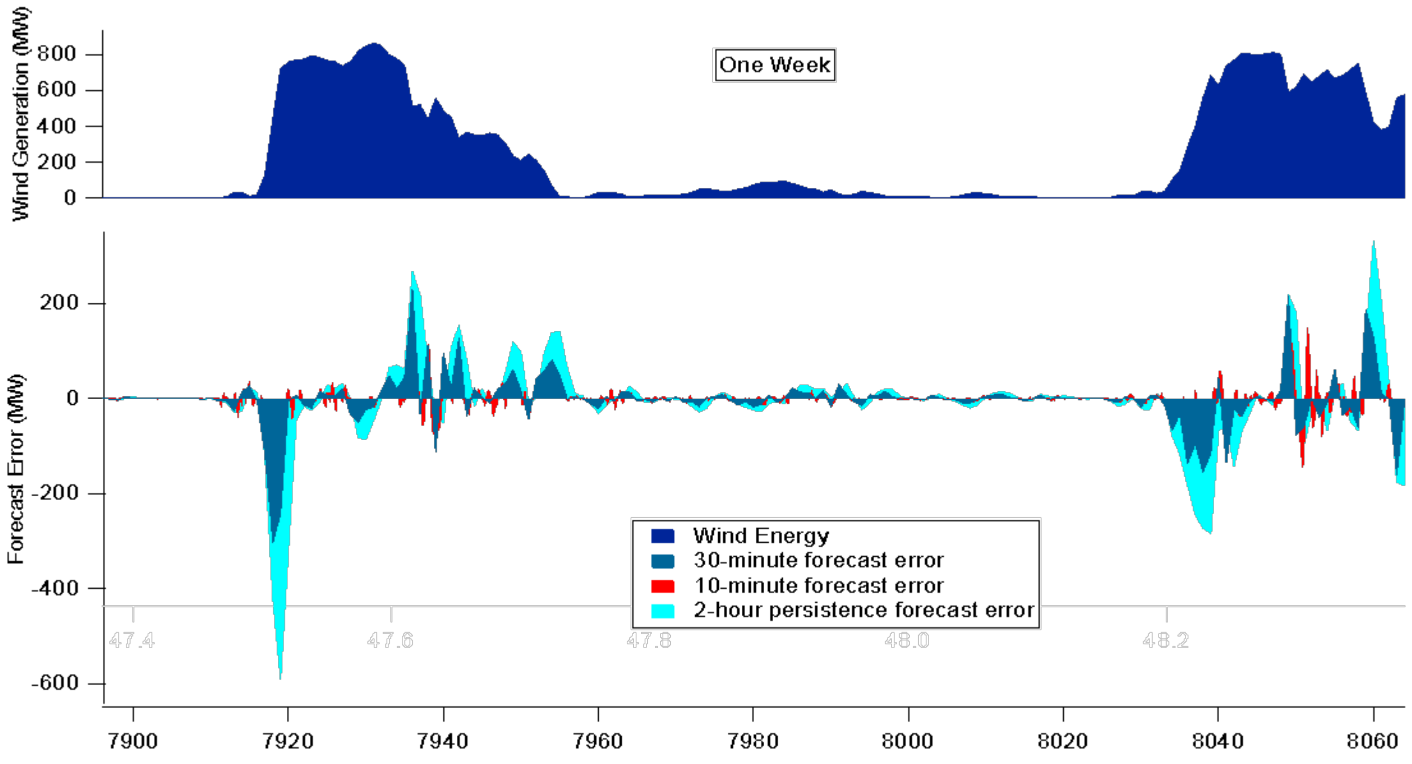


9) Isn't all the existing flexibility already used up?

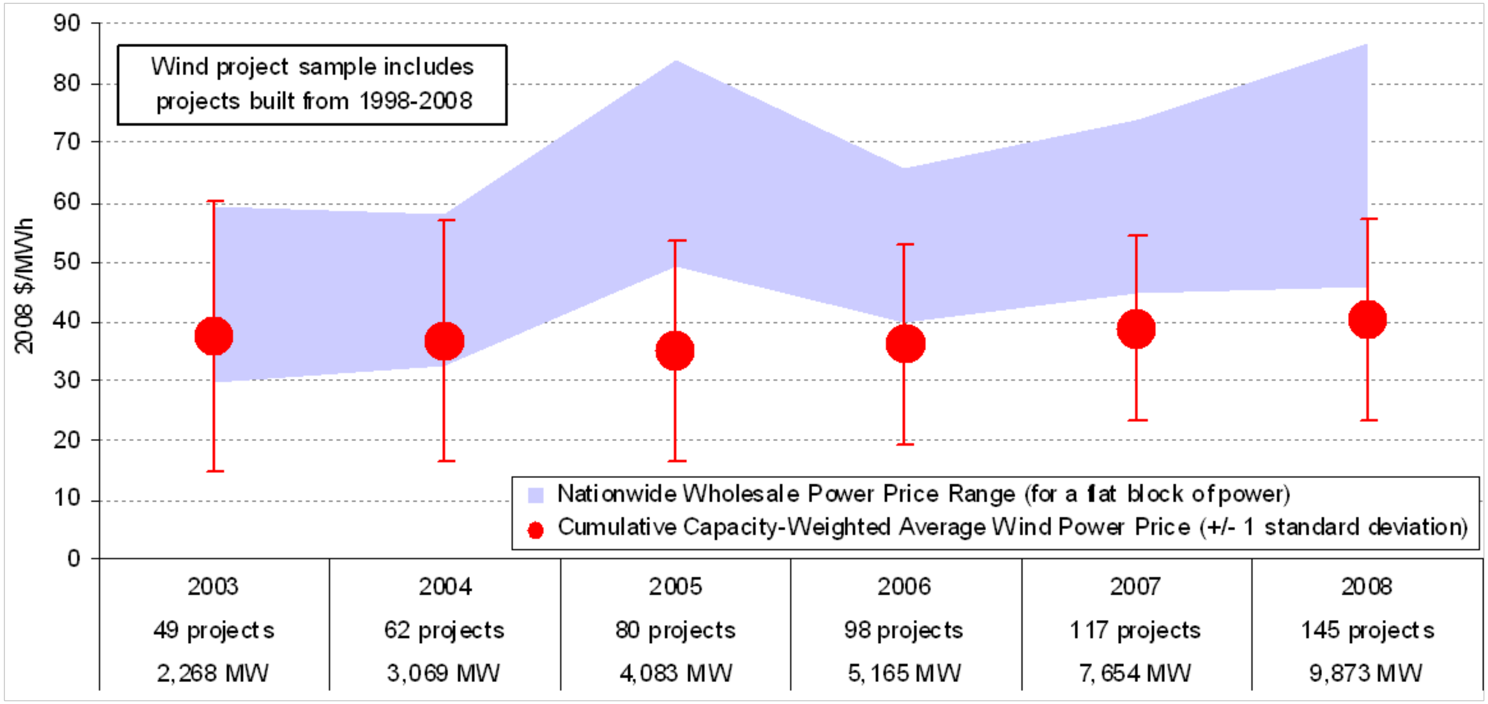
- Additional sources of flexibility may be needed at high penetration rates
  - newer types of generation: CTs, reciprocating engines
- Institutional flexibility
  - Fast energy markets
  - Sub-hourly scheduling protocols with neighboring balancing areas
- Demand response
- Plug-hybrid vehicles in the future

9) Isn't all the existing flexibility already used up?

- Impact of Inter-BA Wind With Slow Schedule Response
- Extra installed capacity is required in the host BA, increasing costs for all
- Larger imbalances and costs will be incurred
- Scheduling inefficiencies restrict units that can respond
- ***Solution: fast scheduling (~5 minutes) between balancing areas***



10) Is wind power is as good as coal or nuclear even though the capacity factor of wind power is so much less?



Average Cumulative Wind and Wholesale Power Prices Over Time. Source: Wiser, Ryan and Mark Bolinger. *Annual Report on U.S. Wind Energy Markets: 2008*. U.S. Department of Energy, http://www1.eere.energy.gov/windandhydro/pdfs/46026.pdf.

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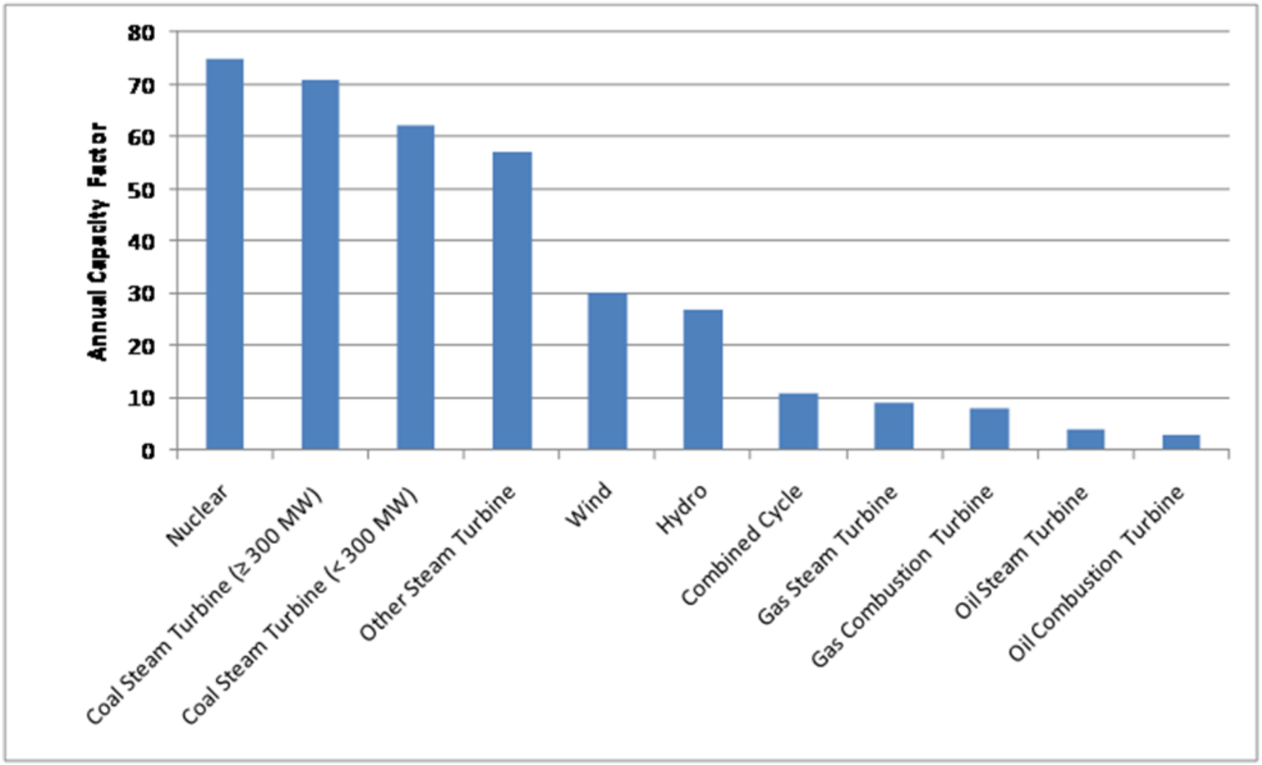
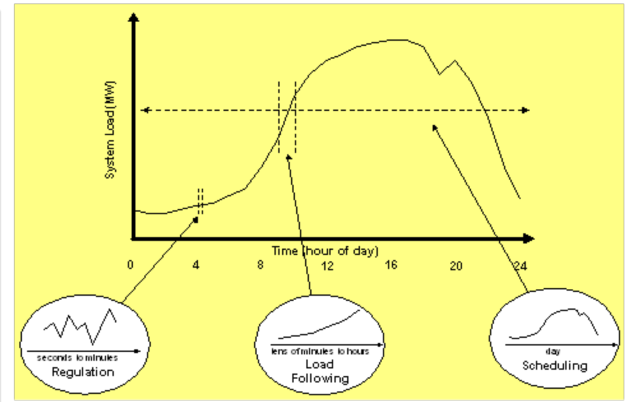
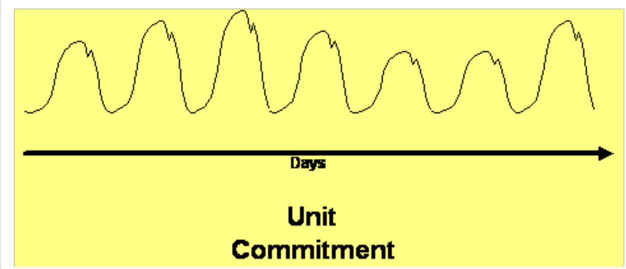


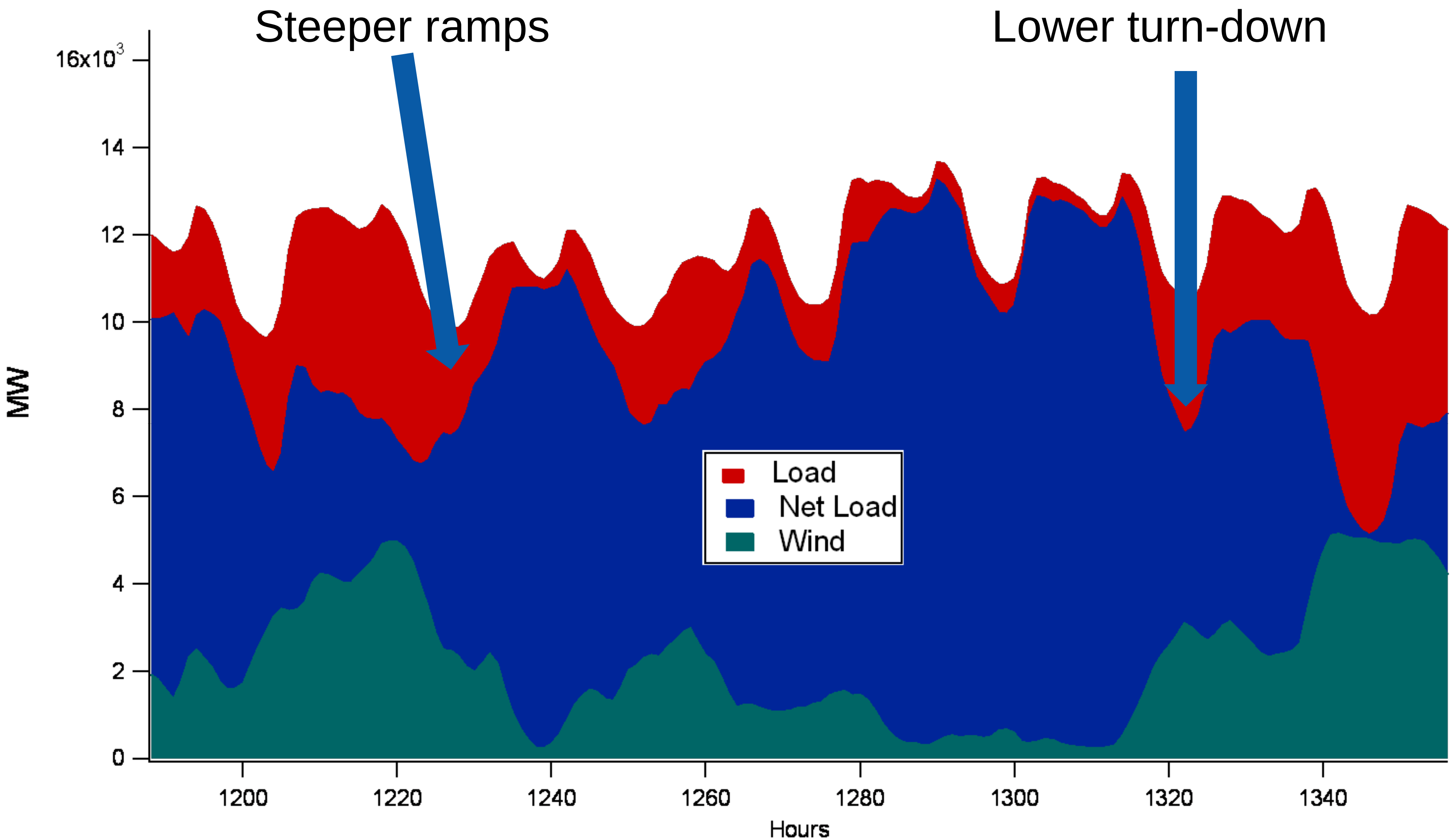


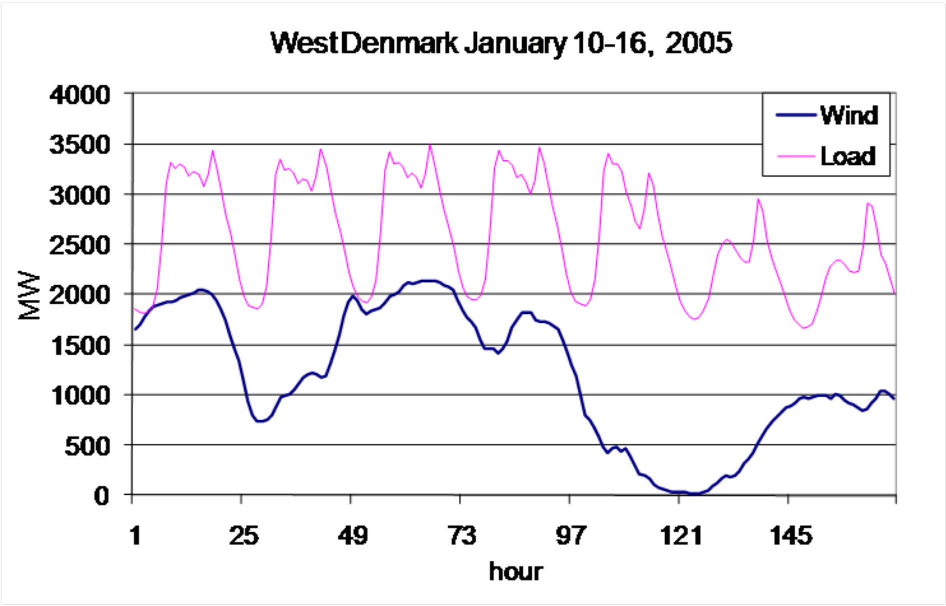


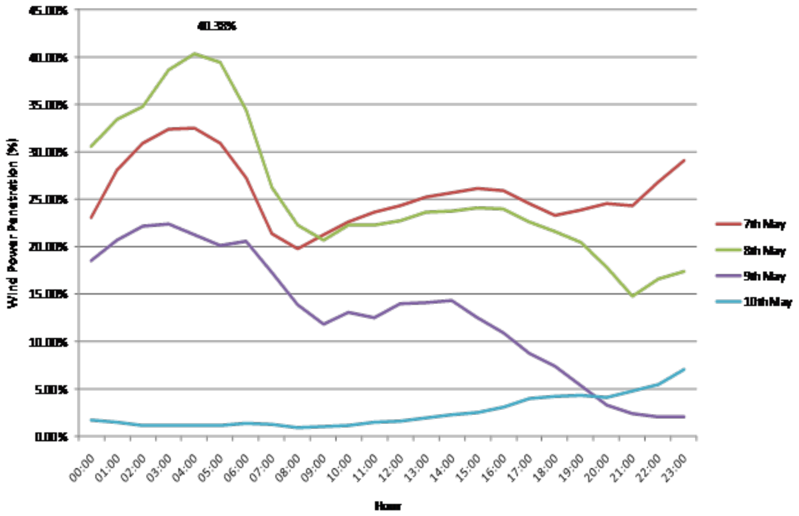
Midwest ISO Plant Capacity Factor by Fuel Type (June 2005–May 2006)

11) Is there a limit to how much wind can be accommodated by the grid?

- Studies done so far in the U.S. have not identified a physical limit, up to 30% energy penetration
- However, changes in standard operational and planning techniques may need to change
  - Larger electrical footprints for system balancing
  - Sub-hourly dispatch within balancing areas
  - Sub-hourly scheduling *between* balancing areas
  - More flexible generating technology
    - Fast ramp
    - Low turndown
    - Quick startup
  - Responsive load
  - Incorporation of wind forecasts into standard operations


Steeper ramps
Lower turn-down
16x10^3
14
12
10
8
6
4
2
0
MW
1200
1220
1240
1260
1280
1300
1320
1340
Hours
Load
Net Load
Wind


West Denmark January 10-16, 2005
Wind
Load
MW
4000
3500
3000
2500
2000
1500
1000
500
0
1
25
49
73
97
121
145
hour


Wind Power Penetration (%)
45.00%
40.00%
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
40.38%
00:00
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20:00
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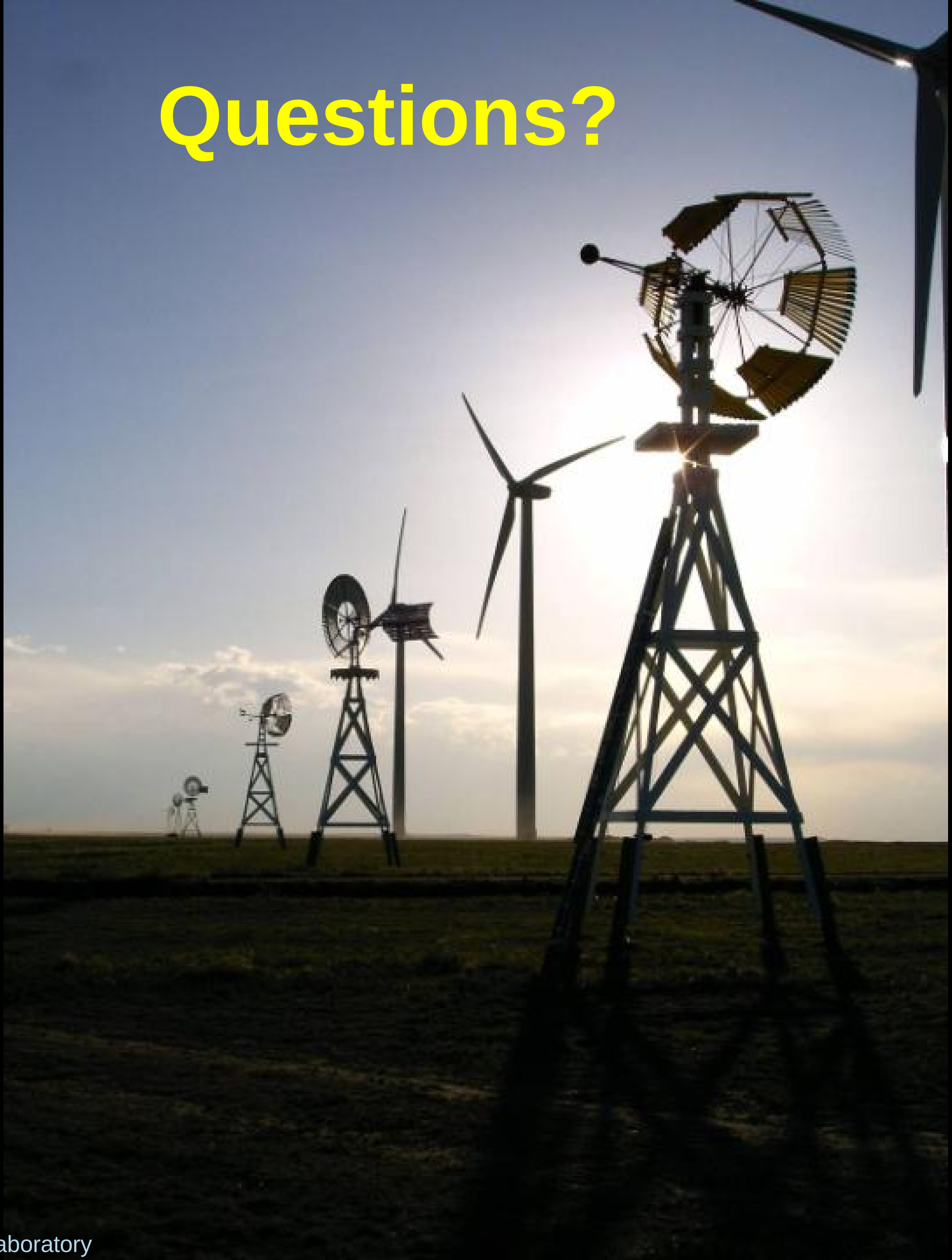
23:00
Hour
7th May
8th May
9th May
10th May

Summary

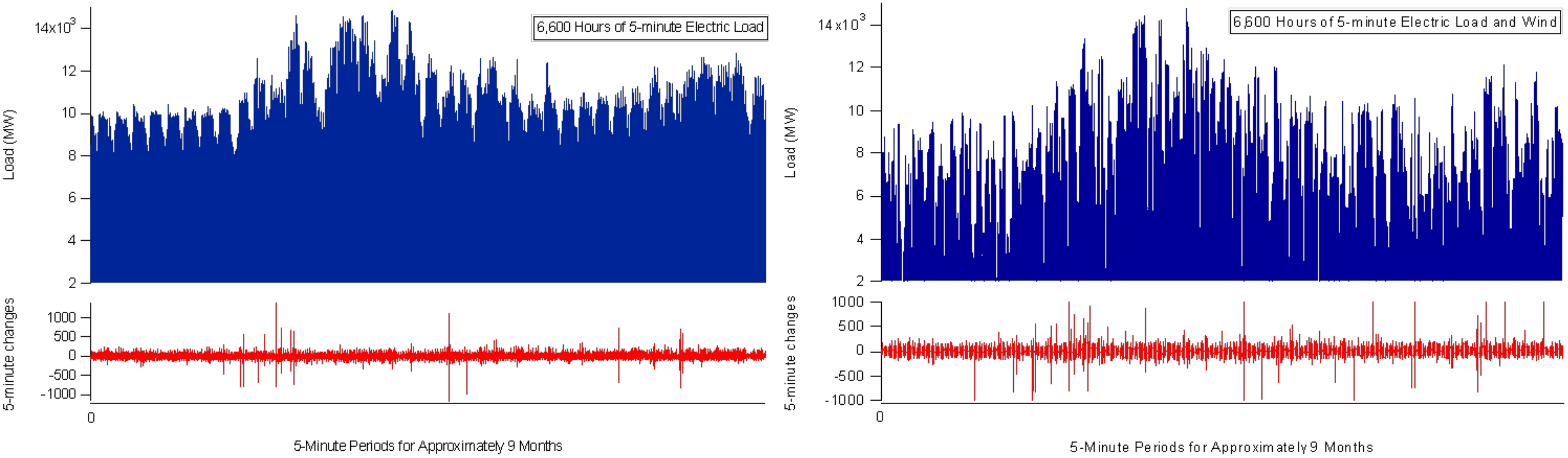
- Wind energy adds additional variability and uncertainty to power systems operations
- New methods for planning and operating the system may be needed to achieve higher penetration rates
- Much analysis is ongoing to address operational and planning issues


Questions?

Appendix Topics

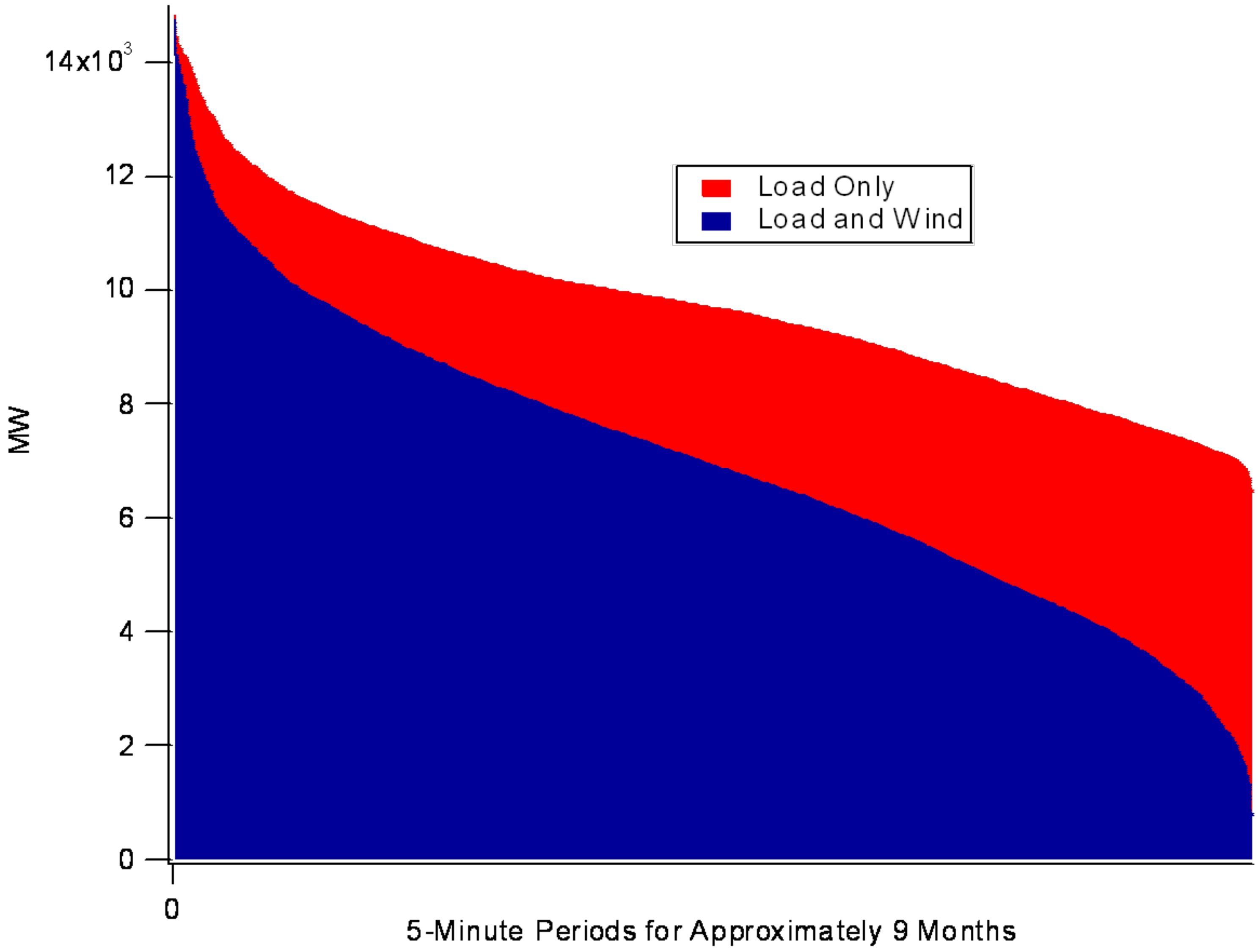
- High wind penetration integration: what does it take?
  - Technical flexibility
  - Institutional flexibility
    - Ability to access the existing flexibility on an economic basis
    - Reduce the need for flexibility by running larger balancing areas
    - Inter-Balancing Area Wind Deliveries
- Wind Integration Studies Introduction

Impact of 25% Wind Energy Penetration: 5-minute data

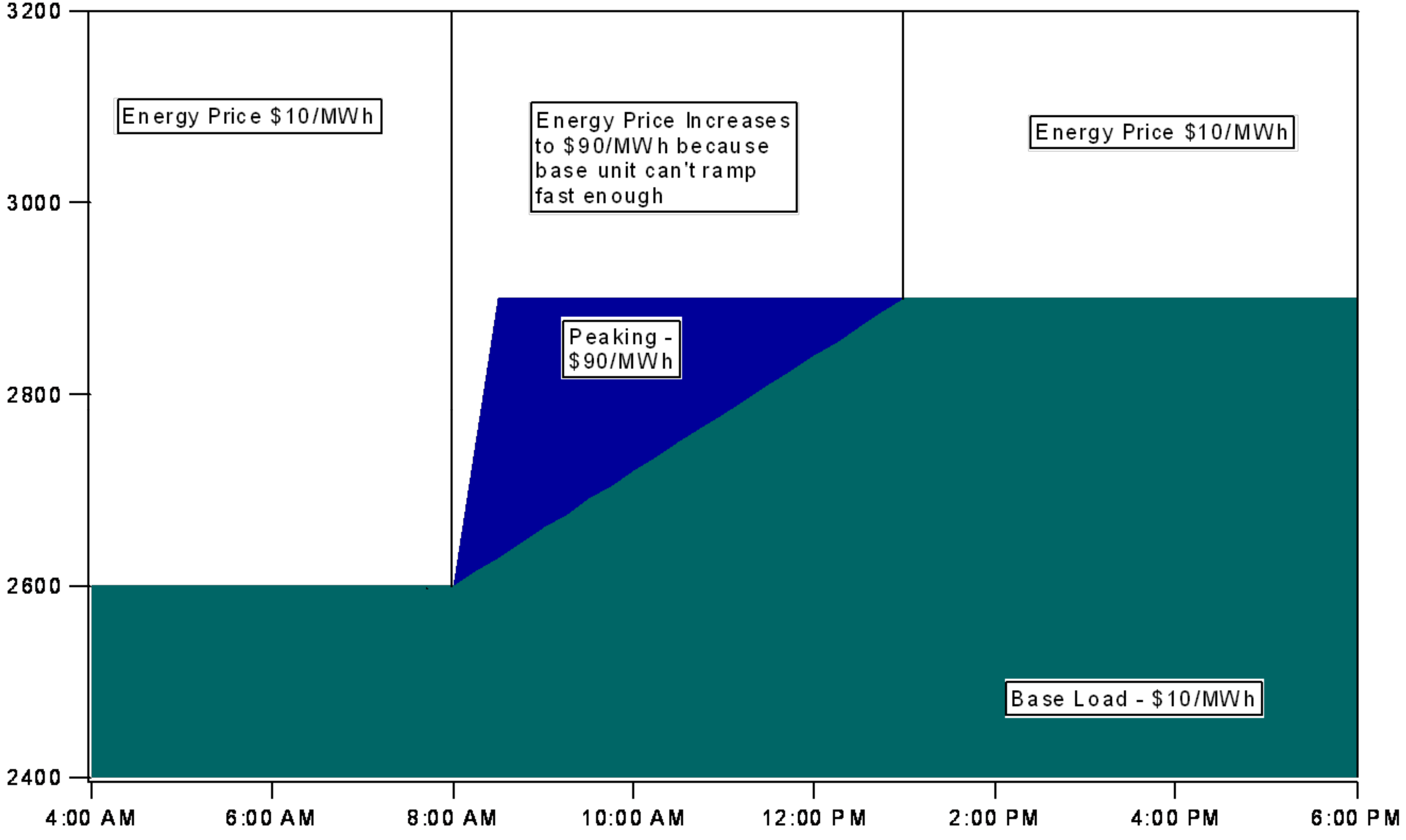


- Ramp requirements increase with 25% wind energy penetration. The upper panel also shows the importance of being able to achieve lower minimum loads by the conventional generation fleet.

Lower Turn-down is required

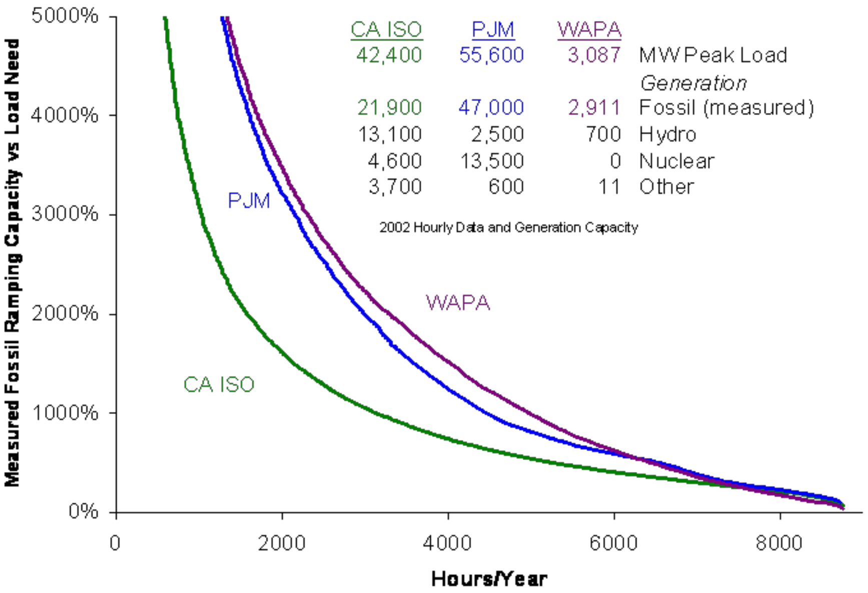


Can the non-wind fleet ramp quickly enough?



Better use of existing flexibility

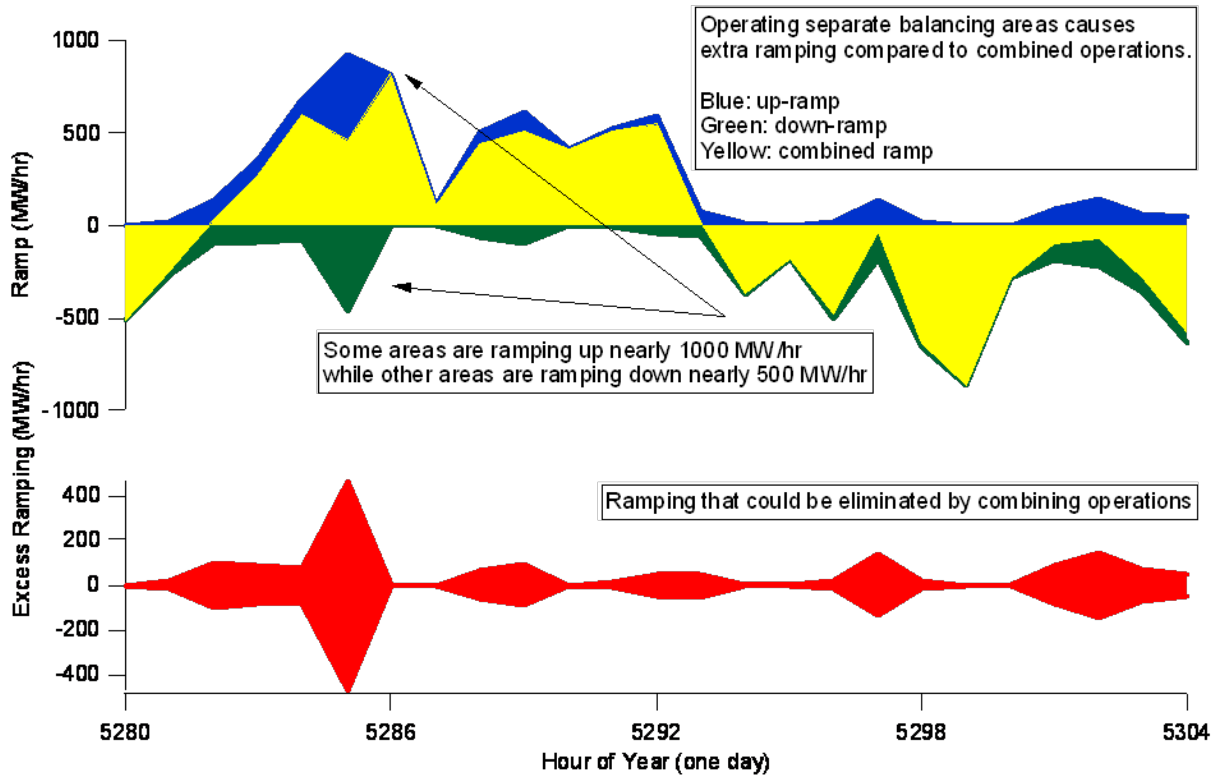
- Tap into maneuverable generation that may be "behind the wall"[1]
- Provide a mechanism (market, contract, other) that benefits system operator and generator
- Fast energy markets help provide needed flexibility[2] and can often supply load following flexibility at no cost[3]



[1]Kirby & Milligan, 2005 Methodology for Examining Control Area Ramping Capabilities with Implications for Wind
http://www.nrel.gov/docs/fy05osti/38153.pdf
[2]Kirby & Milligan, 2008 Facilitating Wind Development: The Importance of Electric Industry Structure.
http://www.nrel.gov/docs/fy08osti/43251.pdf
[3]Milligan & Kirby 2007, Impact of Balancing Areas Size, Obligation Sharing, and Ramping Capability on Wind Integration .
http://www.nrel.gov/docs/fy07osti/41809.pdf

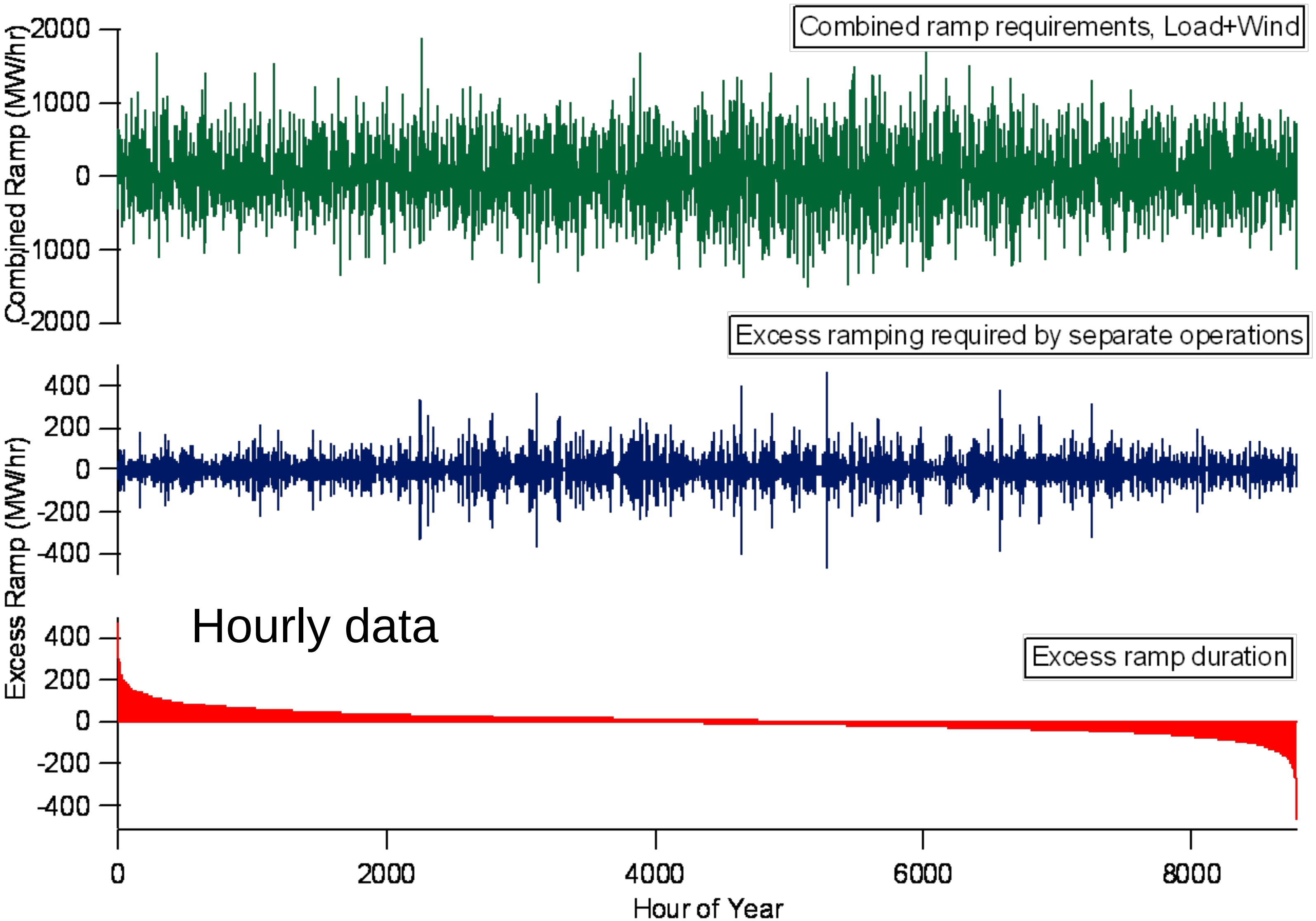
Acquire additional flexibility across BAs

- Reduce the need for ramping by combined BAs (real or virtual)
  - Ramping *capability* adds linearly
  - Ramping *need* adds less than linearly

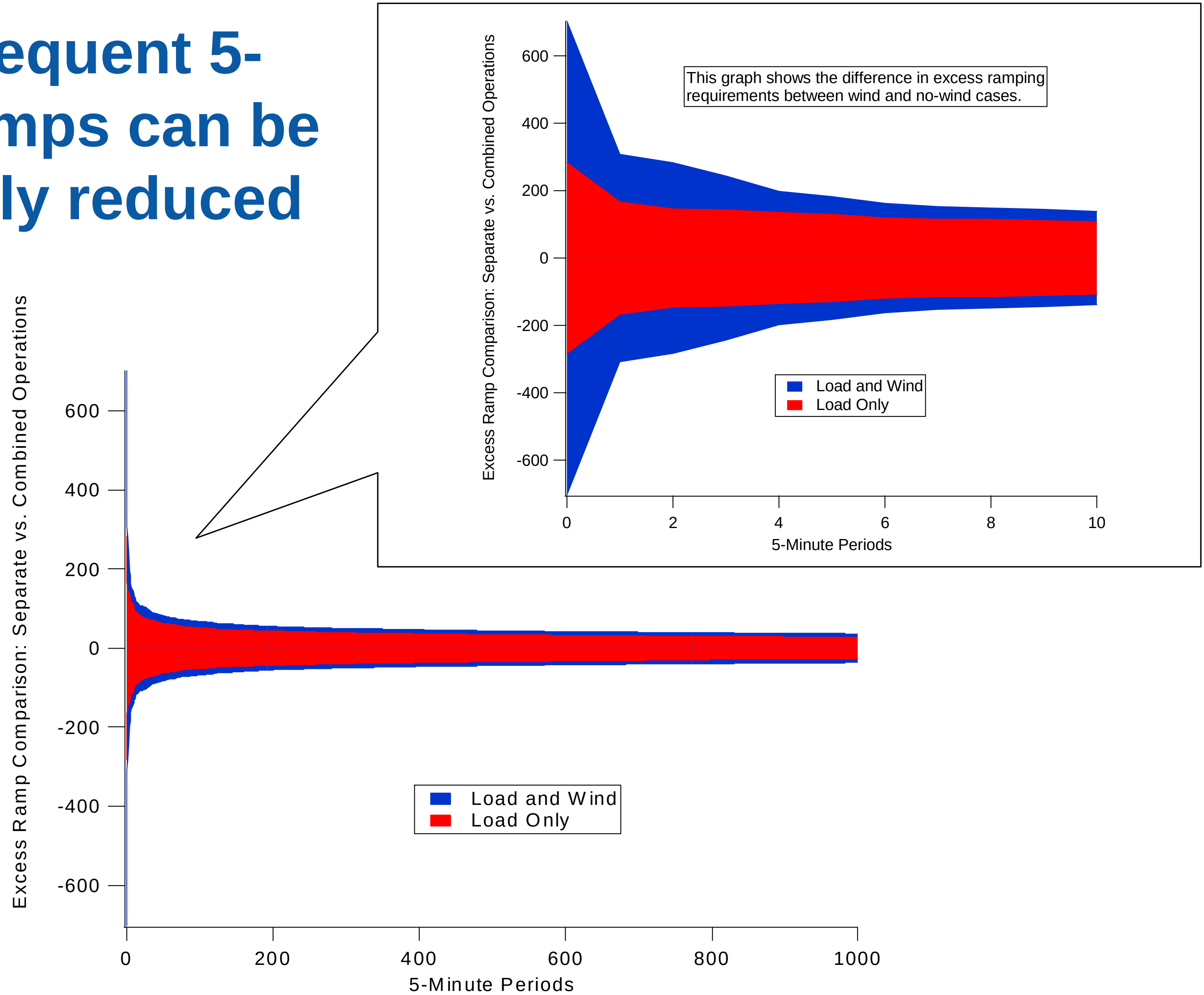


Milligan & Kirby 2007, Impact of Balancing Areas Size, Obligation Sharing, and Ramping Capability on Wind Integration . http://www.nrel.gov/docs/fy07osti/41809.pdf

BA Consolidation Reduces Ramp Requirements



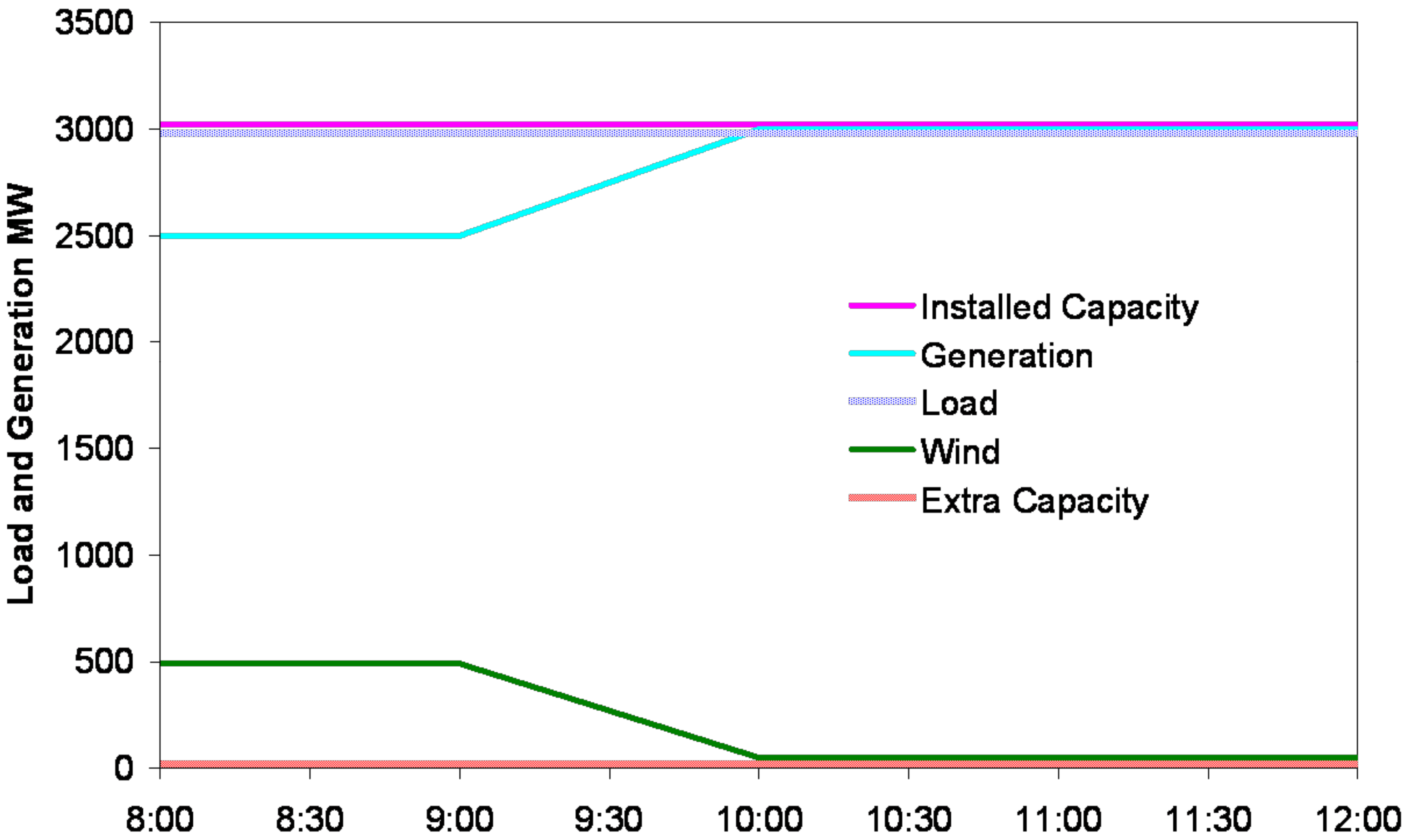
Large, infrequent 5-Minute Ramps can be significantly reduced



Milligan & Kirby 2008, An Analysis of Sub-Hourly Ramping Impacts of Wind Energy and Balancing Area Size .

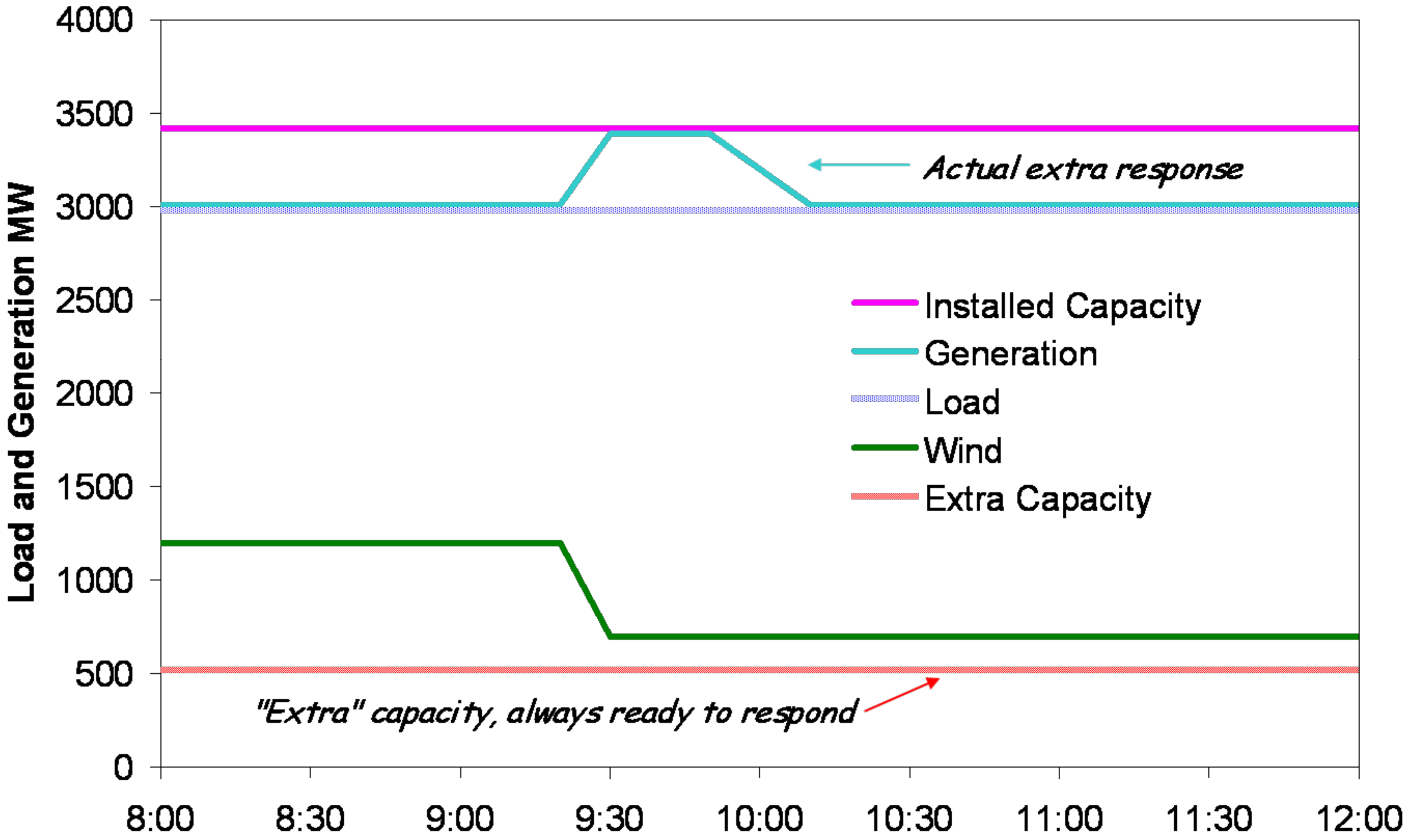
Inter-Balancing Area Wind Delivery

Wind Serves Internal BA Load

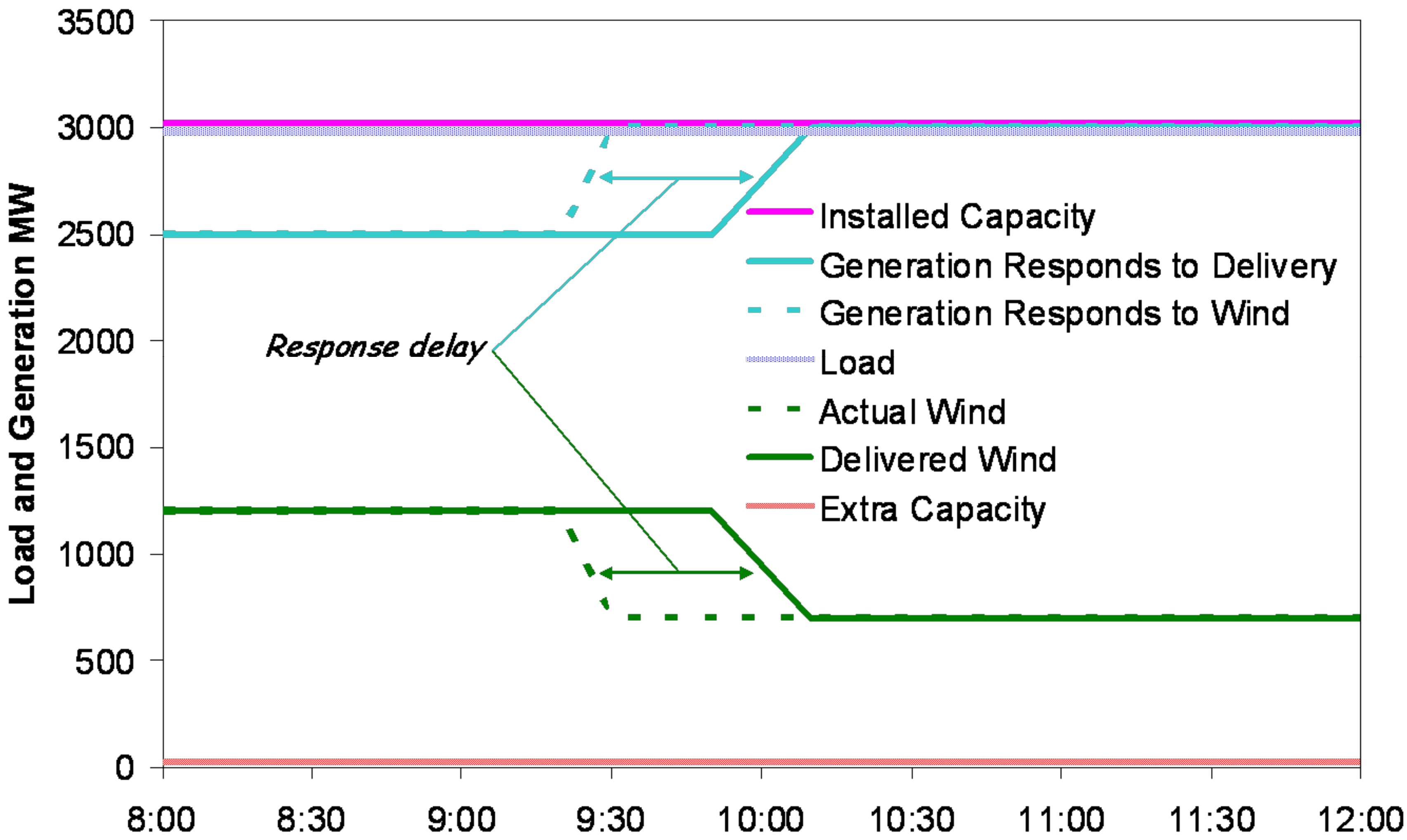


Kirby and Milligan (2009), *Capacity Requirements to Support Inter-Balancing Area Wind Deliveries*, available at www.nrel.gov/publications

Wind Serves External Load

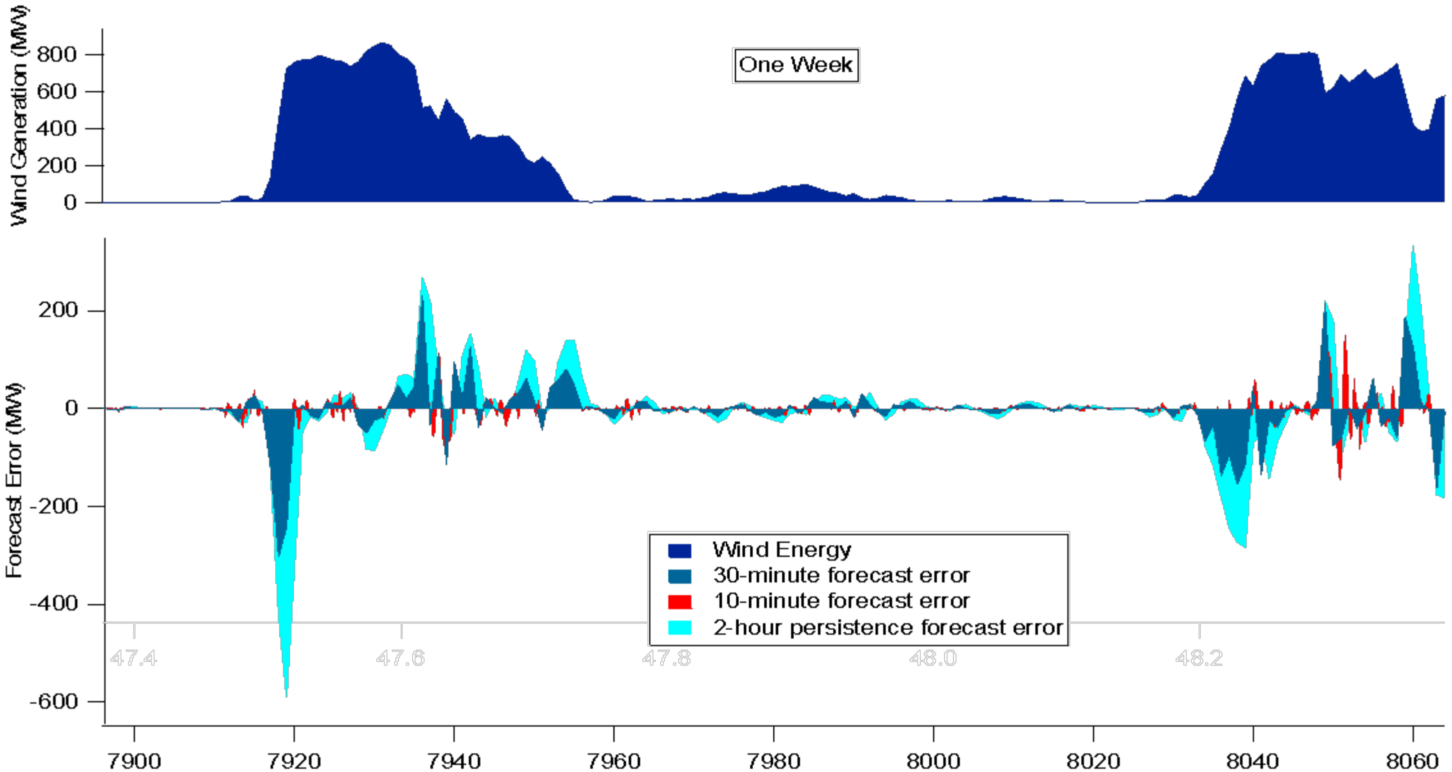


External BA Receives Wind



Impact of Inter-BA Wind With Slow Schedule Response

- Extra installed capacity is required in the host BA, increasing costs for all
- Larger imbalances and costs will be incurred
- Scheduling inefficiencies restrict units that can respond



Inter-Balancing Area Wind Delivery Can be Efficient

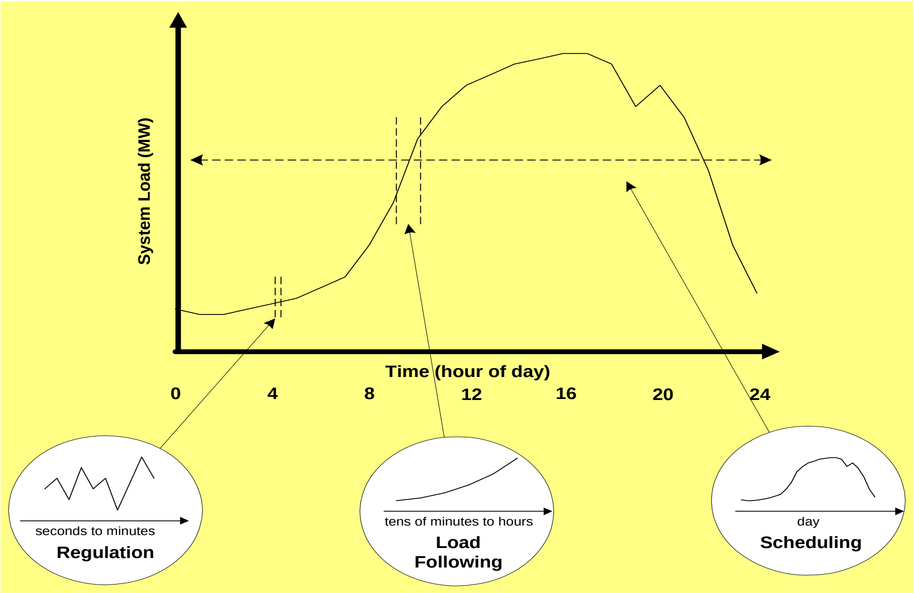
- Dynamic schedule or pseudo-tie to move wind variability to load center
- Sub-hourly BA scheduling
- Sub-hourly inter-BA scheduling
- Faster market-clearing
- Faster wind forecast updates
- Bi-lateral agreement between the BAs
- Combined operation

Wind Integration Studies

Wind integration studies address the following concerns

- Reliable power system operation requires balance between load and generation *within acceptable statistical limits*
- Output of wind plants cannot be controlled and scheduled with high degree of accuracy
- Wind plants becoming large enough to have measurable impact on system operating cost
- System operators concerned that ***additional*** variability introduced by wind plants will increase system operating cost

Time Frames of Wind Impact



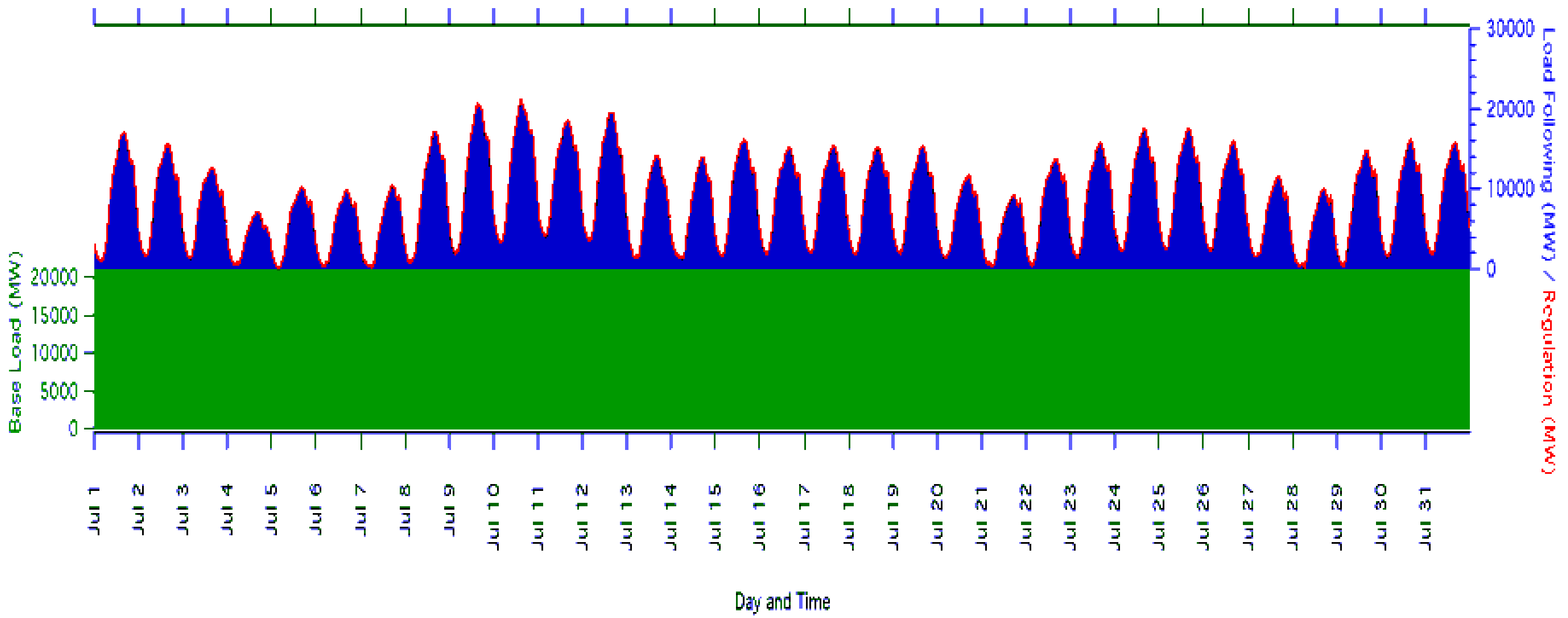
Typical U.S. terminology

- 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?
- Capacity value (planning): based on reliability metric (ELCC=effective load carrying capability)

Decomposition of Control Area Loads

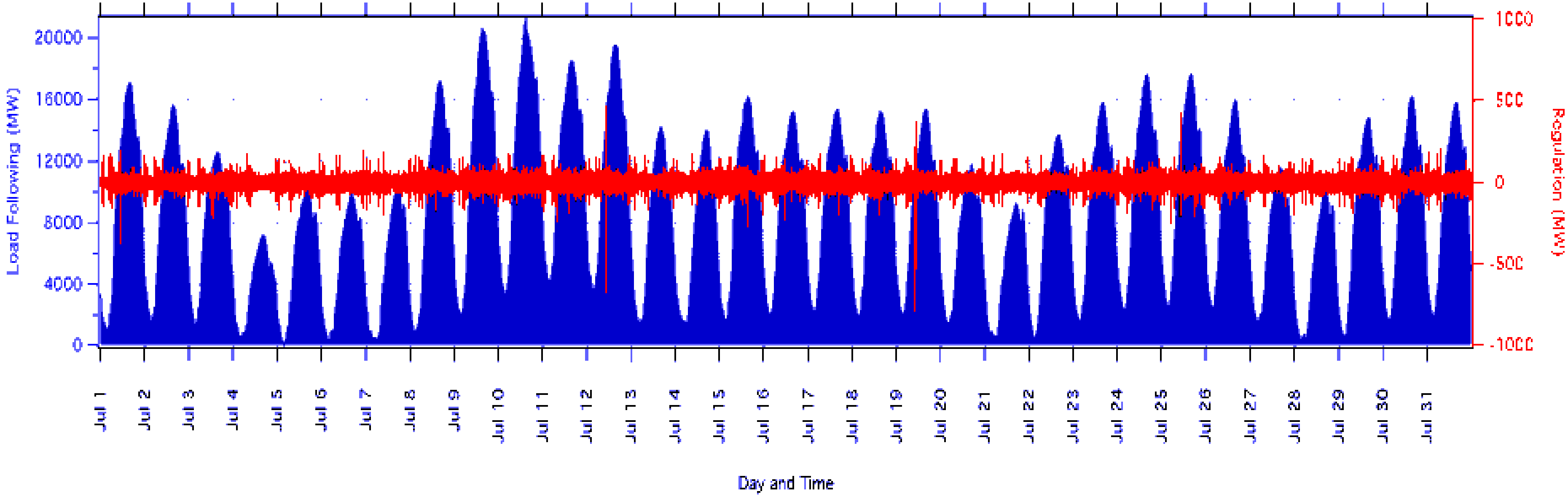
•Control area load & generation can be decomposed into three parts:

- Base Load
- Load Following
- Regulation



Regulation & Load Following

	REGULATION	*LOAD FOLLOWING*
Patterns	*Random, uncorrelated*	*Largely correlated*
Generator control	*Requires AGC*	*Manual*
Maximum swing (MW)	*Small*	*10 – 20 times more*
Ramp rate (MW/minute)	*5 – 10 times more*	*Slow*
Sign changes	*20 – 50 times more*	*Few*



Impact of Variable Power Sources

- Power system is designed to handle tremendous variability in loads
- Wind adds to that variability
- System operator must balance loads=resources (within statistical tolerance)
- Key implication: ***It is not necessary or desirable to match wind's movements on a 1-1 basis***

Typical Objective of Integration Studies

Determine the physical impact of wind on system operation across important time frames

- Regulation (a capacity service; AGC)
- Load following (ramp and energy components)
- Unit commitment (scheduling)
- Planning/capacity credit (same as capacity value)

Use appropriate prices/costs to assess ancillary service cost impact of wind based on the measured physical impacts

Not all studies focus on all time frames

Comparison of Cost-Based U.S. Operational Impact Studies

Date	Study	Wind Capacity Penetration (%)	Regulation Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commitment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Tot Oper. Cost Impact ($/MWh)
May ‘03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep ‘04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
June ‘06	CA RPS	4	0.45*	trace	na	na	0.45
Feb ‘07	GE/Pier/CAIAP	20	0-0.69	trace	na***	na	0-0.69***
June ‘03	We Energies	4	1.12	0.09	0.69	na	1.90
June ‘03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.60
April ‘06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April ‘06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97
Dec ‘06	MN 20%	31**					4.41**
Jul ‘07	APS	14.8	0.37	2.65	1.06	na	4.08

* 3-year average; total is non-market cost

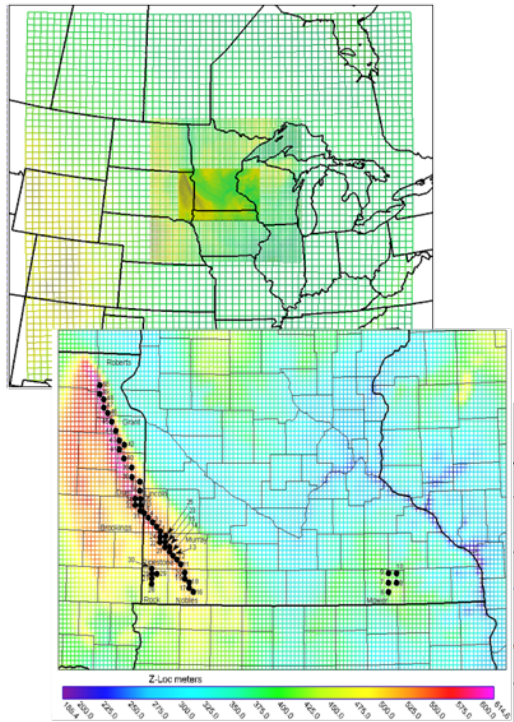
** highest integration cost of 3 years; 30.7% capacity penetration corresponding to 25% energy penetration; 24.7% capacity penetration at 20% energy penetration

*** found $4.37/MWh reduction in UC cost when wind forecasting is used in UC decision

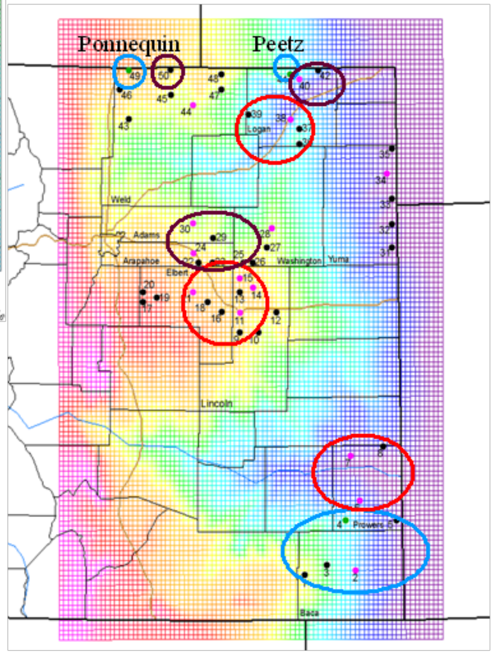
Where Does Wind Data Come From?

- Meso-scale meteorological modeling that can “re-create” the weather at any space and time
- Maximum wind power at a single point ~ 30 MW to capture geographic smoothing
- Model is run for the period of study and must match load time period
- Wind plant output simulation and fit to actual production of existing plants

Minnesota: Xcel



Colorado: Xcel

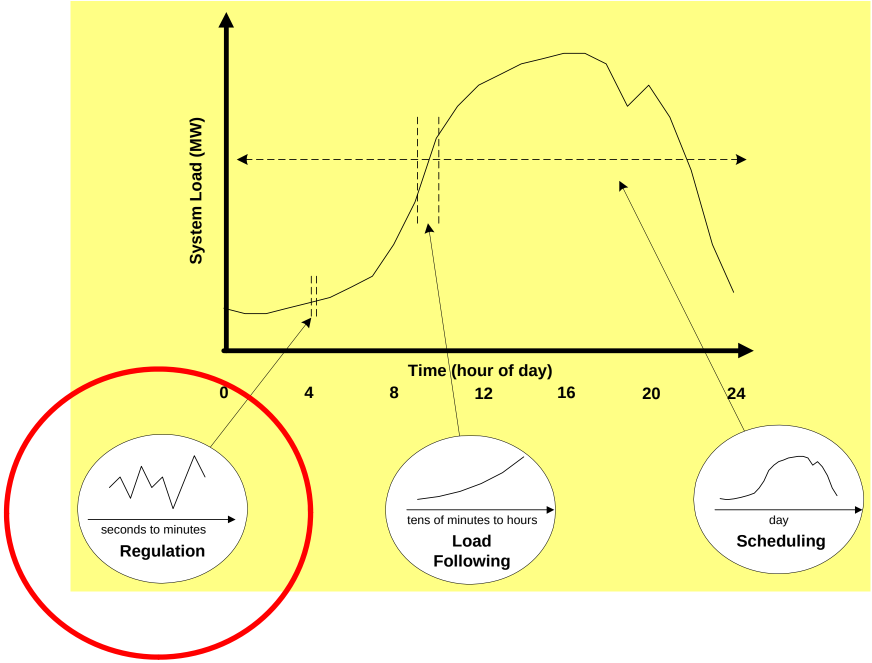


How Are Wind's Impacts Calculated?

- Main tool is production simulation
  - Detailed data for
    - Load
    - Wind
    - Other generation
- Simulation is augmented by statistical analysis
  - Sub-hourly is beyond scope of most production models
  - Provides additional insights and excursions to interesting/challenging situations

How is Regulation Impact Calculated?

- Based on actual high-frequency (fast) system load data and wind data
- If wind data not available, use NREL high-resolution wind production data characteristics
- Impact of the wind variability is then compared to the load variability
- Regulation cost impact of wind is based on physical impact and appropriate cost of regulation (market or internal)



–Realistic calculation of wind ***plant*** output (linear scaling from single anemometer is incorrect)

How is Load Following Impact Calculated?

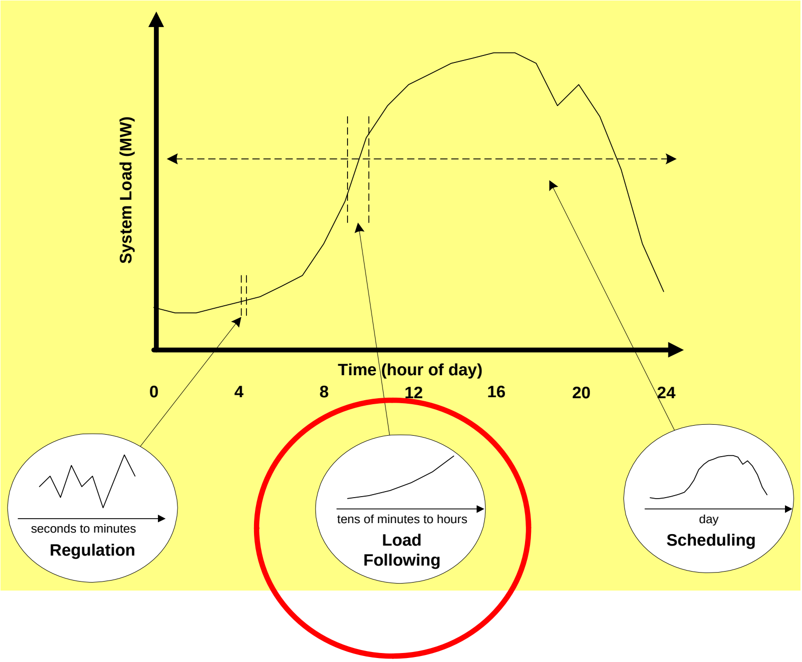
Power system simulation and statistical analysis

Based on actual system load data

…and wind data from *same* time period

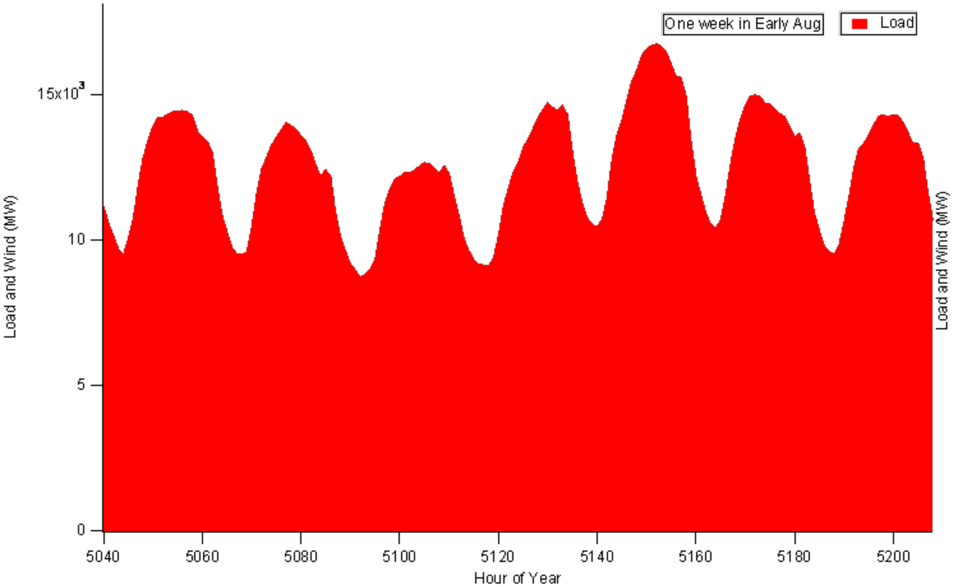
- Meteorological simulation to capture ***realistic*** wind profile, typically 10-minute periods and multiple simulated/actual measurement towers
- Realistic calculation of wind ***plant*** output (linear scaling from single anemometer is incorrect)

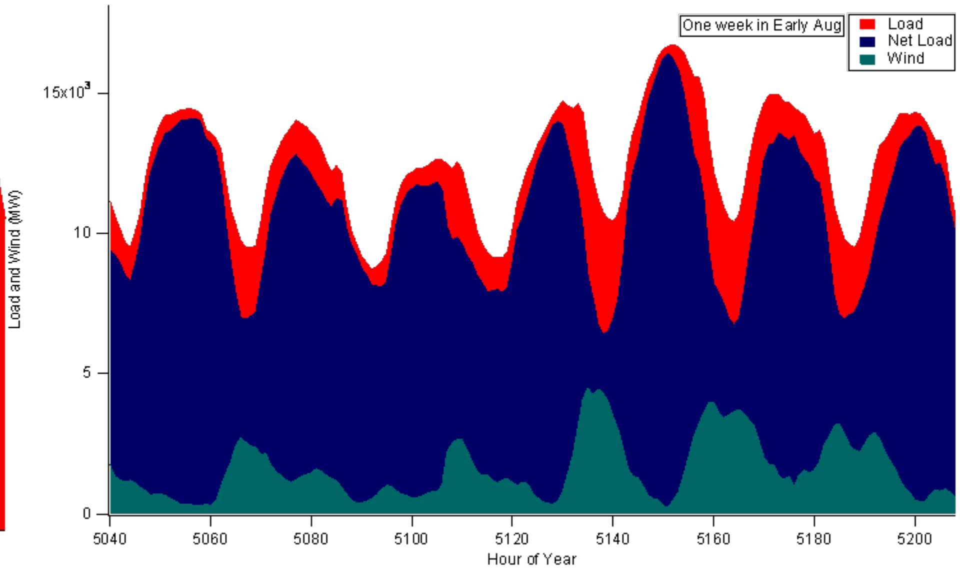
Wind variability added to *existing system variability* → Implies no one-one backup for wind



How is Unit Commitment Impact Calculated?

- Requires a realistic system simulation for at least one year (more is better)
- Compare system costs with and without wind
- Use load and wind forecasts in the simulation
- Separate the impacts of variability from the impacts of uncertainty





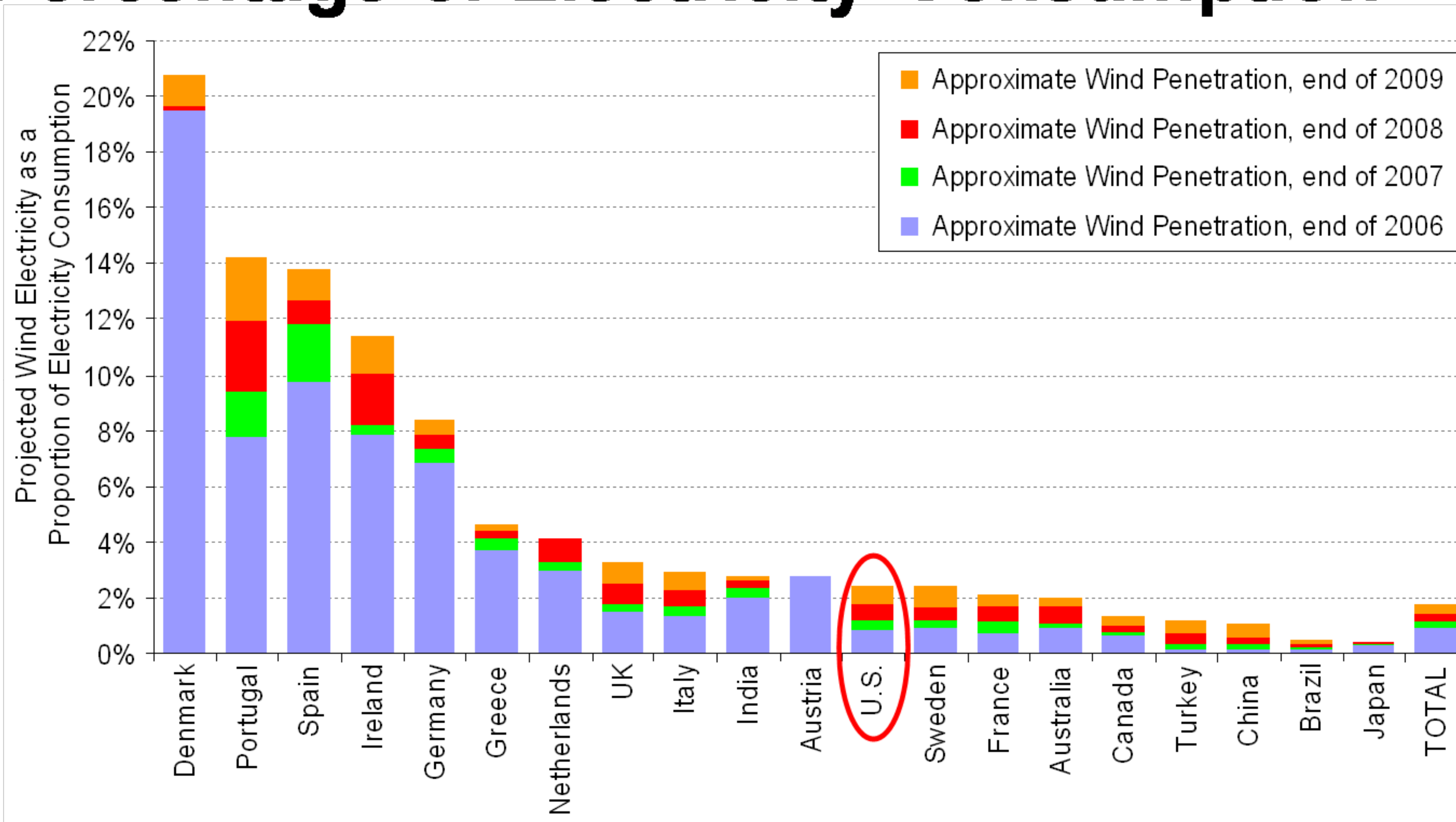
Study Best-Practices

- Start by quantifying physical impacts
  - Detailed weather simulation or actual wind power data
  - Ensure wind and load data from same time period
- Divide the physical and cost impacts by time scale and perform detailed system simulation and statistical analysis
  - Regulation
  - Load following and imbalance
  - Scheduling and unit commitment
  - Capacity value
- Utilize wind forecasting best practice and combine wind forecast errors with load forecast errors
- Examine actual costs independent of tariff design structure

Stakeholder Review Best Practices

- Technical review committee (TRC)
  - Bring in at beginning of study
  - Discuss assumptions, processes, methods, data
- Periodic TRC meetings with advance material for review

U.S Lagging Other Countries in Wind As a Percentage of Electricity Consumption



Note: Figure only includes the 20 countries with the most installed wind power capacity at the end of 2009

From LBL 2009 Wind Technologies Market Report

Example of high penetration from Ireland