Finding Flexibility in the Existing Grid

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PIX 10927

PIX 15996

PIX 14898

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Grid Integration of Renewables Workshop

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Wind and Solar: Variable and Uncertain

Variability – Wind and solar generator outputs vary as the intensity of their energy sources (wind and sun);

- Several timescales: minute (regulation), hour (ramping), diurnal, seasonal.

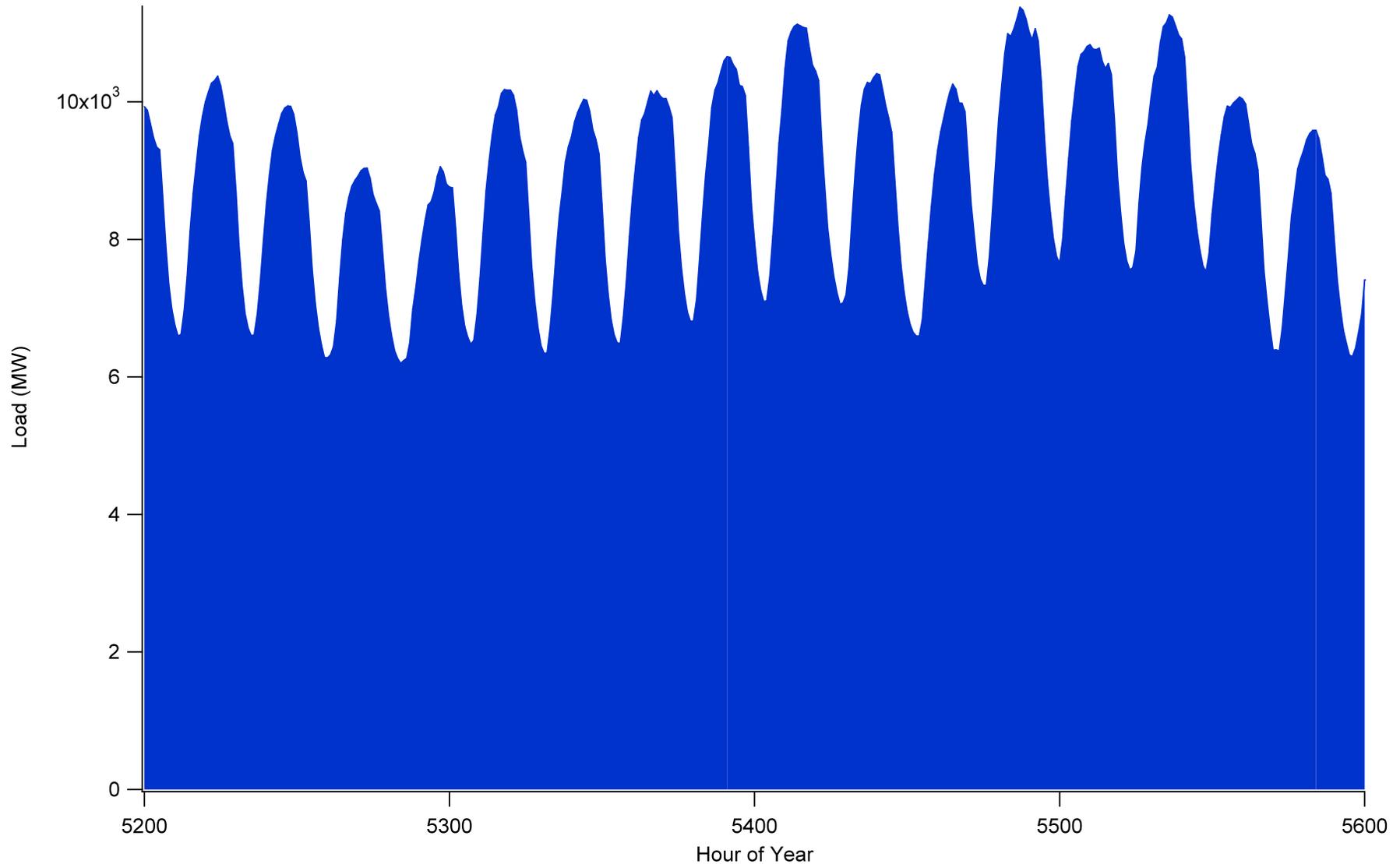**Uncertainty –** Wind and solar generation are similar to "load";

- Not dispatchable – output is predicted by a forecast,
- Actual power output is different than forecast output.

A perfect forecast eliminates **uncertainty**, but there is still **variability.**
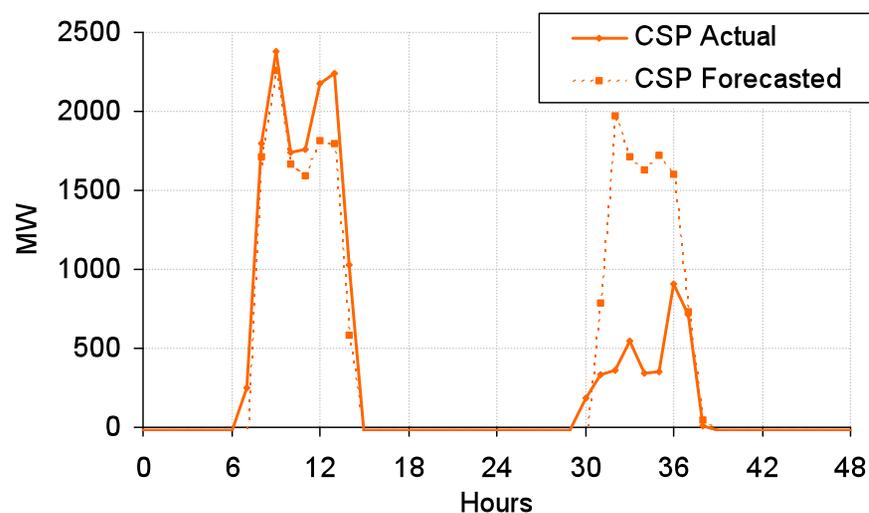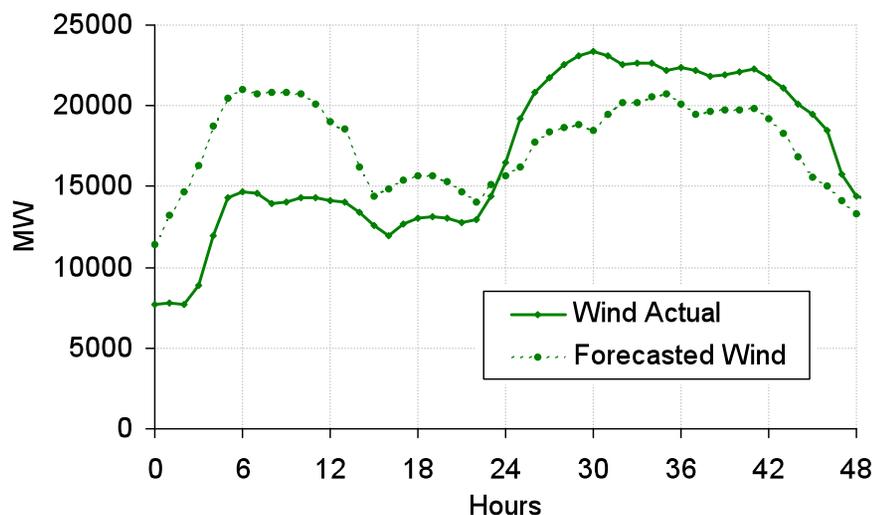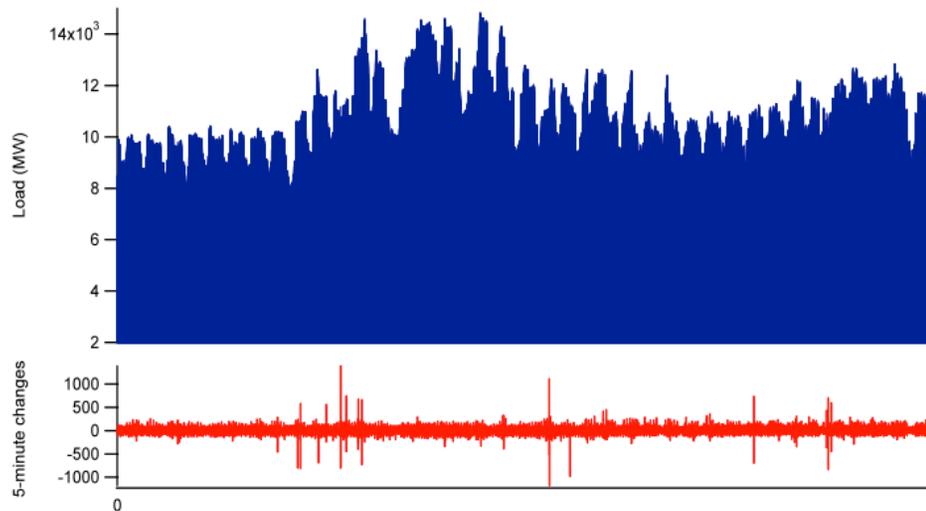
Load: Variable and Uncertain

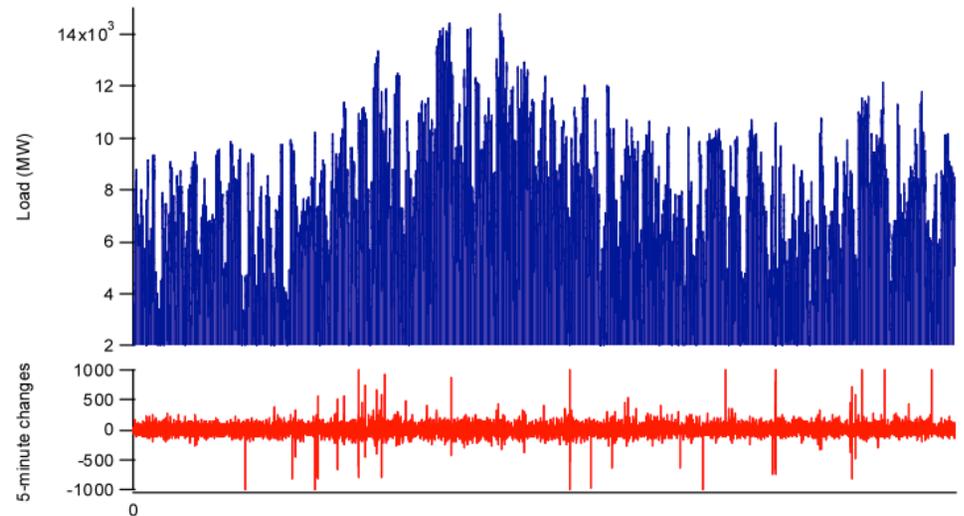**The power system is designed to handle variability and uncertainty in the load.**

Impact of 25% Wind

No wind

25% wind energy

Increased ramps
Lower minimum net load

Impact of 35% wind/solar

Net Load
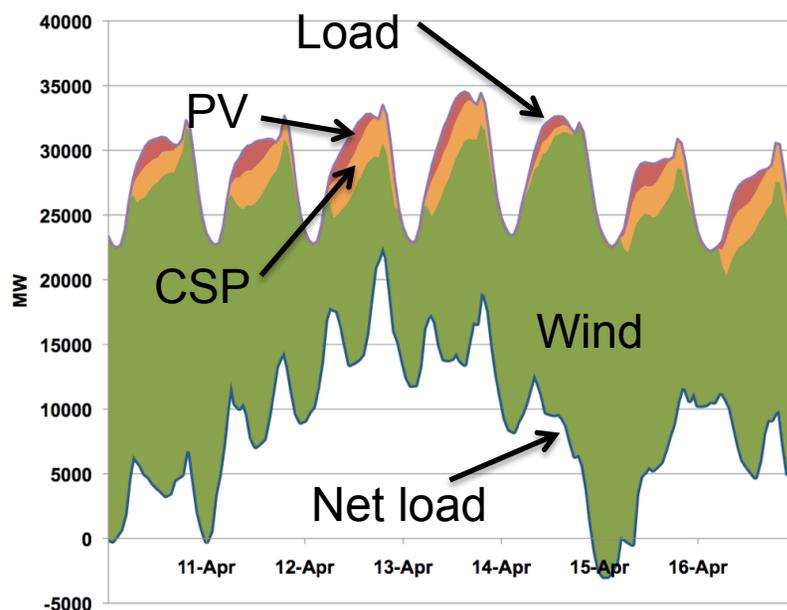
Dispatch

Need for conventional plants to cycle and ramp
Need for wind to curtail

This was the worst week of the 3 years studied in the Western Wind and Solar Integration Study (http://www.nrel.gov/wwsis)

We need *Flexibility*
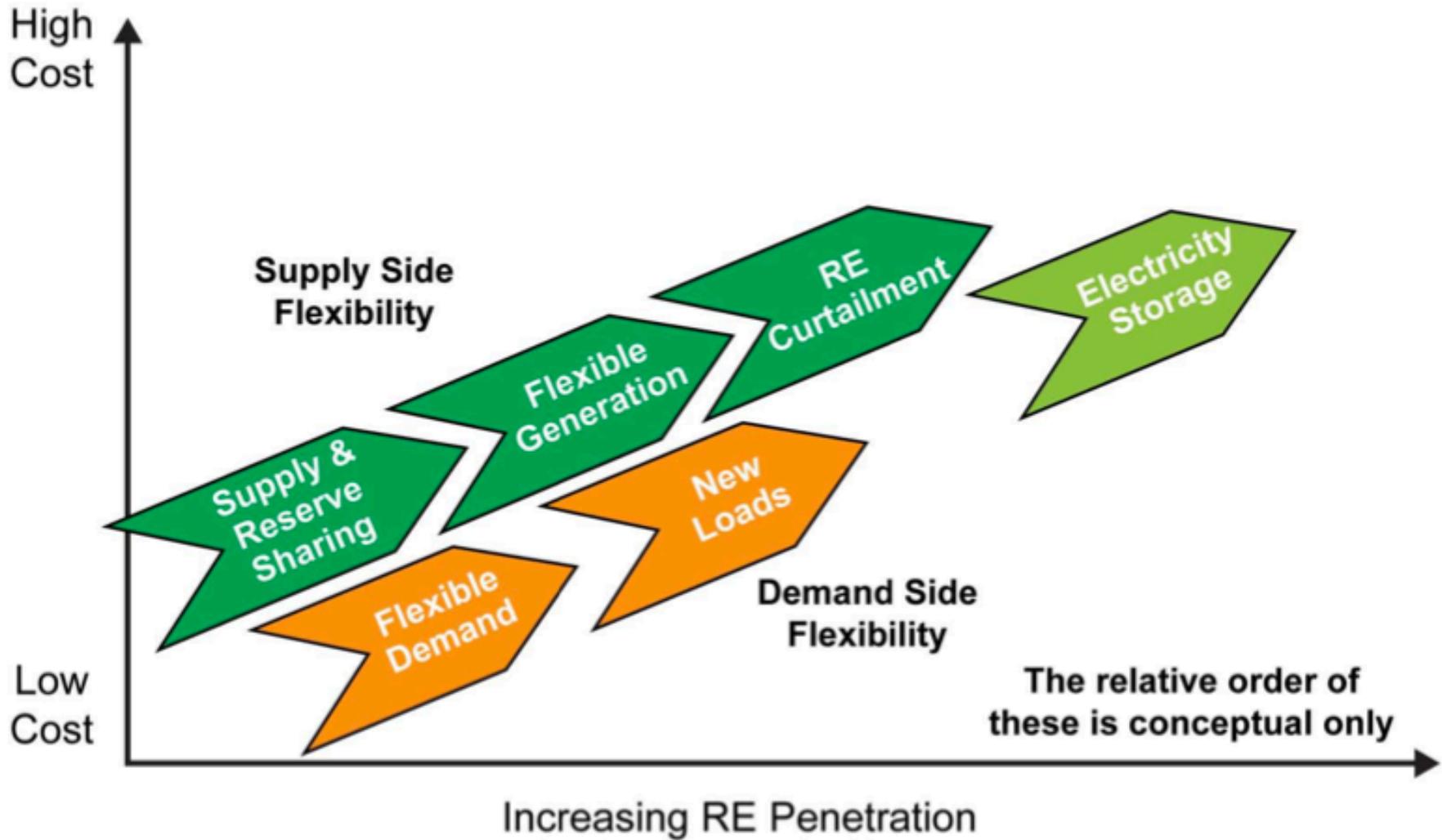
Source: DOE Wind Program

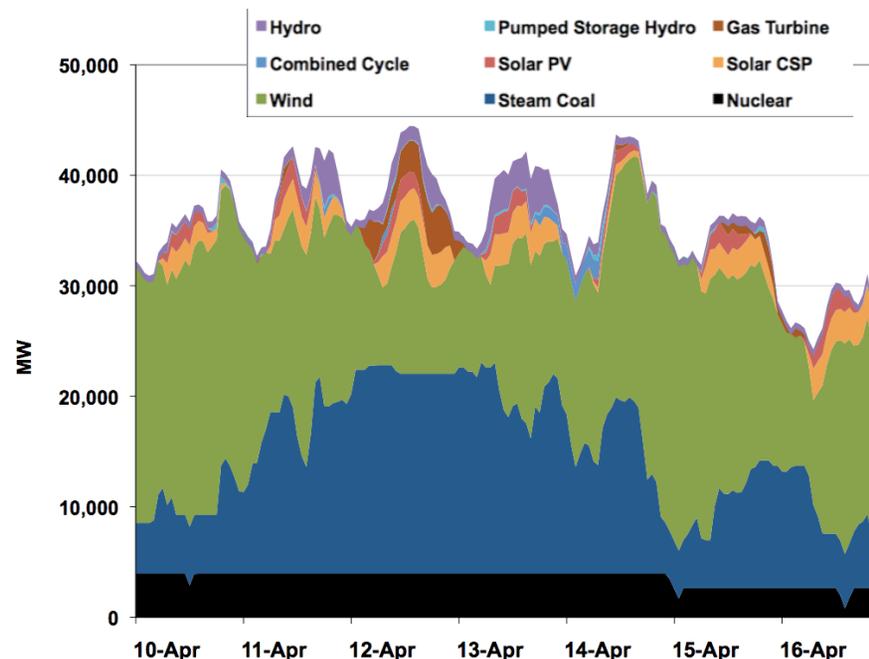# Sources of Flexibility

(or reductions of need for flexibility)

Institutional:

- Fast markets
- Balancing area (BA) cooperation
- Transmission
- Rolling unit commitment
- Demand response
- Curtailment

Technological:

- Non-renewable generation fleet
- Forecasting
- Demand response
- Reserves
- New loads (PHEV)
- Storage

Better Use of Existing Flexibility

Analysis of 3 different balancing areas showed that all 3 have excess load-following capability inherent in the conventional thermal generation mix.
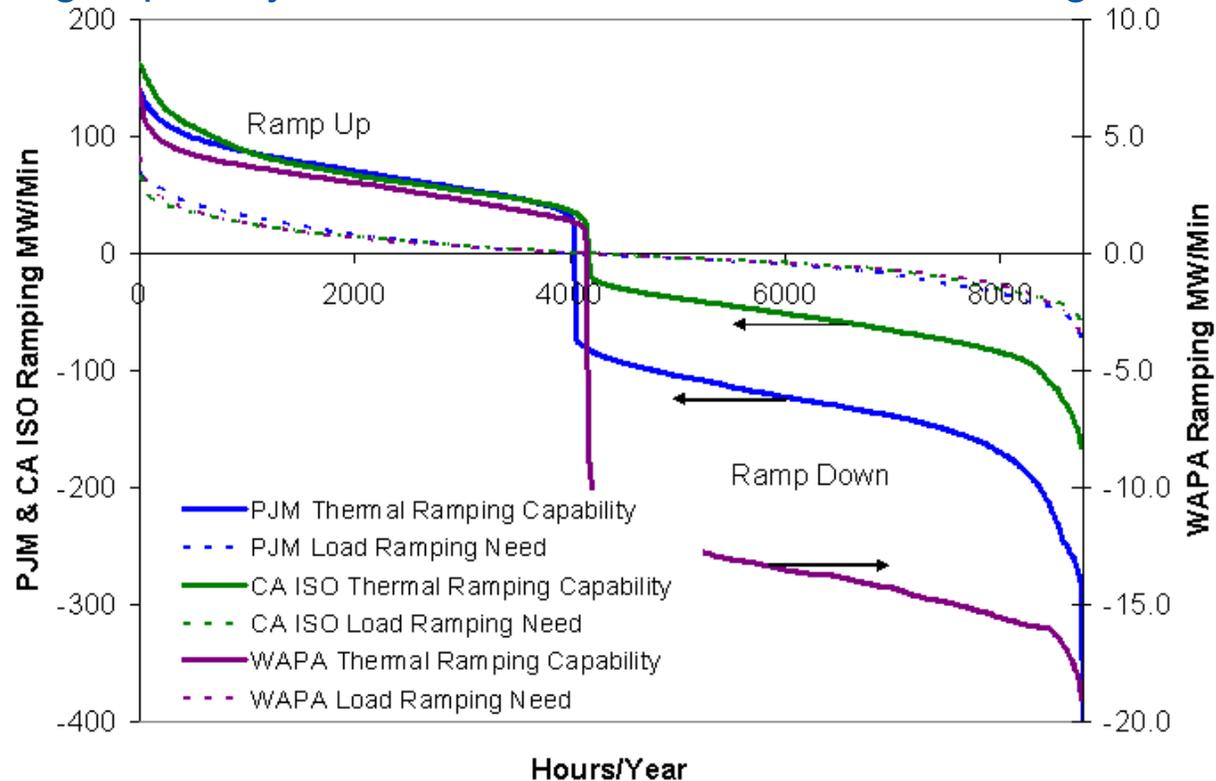
Fast energy markets help provide needed flexibility and can often supply load following flexibility at no cost.

Source: Kirby and Milligan, NREL, http://www.nrel.gov/docs/fy05osti/38153.pdf

Fast Markets

- Impact of wind between Balancing Areas with slow schedule response;
- Extra installed capacity is required in the host BA, increasing costs for all;
- Larger imbalances and costs; inefficiencies restrict units for response;
- *Solution: fast scheduling (~5 minutes) between balancing areas.*

Fast scheduling leads to 80% reduction in 10 min ramps in Northwest
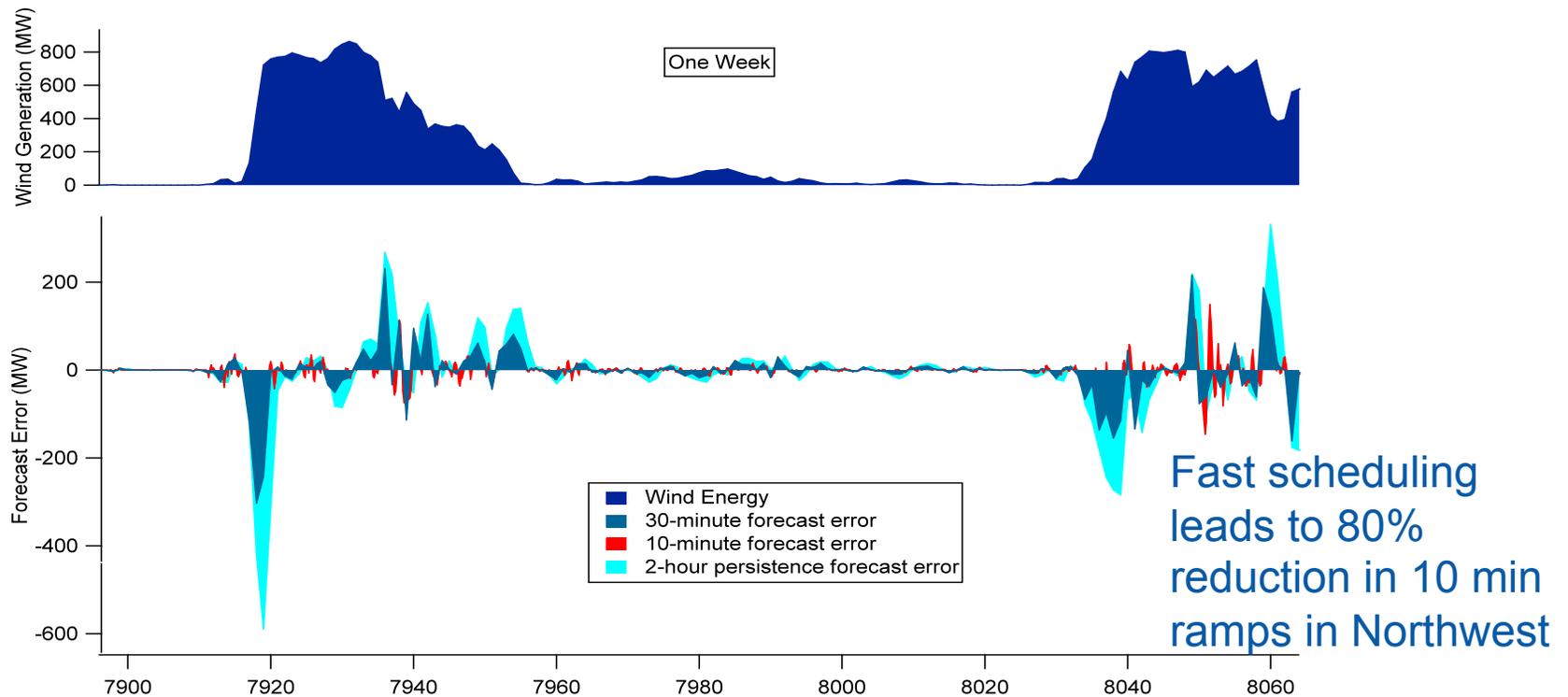
Source: Milligan and Kirby, NREL, http://www.nrel.gov/docs/fy10osti/48192.pdf

Balancing Area Cooperation

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

Operating separate balancing areas causes extra ramping compared to combined operations.

Blue: up-ramp
Green: down-ramp
Yellow: combined ramp

Some areas are ramping up nearly 1000 MW/hr while other areas are ramping down nearly 500 MW/hr

Ramping that could be eliminated by combining operations
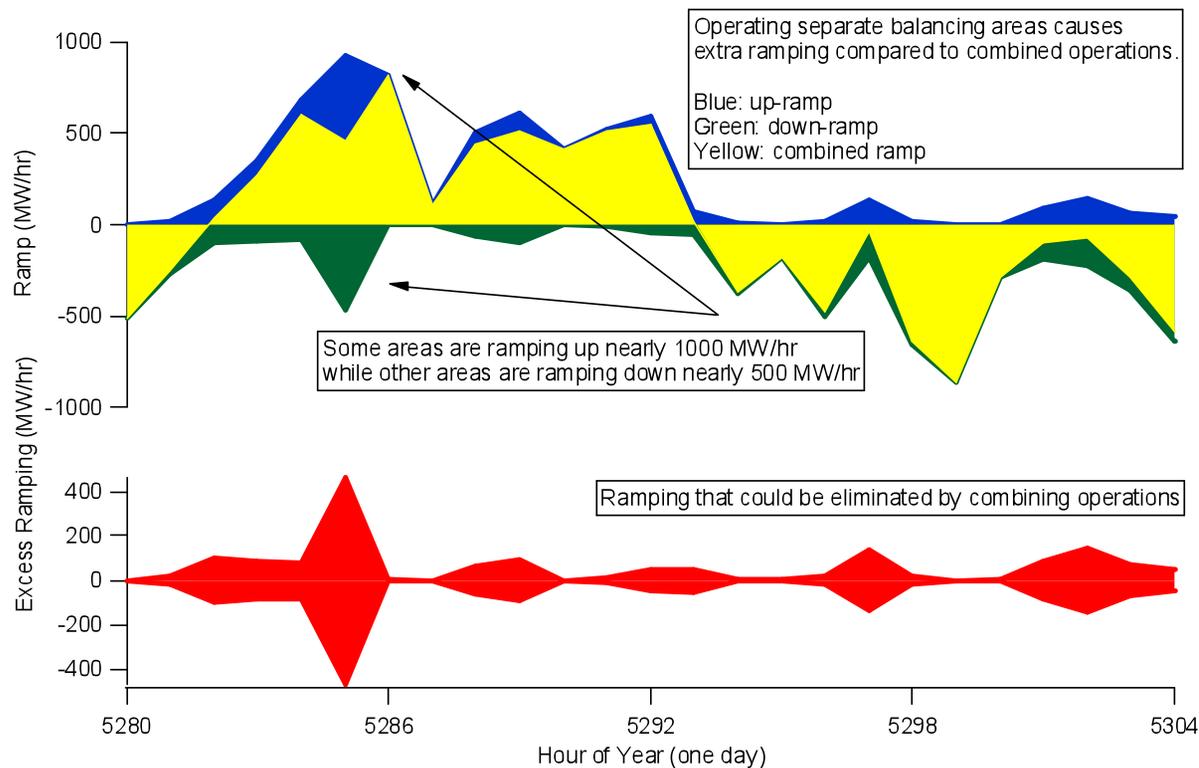
Source: Milligan & Kirby, NREL, http://www.nrel.gov/docs/fy07osti/41809.pdf

Increasing efficiency of transmission utilization

Figure 6 – ATC available 95 percent of the Time

Source: WECC Historical Analysis Working Group, http://wecc.biz, June 2010

Regions and Balancing Authorities

NPCC
MRO
WECC
RFC
SERC FRCC
SPP
TRE

Dynamically Controlled Generation

*Bubble size is determined by acronym width

Note: The highlighted area between SPP and SERC denotes overlapping Regional area boundaries: For example, some load serving entities participate in one Region and their associated transmission owner/operators in another.
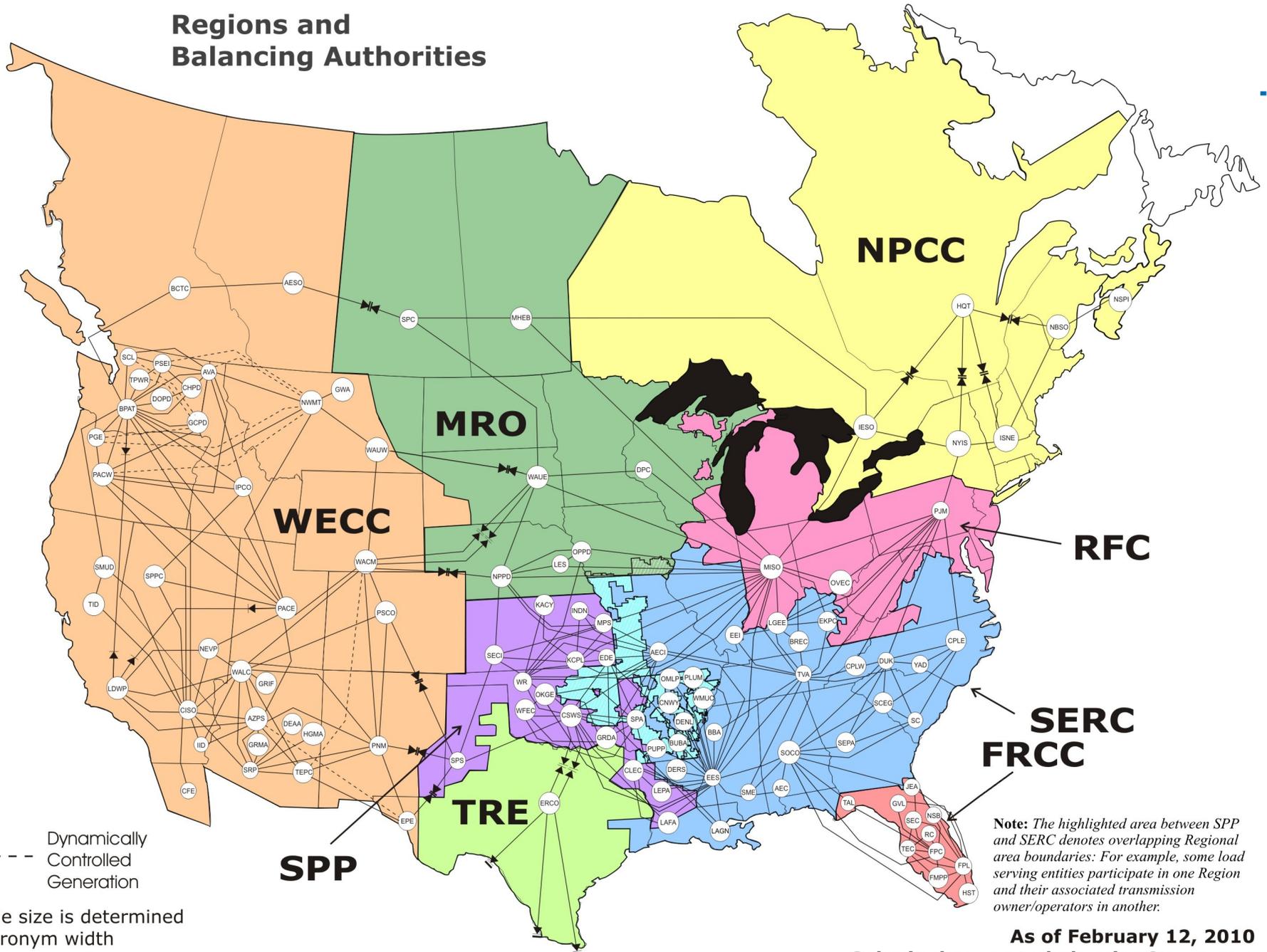
As of February 12, 2010
Submit changes to balancing@nerc.com

Rolling Unit Commitment

Typical Errors -- Individual Wind Farm
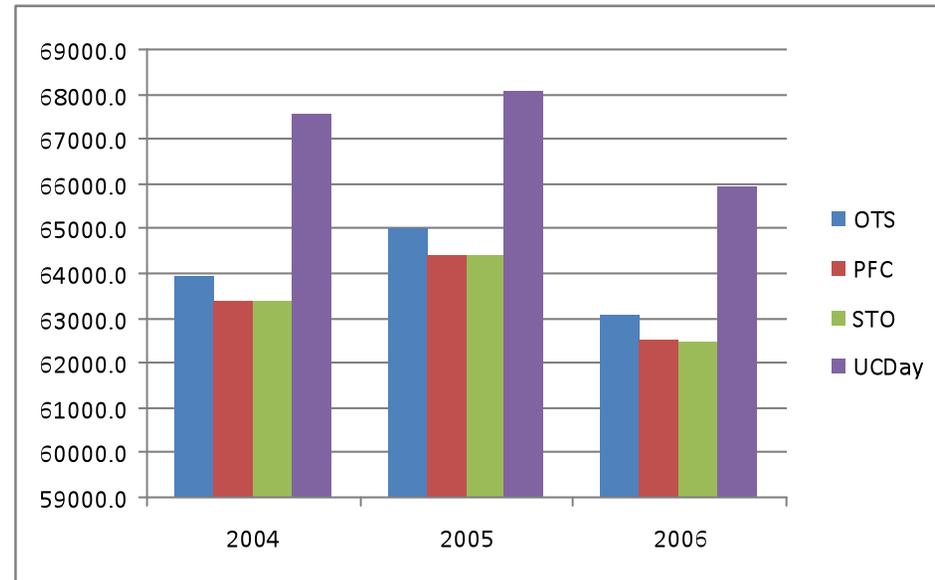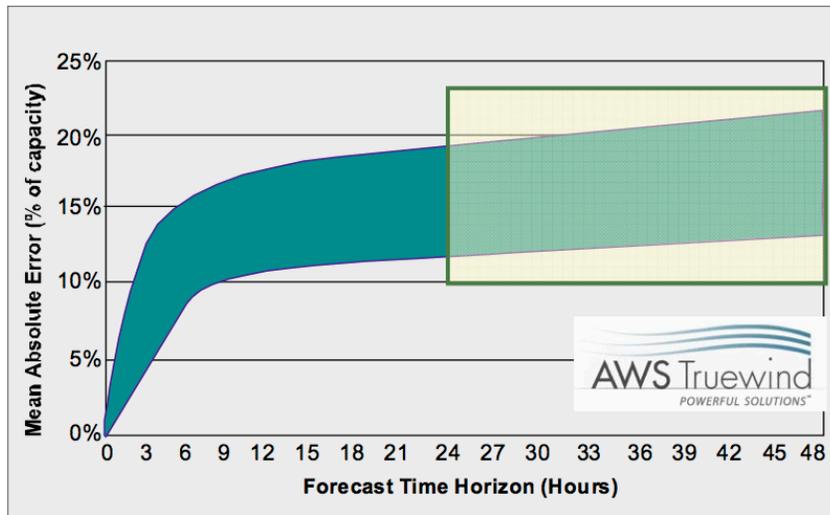
- Day-ahead is more expensive than rolling unit commitment
- Perfect forecasts give a slight savings over rolling unit commitment

OTS =Deterministic planning updated every three hours. Only one wind power production and load forecast taken into account

PFC = Perfect foresight, deterministic

STO = Stochastic planning using scenario trees with 6 forecasts, unit commitment updated every 3 hours

UCDay = Stochastic planning, unit commitment for units with start times greater than 1 hour, updated once per day in the day-ahead market

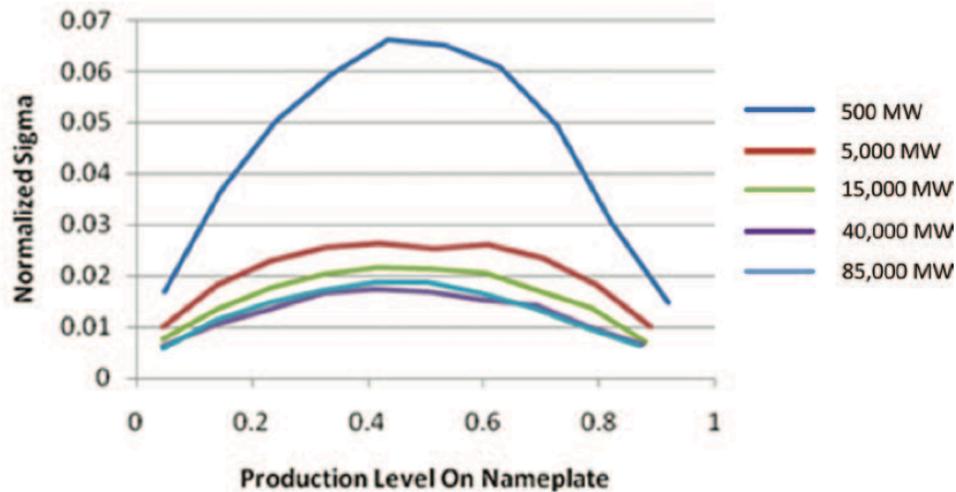Source: (left) AWS Truewind and (right) Milligan and Ela, NREL

Demand Response to Provide Reserves

ERCOT Limits Loads to Supplying 1150 MW of AS and Loads Provide All They Can

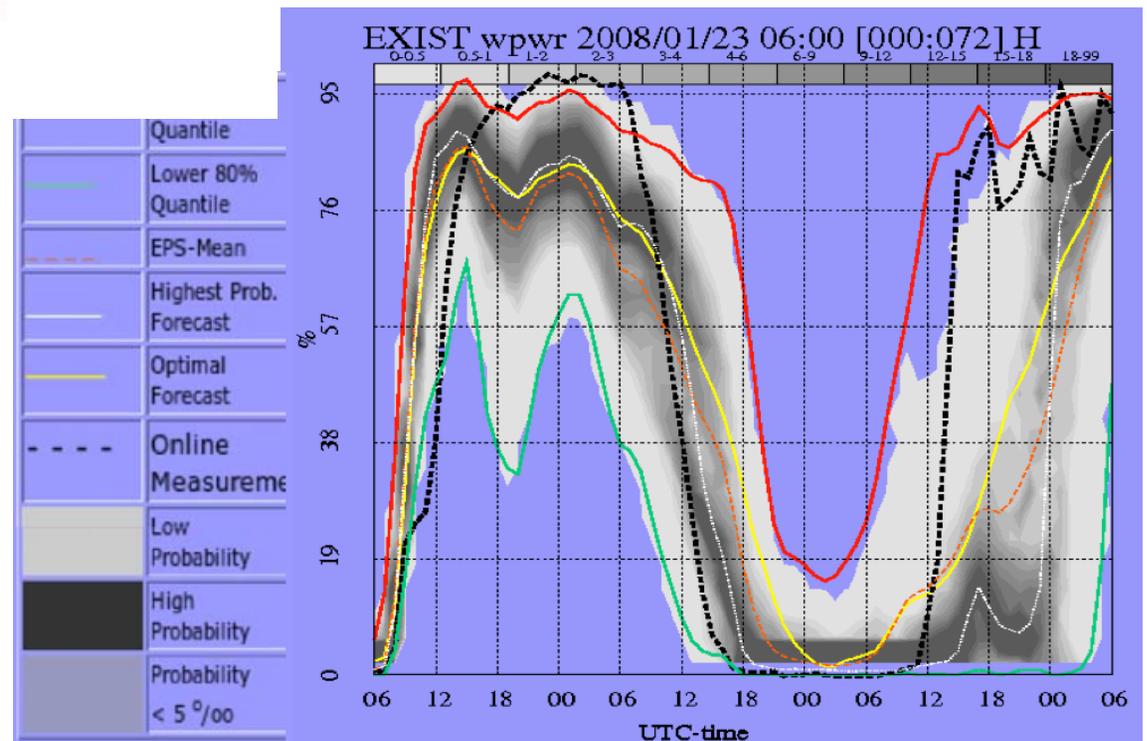Provision of Responsive Reserves by LaaRs
Daily Average
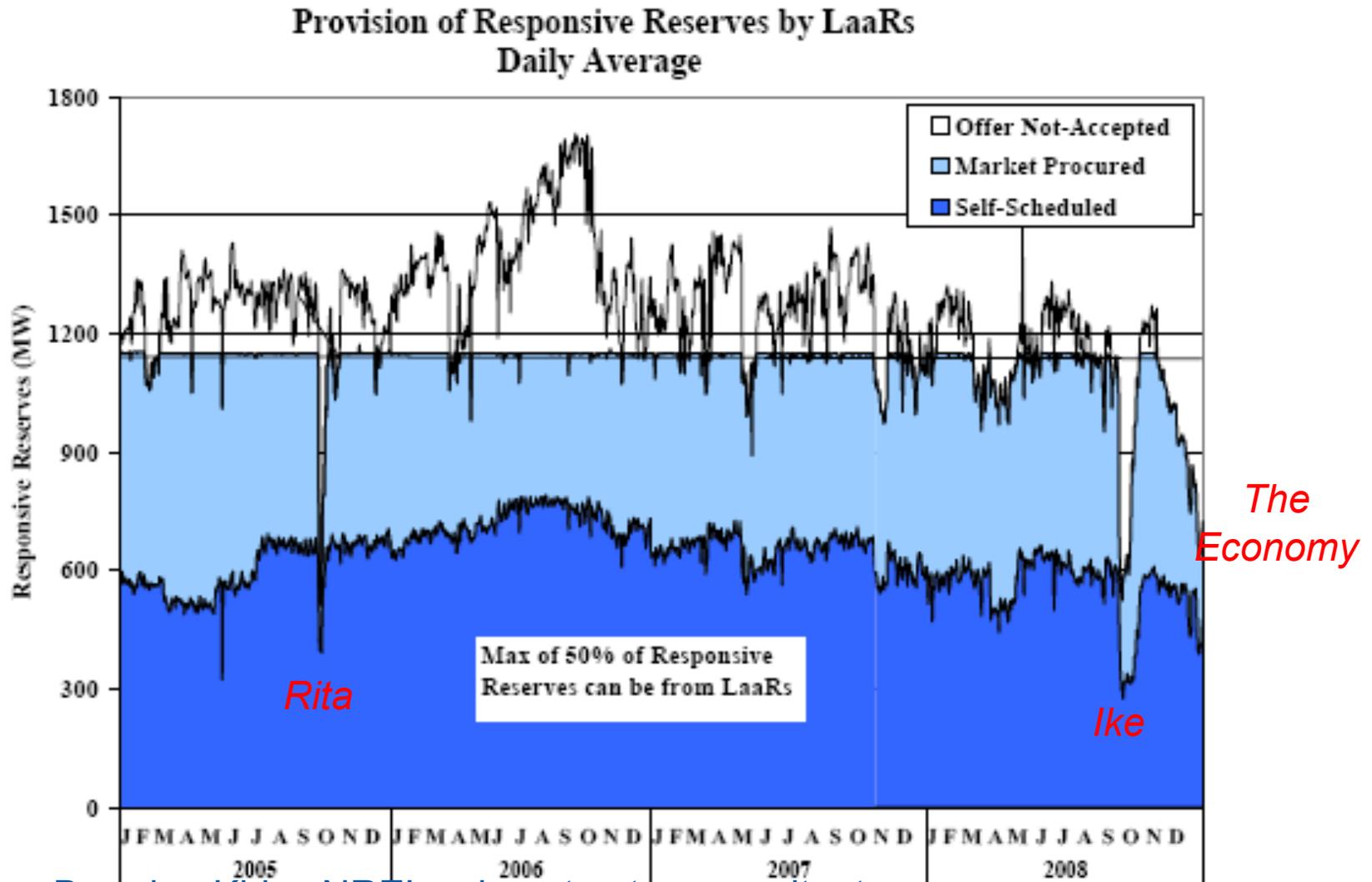
Source: Brendan Kirby, NREL subcontractor consultant.

Smart Reserves

Reserve demand as a function of predicted operating levels (wind, solar, load) and predicted confidence levels
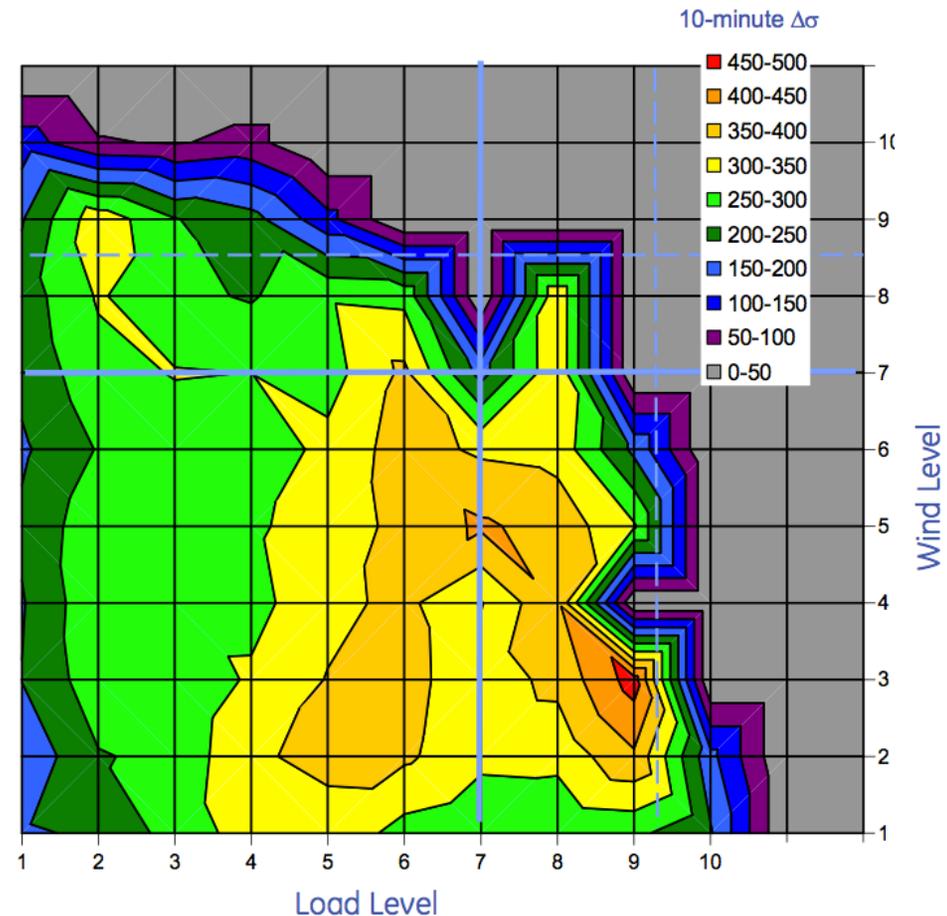
Source: (left) EWITS,
www.nrel.gov/ewits,
(right) Mohrlen, http://
www.uwig.org/members/
Phoenix/14-Mohrlen-panel.pdf

Reserves as a function of wind and load

Hold reserves as a function of load and wind levels:

- Simple rules – x% of load plus y% of wind production up to some maximum

Source: Western Wind and Solar Integration Study
(http://www.nrel.gov/wwsis)

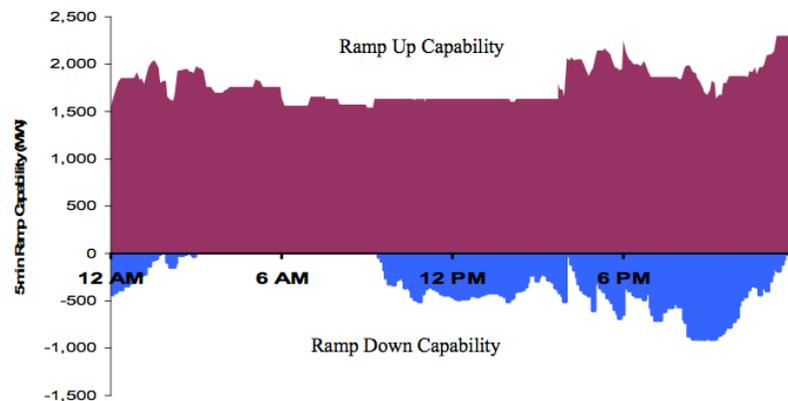# Curtailment to Relieve Minimum Generation Issues

Figure ES-7: 5-minute ramp up and down capability for May 28, 2012

Potential operator actions:

- Curtail a block of wind when system approaches minimum generation dispatch
- Curtail wind (dispatch signal) in the minutes timeframe when other plants at minimum
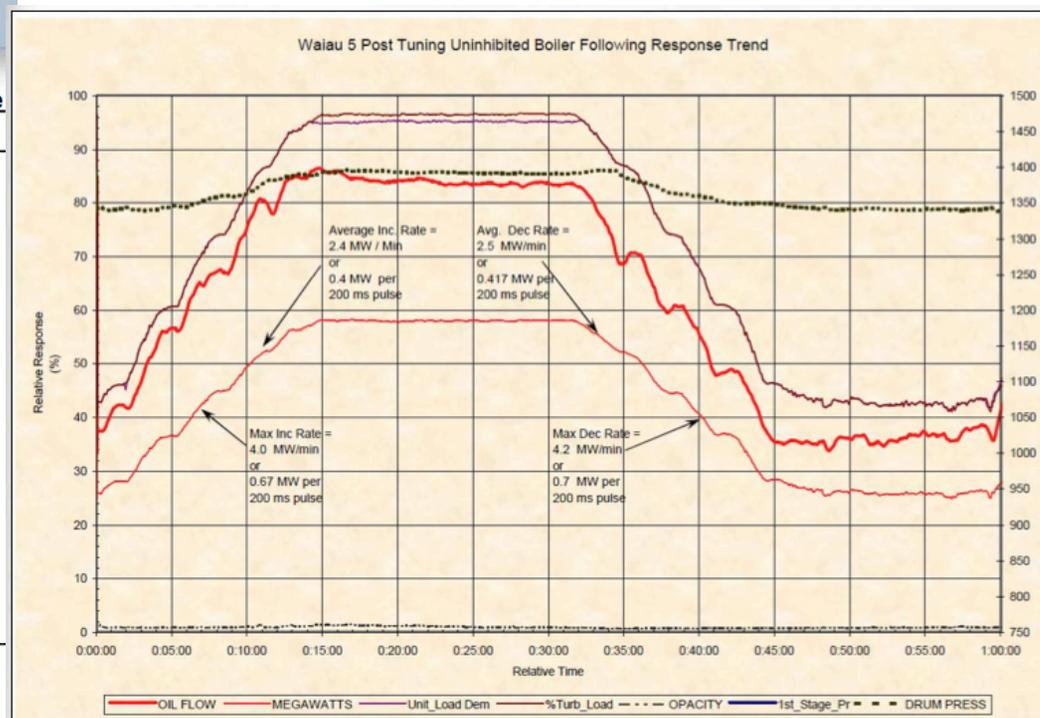- Curtail wind (AGC signal) to provide down regulation when other plants at minimum

Source: CAISO, http://www.caiso.com/2804/2804d036401f0.pdf

Source: GE, http://www.uwig.org/members/QBworkshop/Piwko-QBWork.pdf

Improving the Existing Generation Fleet

Average age of HECO Cycling Steam Units	54.3	Years
Average age of HECO Base Load Steam Units	39.3	Years

Unit	Capability	Type	Operating Mode	Service Date	Age
HECO Generating Units					
Honolulu 8	56	Steam, Non-Reheat	Cycling	1954	55
Honolulu 9	57	Steam, Non-Reheat	Cycling	1957	52
Waiau 3	49	Steam, Non-Reheat	Cycling	1947	62
Waiau 4	49	Steam, Non-Reheat	Cycling	1950	59
Waiau 5	57	Steam, Non-Reheat	Cycling	1959	50
Waiau 6	56	Steam, Non-Reheat	Cycling	1961	48
Waiau 7	92	Steam, Reheat	Base	1966	43
Waiau 8	94	Steam, Reheat	Base	1968	41
Waiau 9	53	Combustion Turbine	Peaking	1973	36
Waiau 10	54	Combustion Turbine	Peaking	1973	36
Kahe 1	92	Steam, Reheat	Base	1963	46
Kahe 2	89	Steam, Reheat	Base	1964	45
Kahe 3	92	Steam, Reheat	Base	1970	39
Kahe 4	93	Steam, Reheat	Base	1972	37
Kahe 5	142	Steam, Reheat	Base	1974	35
Kahe 6	142	Steam, Reheat	Base	1981	28
Major Independent Power Producers					
HPOWER	46	Steam, Non-Reheat	Base	1990	19
Kalaeloa	208	Combined Cycle	Base	1991	18
AES	180	Steam, Reheat	Base	1992	17

Waiau 5 Post Tuning Uninhibited Boiler Following Response Trend

Source: HECO, http://www.uwig.org/members/QBworkshop/Arakawa-Hetherington-QBWork.pdf

Forecasting Reduces the Need for Flexibility
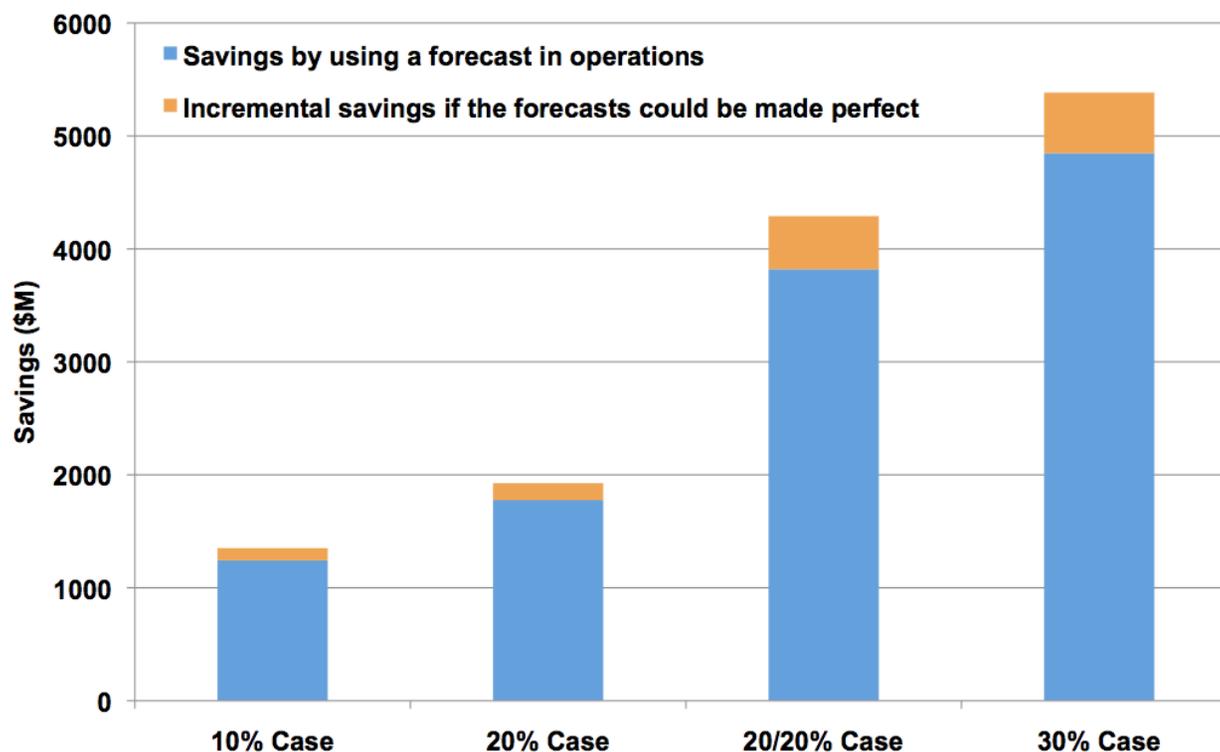
Western Wind and Solar Integration Study: Forecasting saves up to 14% in annual operating costs. If forecasts were perfect, an additional 1-2% could be saved.
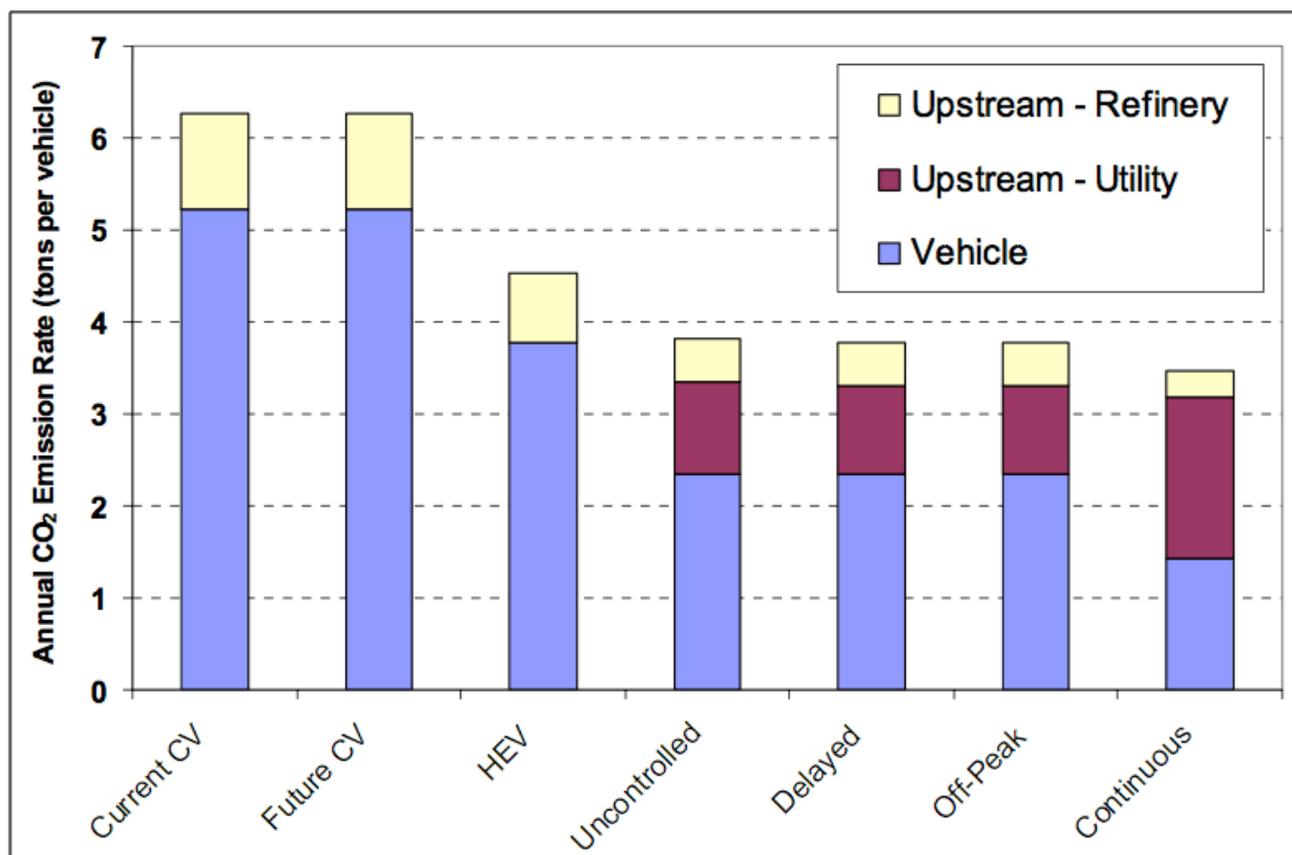
Source: http://www.nrel.gov/wwsis

New Loads – PHEV's

Figure 19: Net Vehicle CO$_2$ Emissions Rates

Source: Parks, Denholm and Markel, NREL, Xcel Analysis, http://www.nrel.gov/docs/fy07osti/41410.pdf

Better Use of Existing Storage Facilities

Penetration Level	10%
Hourly analysis	$2.26/MWh
Regulation	$0.20/MWh
Gas supply (1)	$1.26/MWh
Total	**$3.72/MWh**

(1)   Costs includes the benefits of additional gas storage.

If we restrict existing 300-MW pumped hydro unit from following wind variability, costs would be $1.30/ MWh higher.

Source: DeMeo, et al, IEEE Power & Energy, Nov/Dec 2005, Xcel/PSCO/ Enernex study

Complex System with a Lot of Moving Parts
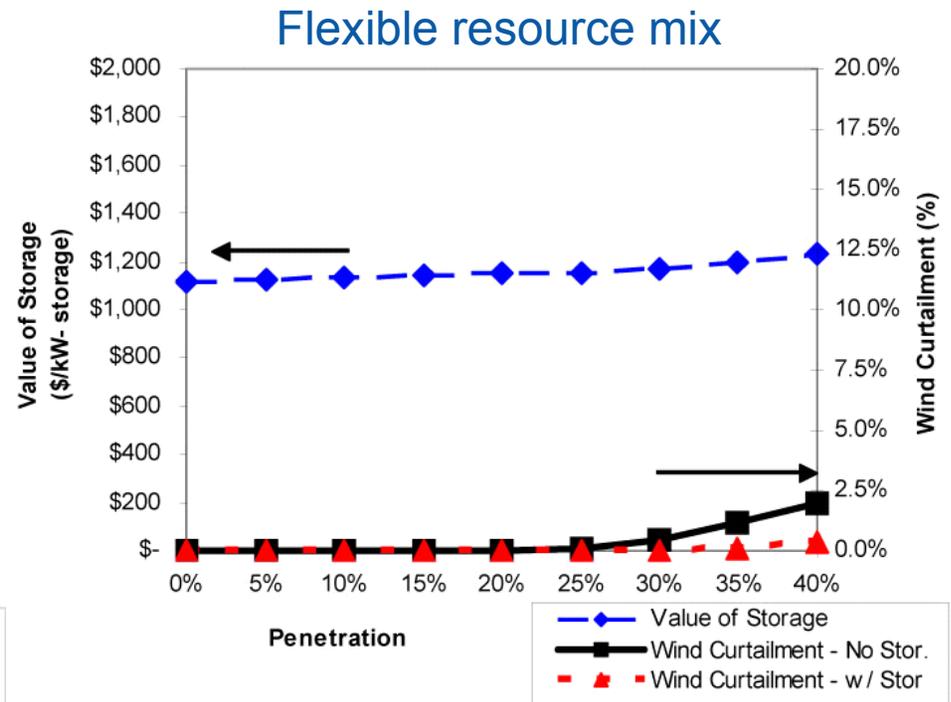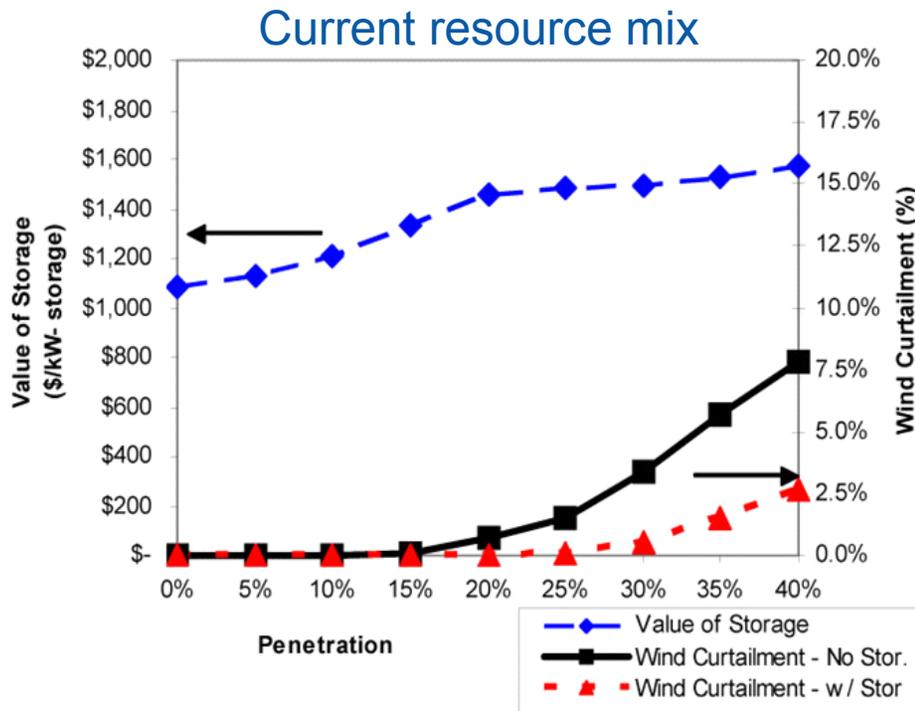
Value of Storage depends on the flexibility of the fleet

Source: Andrew Mills, LBNL, http://www.uwig.org/members/Denver2008/OIIS/
Mills.pdf

For More Information

http://www.uwig.org

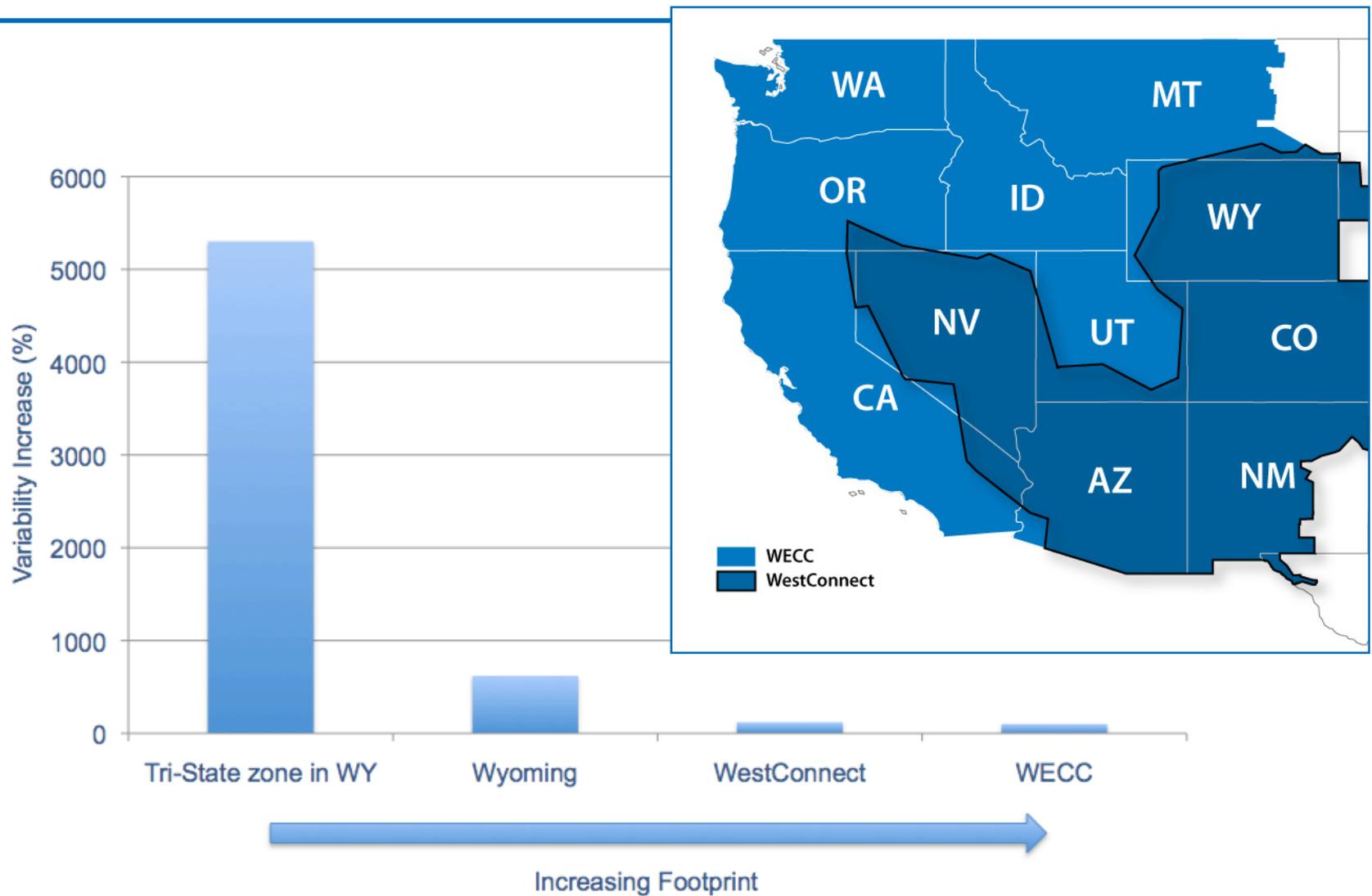http://www.nrel.gov/wind/systemsintegration/
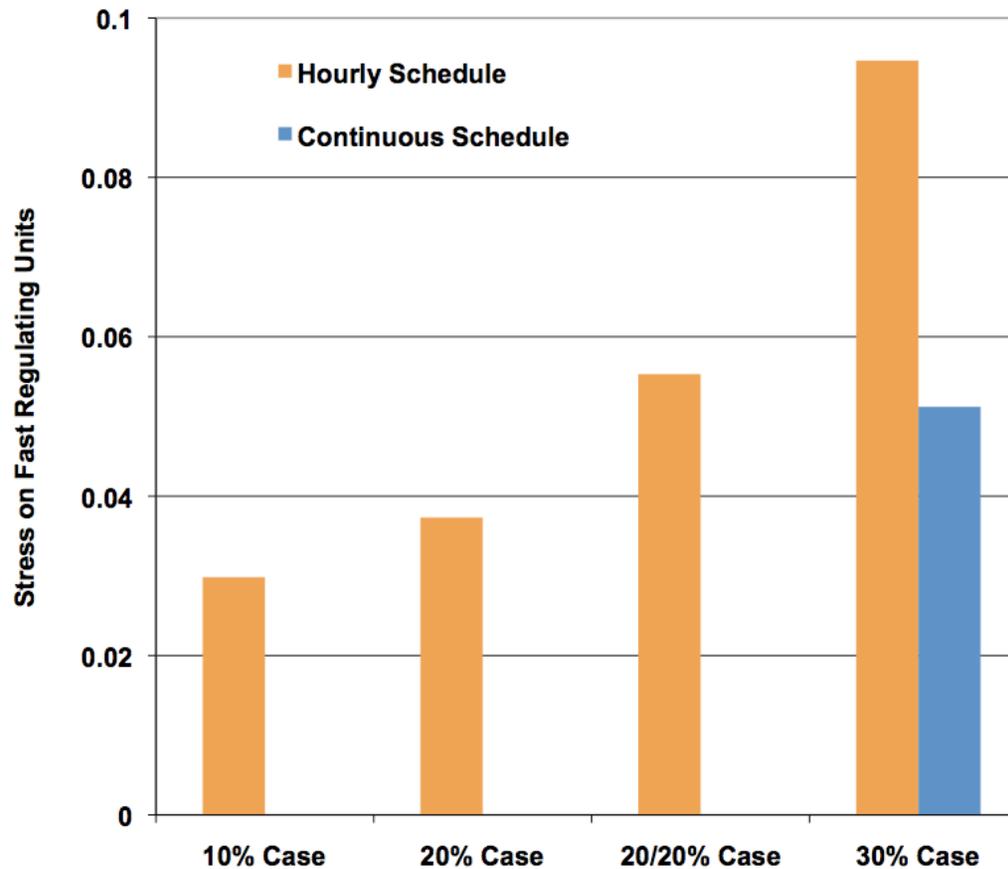
Debbie Lew

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303-384-7037

Extra Slides

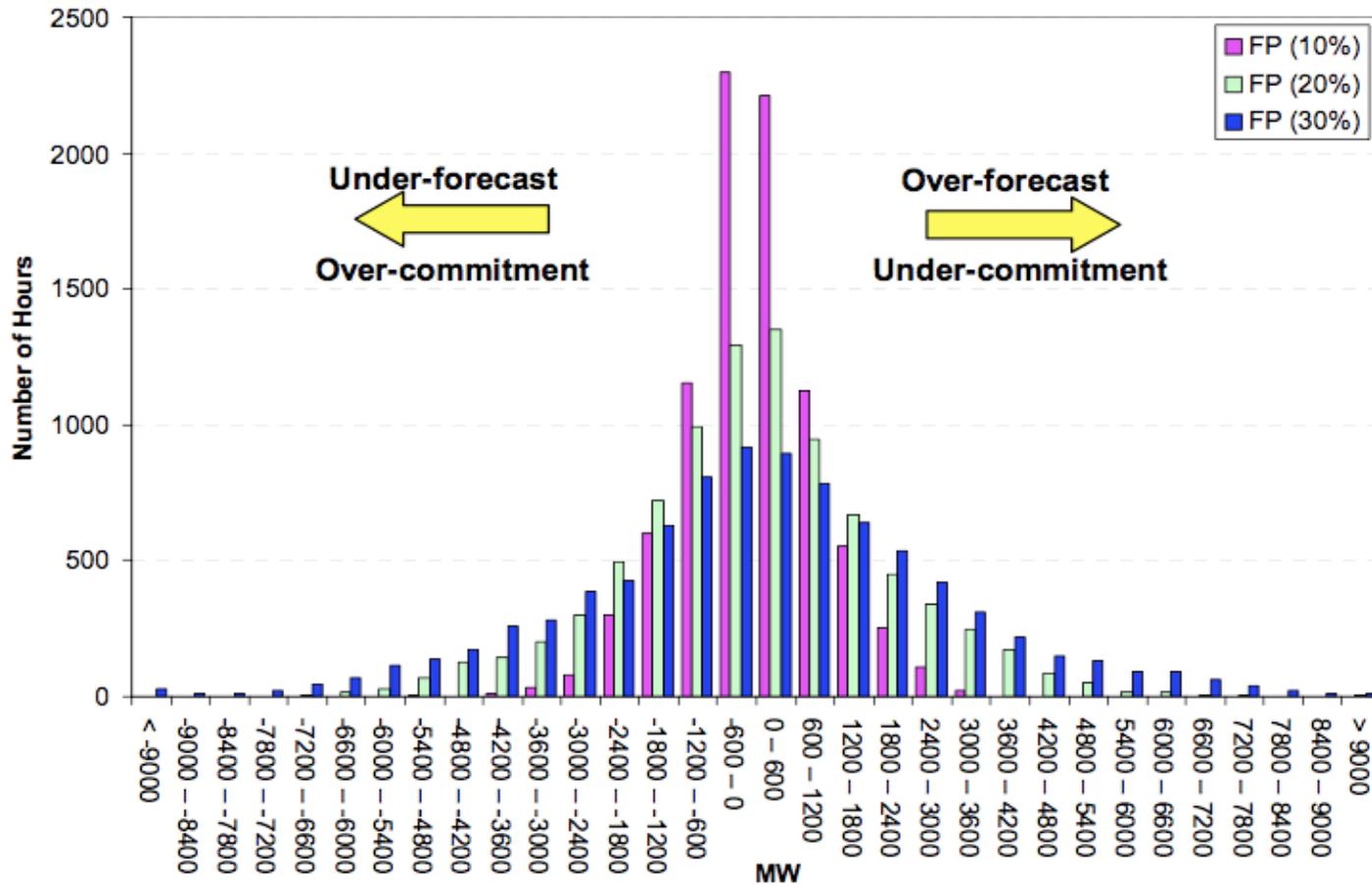# You Need Balancing Area Cooperation

You Need Sub-hourly Scheduling

Hourly scheduling puts more stress on the fast regulating reserves than the wind and solar variability does.

You Need Demand Response (or more expensive measures)

Forecast error distribution

You Need Demand Response (or more expensive measures)

- Using existing rules for contingency reserves, there were occasional reserve shortfalls;

- Increase spinning reserves for every hour of the year;

- Add storage like pumped hydro storage;

- We only have shortfalls for 89 hours of the year (1%), so these options can be expensive;

- Demand response (paying loads to turn off) was found to be effective and was less expensive.
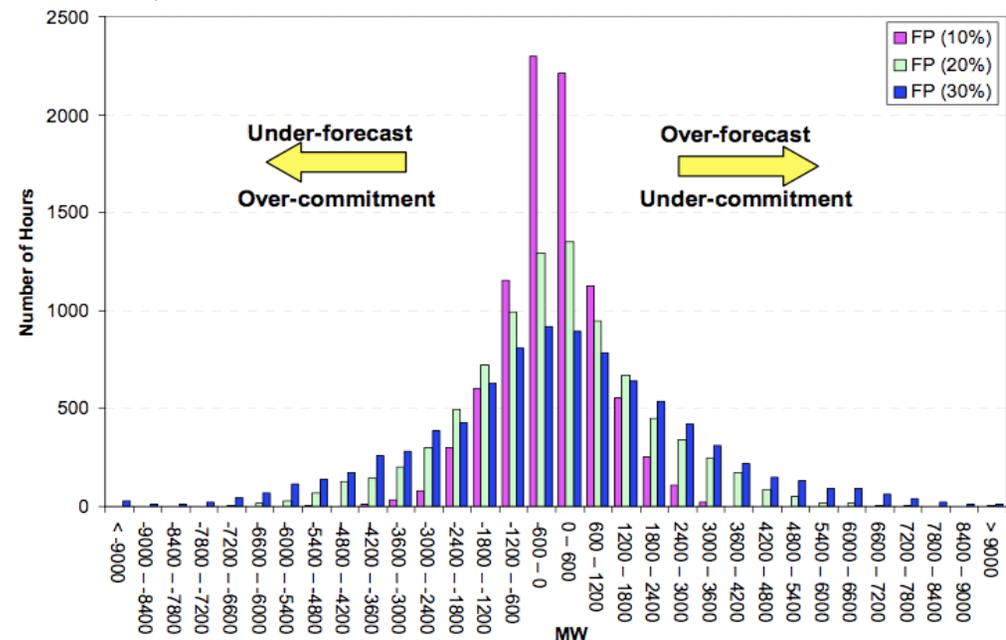
# You Don't Necessarily Need More Variability Reserves

Wind and solar double the variability reserve requirements (load following);

Because wind and solar cause some generators to be turned down rather than off, the system actually has more up-reserves than it does in the no wind/solar case;
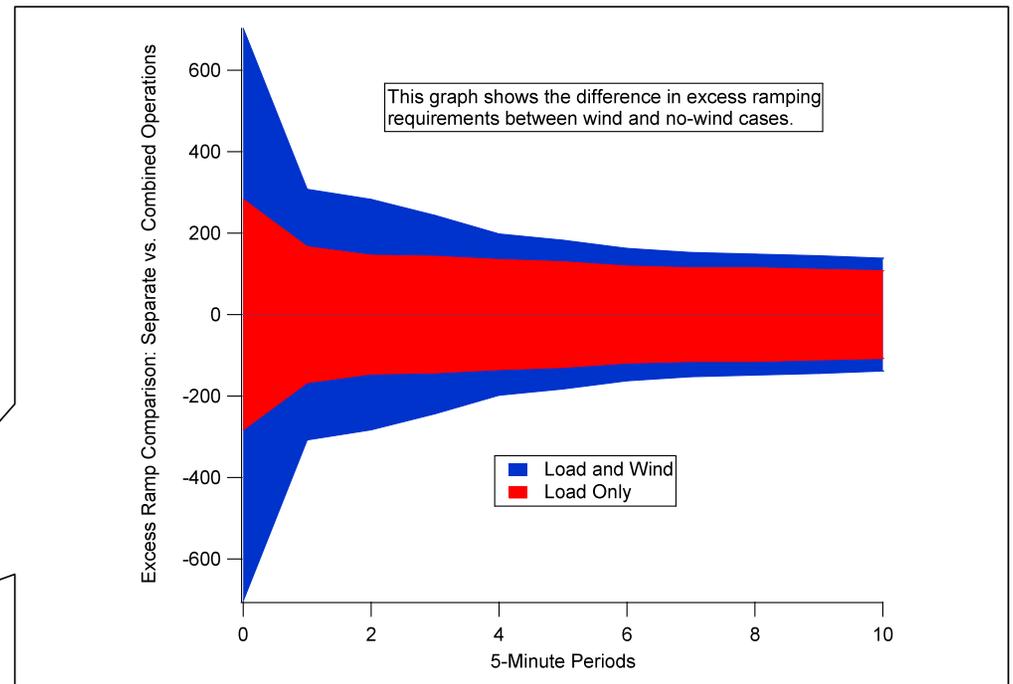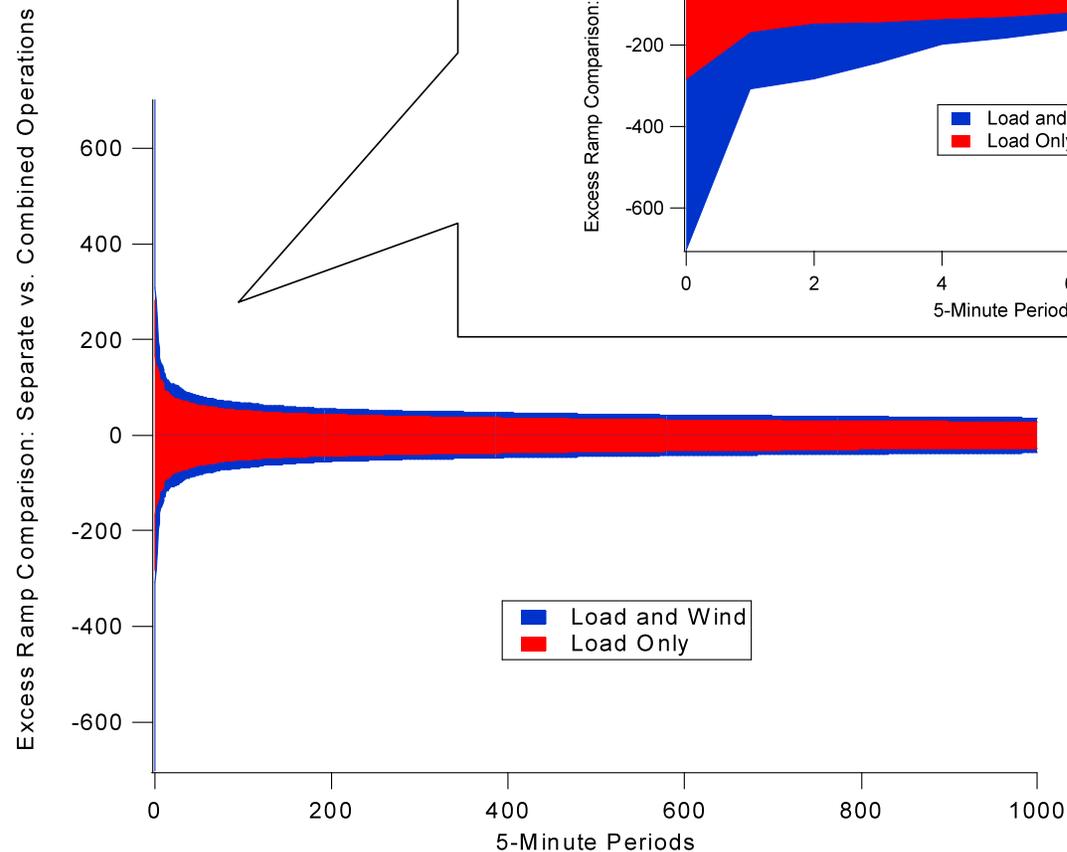
Additional reserves do not need to be committed to cover the increased variability reserve requirement.
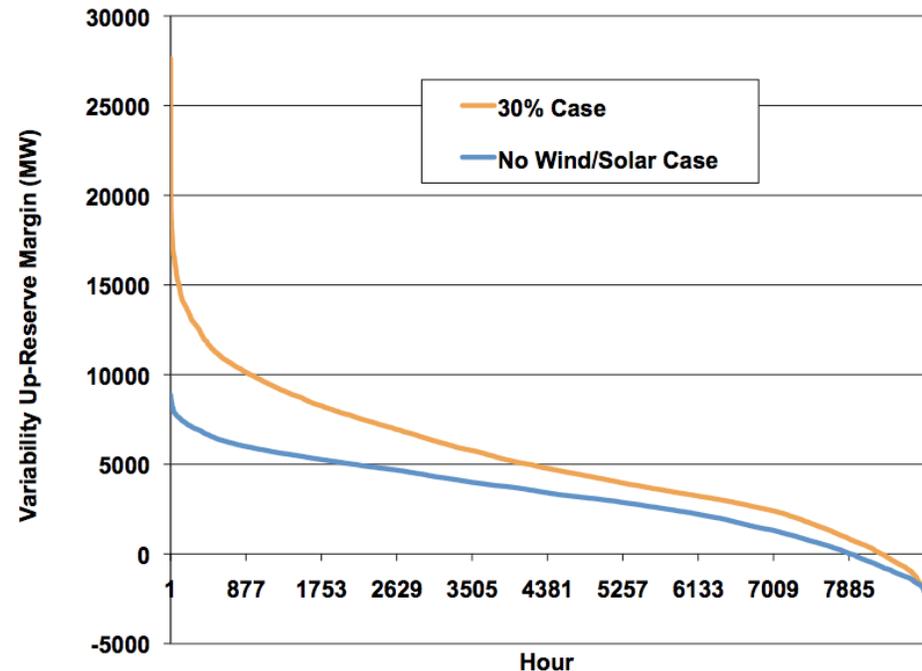
Can the Non-wind Fleet Ramp Quickly Enough?
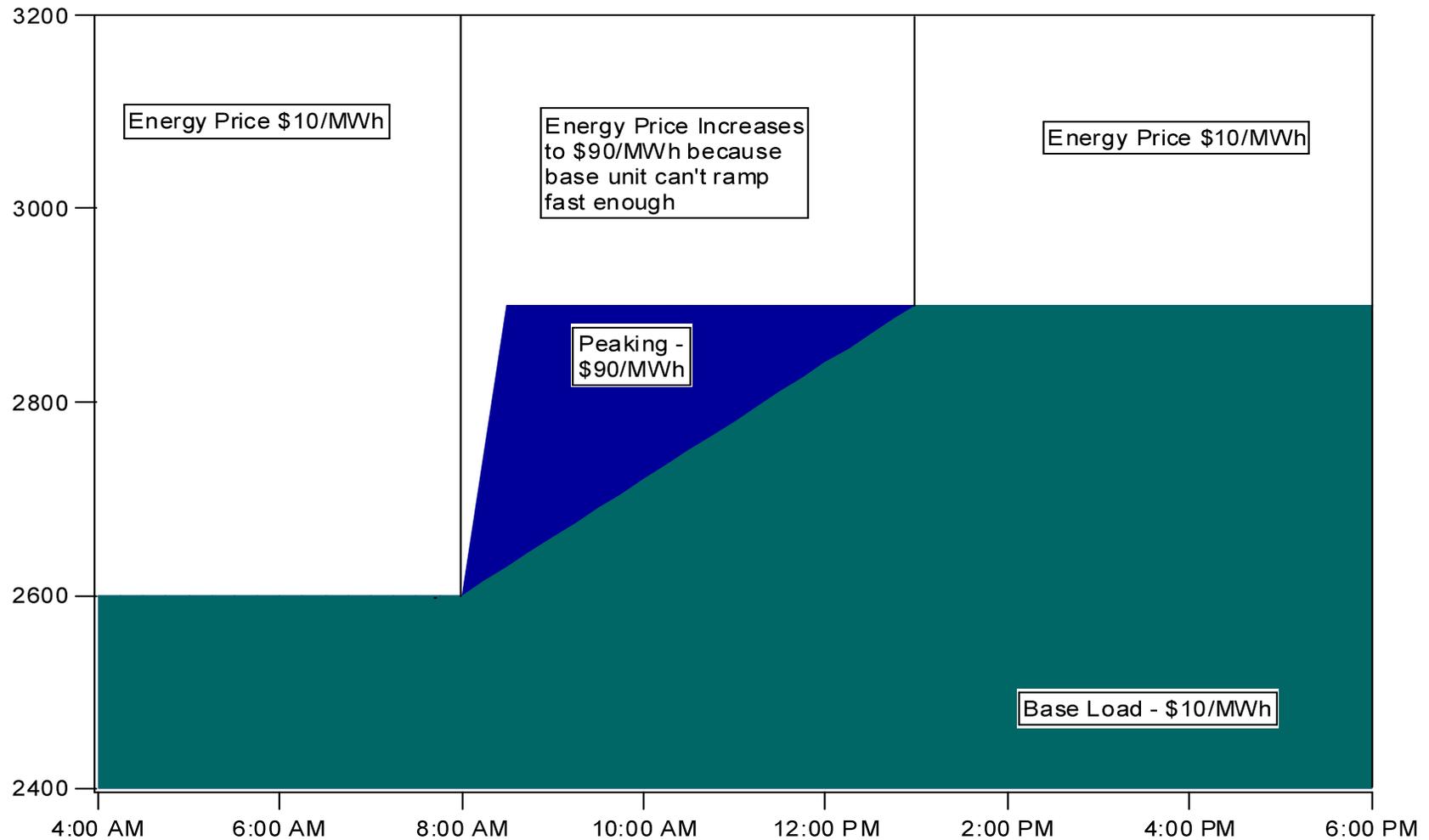
Large, infrequent 5-minute ramps can be significantly reduced.

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

BA Cooperation Reduces Ramp Requirements