GE Energy

Asia Development Bank
Wind Energy Grid Integration Workshop:

OPERATIONS and DISPATCH

Nicholas W. Miller

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Beijing
September 22-23, 2013

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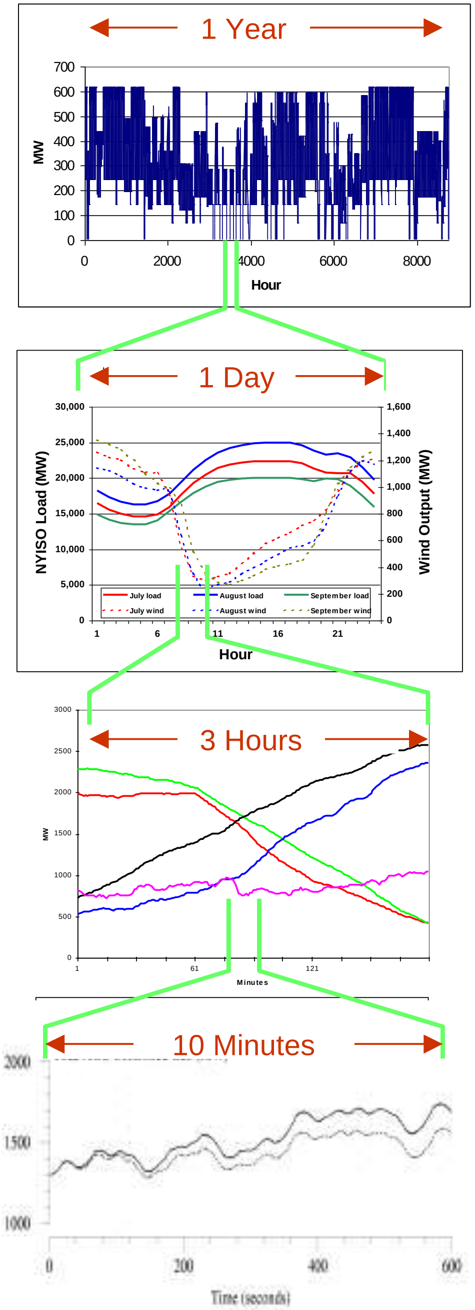
ADB topic list

Wind energy dispatching methodology (International Expert)

- Wind farm as Capacity source or Energy source
- Policies for scheduling wind energy
- Policies for curtailing wind energy
- Comparison different methods
- Software and other tools, processes for scheduling wind energy
- Role of Wind energy forecasting

Time Scales for System Planning and Operation Processes

Time Frame	Planning and Operation Process	Technology Issues
Slower (Years)	Resource and Capacity Planning (Reliability)	Capacity Valuation (UCAP, ICAP) and Long-Term Load Growth Forecasting
	Unit Commitment and Day-Ahead Scheduling	Day-ahead and Multi-Day Forecasting
	Load Following (5 Minute Dispatch)	Hour-Ahead Forecasting and Plant Active Power Maneuvering and Management
Faster (seconds)	Frequency and Tie-Line Regulation (AGC)	Real-Time and Autonomous Protection and Control Functions (AGC, LVRT, PSS, Governor, V-Reg, etc.)



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System Operation Process - Overview

Day Ahead

- Prepare load forecast (Total MW load for each hour of the day)
- Commit units that will run to serve the load (accounts for uncertainty)
- Preliminary dispatch schedule for each unit (by hour)

Units with long startup times are "committed" for operation during the next day

Hour Ahead

- Perform hour-ahead load forecast
- Adjust hourly dispatch for committed units as required to match actual load

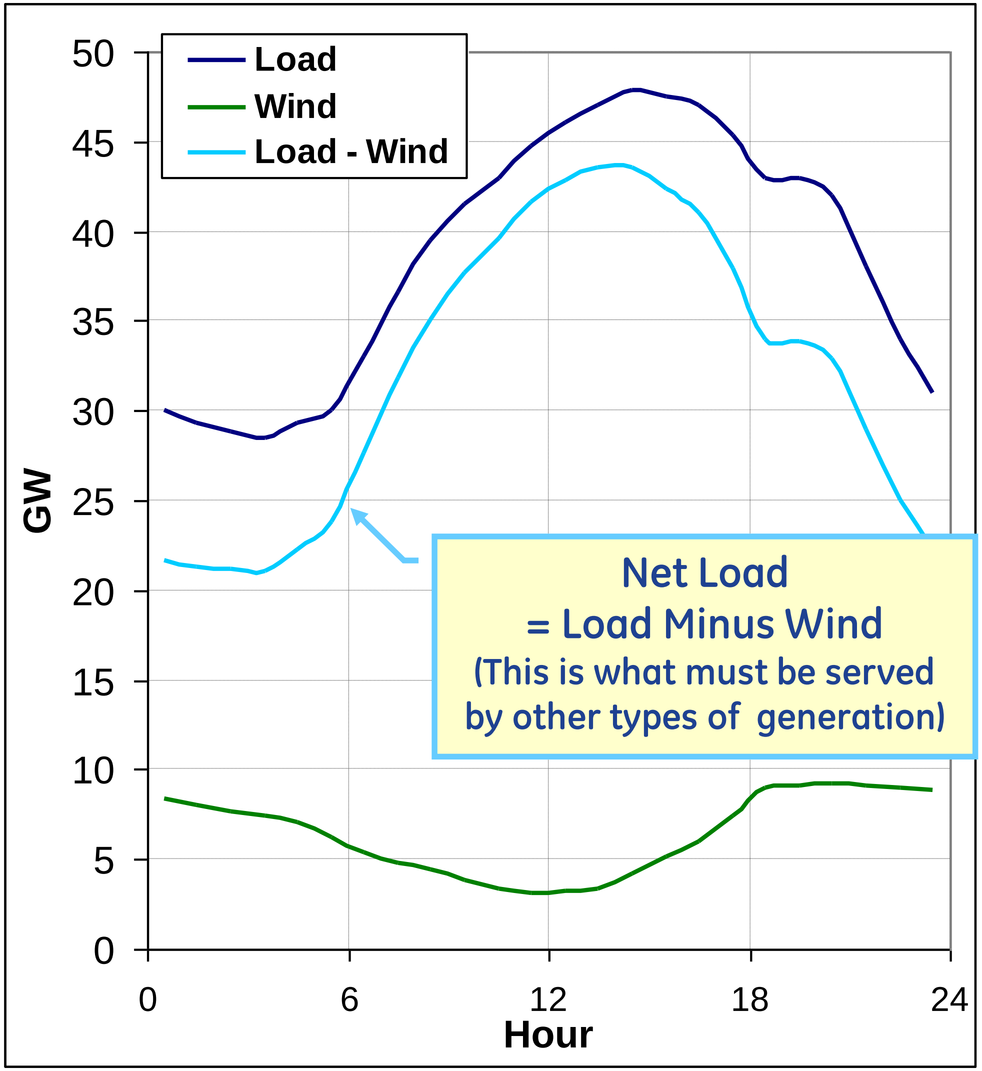
Real Time

- Load-following (typically, dispatch is adjusted at 5-minute intervals)
- Adjustments based on "economic dispatch", using marginal costs or competitive bids
- Regulation (fast adjustments of MW to regulate frequency and intertie power flows)

For grid operations, wind is "similar" to load .

- Like load, wind can be forecast a day ahead
- Grid operators can plan day-ahead operations base on a load forecast and a wind generation forecast
- Dispatchable generation is allocated to serve the net of the forecast load minus the forecast wind
- Uncertainty in the wind forecast adds to the uncertainty in the load forecast
- Adjustments are made using hour-ahead forecasts and real-time data

Dispatchable Generation Serves "Net Load"



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Overview

- Temporal/Spatial Patterns
- Variability in Wind and Load MW
- Uncertainty
- Forecasting for Wind Power

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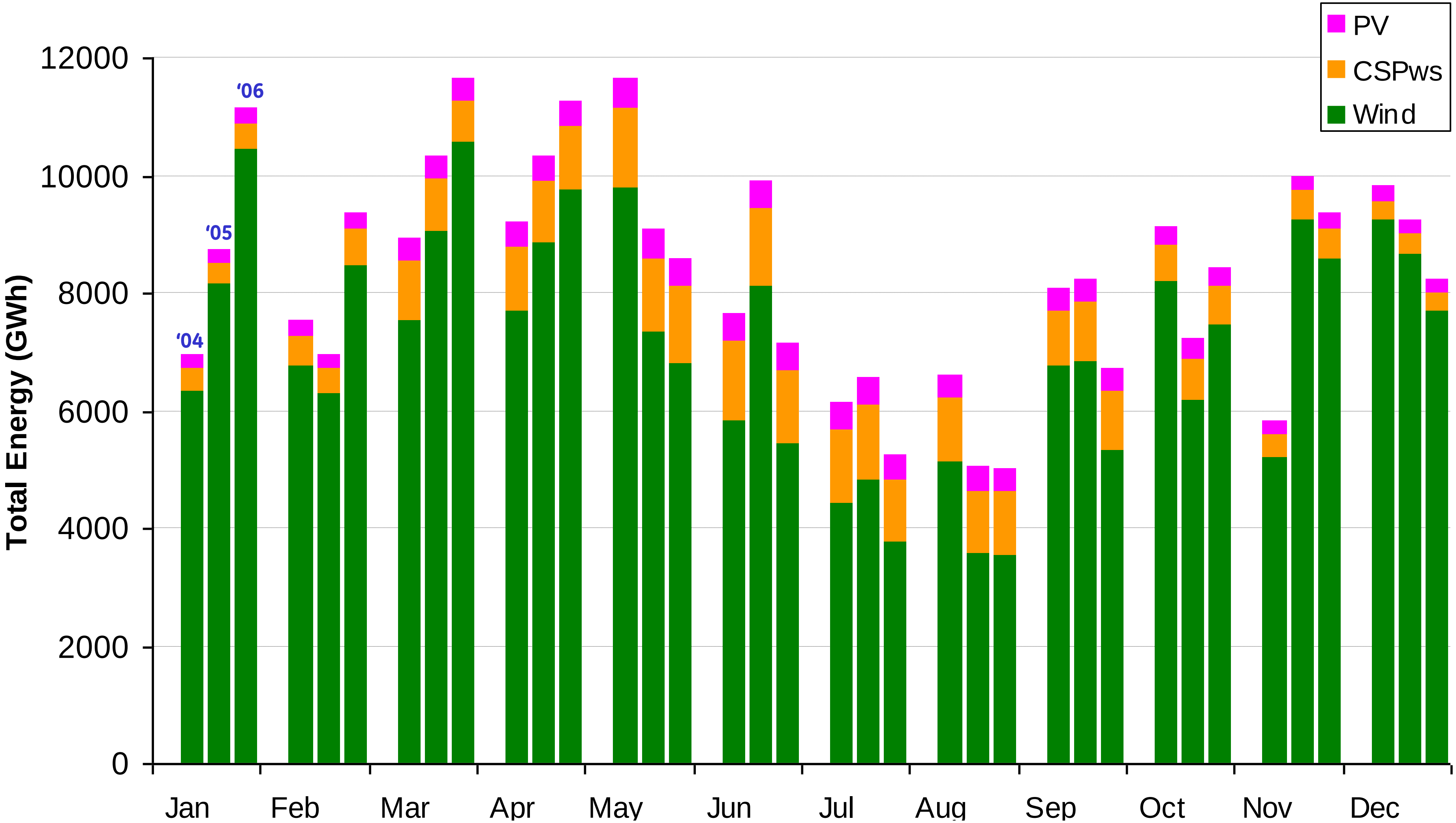
Monthly Energy GWh from Wind & Solar for Years 2004–2006

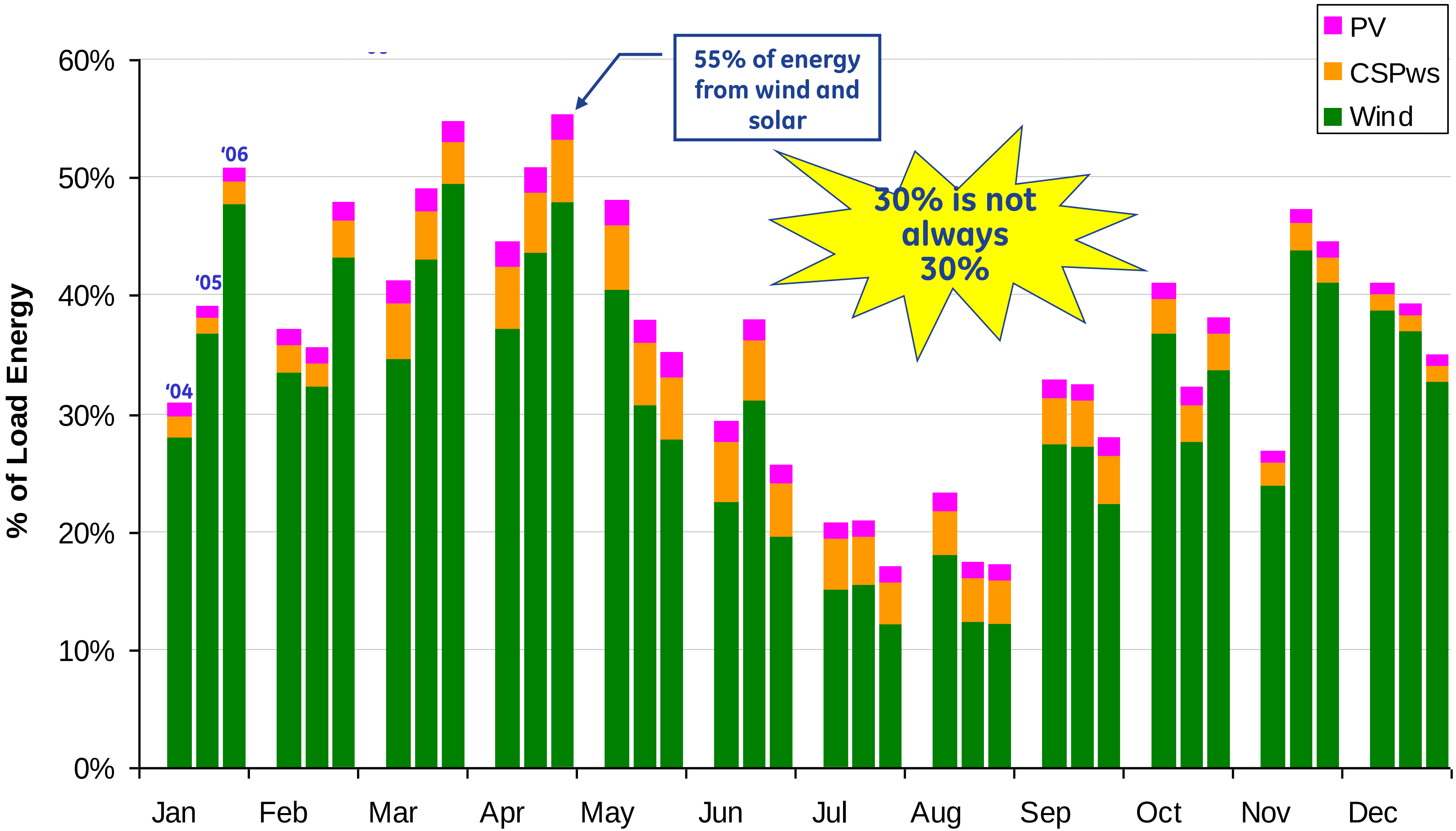
(30% Wind Energy - In Area Scenario)



Notable difference in Wind & Solar energy across the months and over the years

Monthly Energy % from Wind & Solar for Years 2004–2006

(30% Wind Energy - In Area Scenario)



2006 percent monthly energy ranges from 18% (July) to 55% (April) in study footprint

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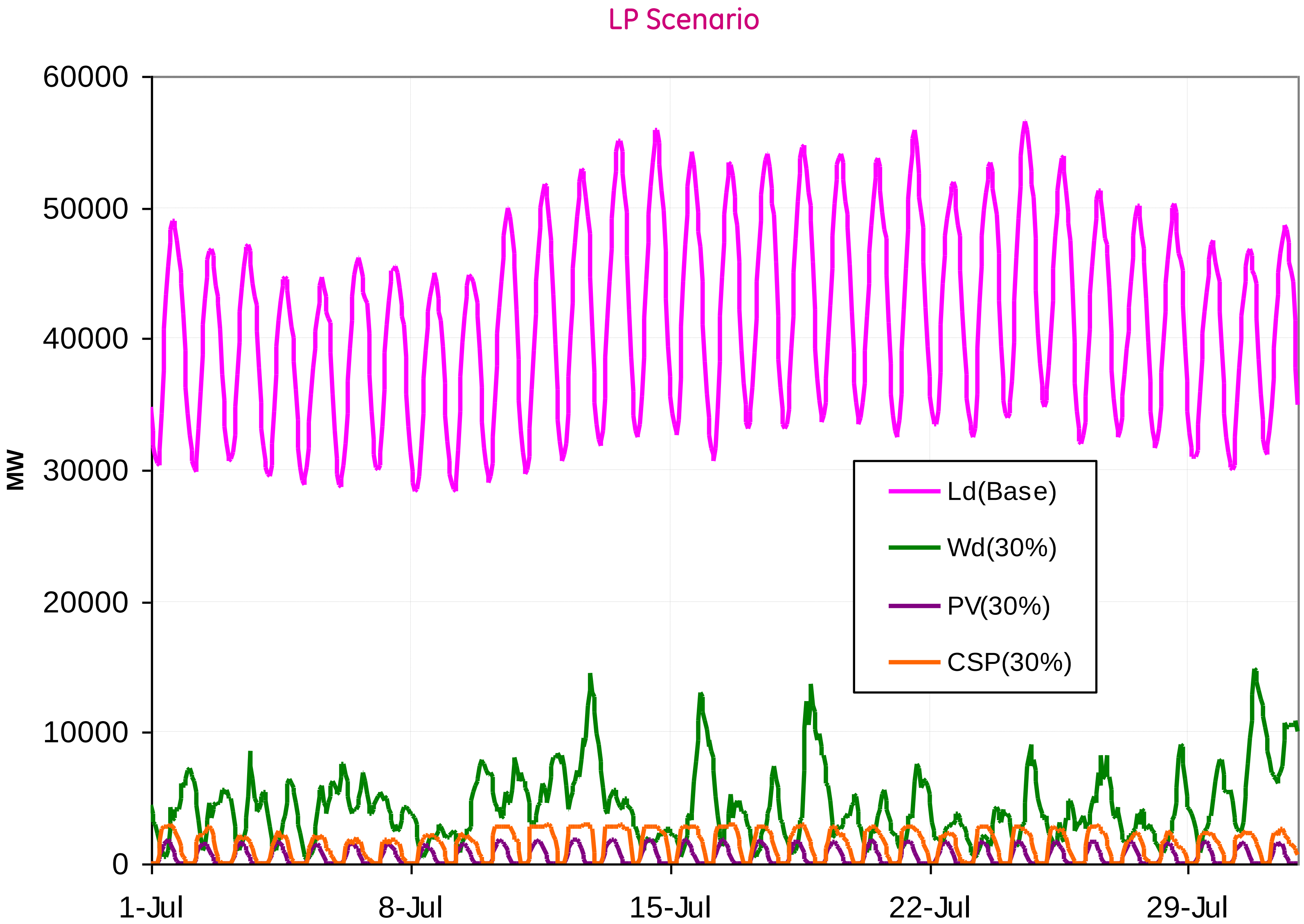
Study Footprint Total Load, Wind and Solar Variation Over Month of July
(30% Wind Energy in Footprint)



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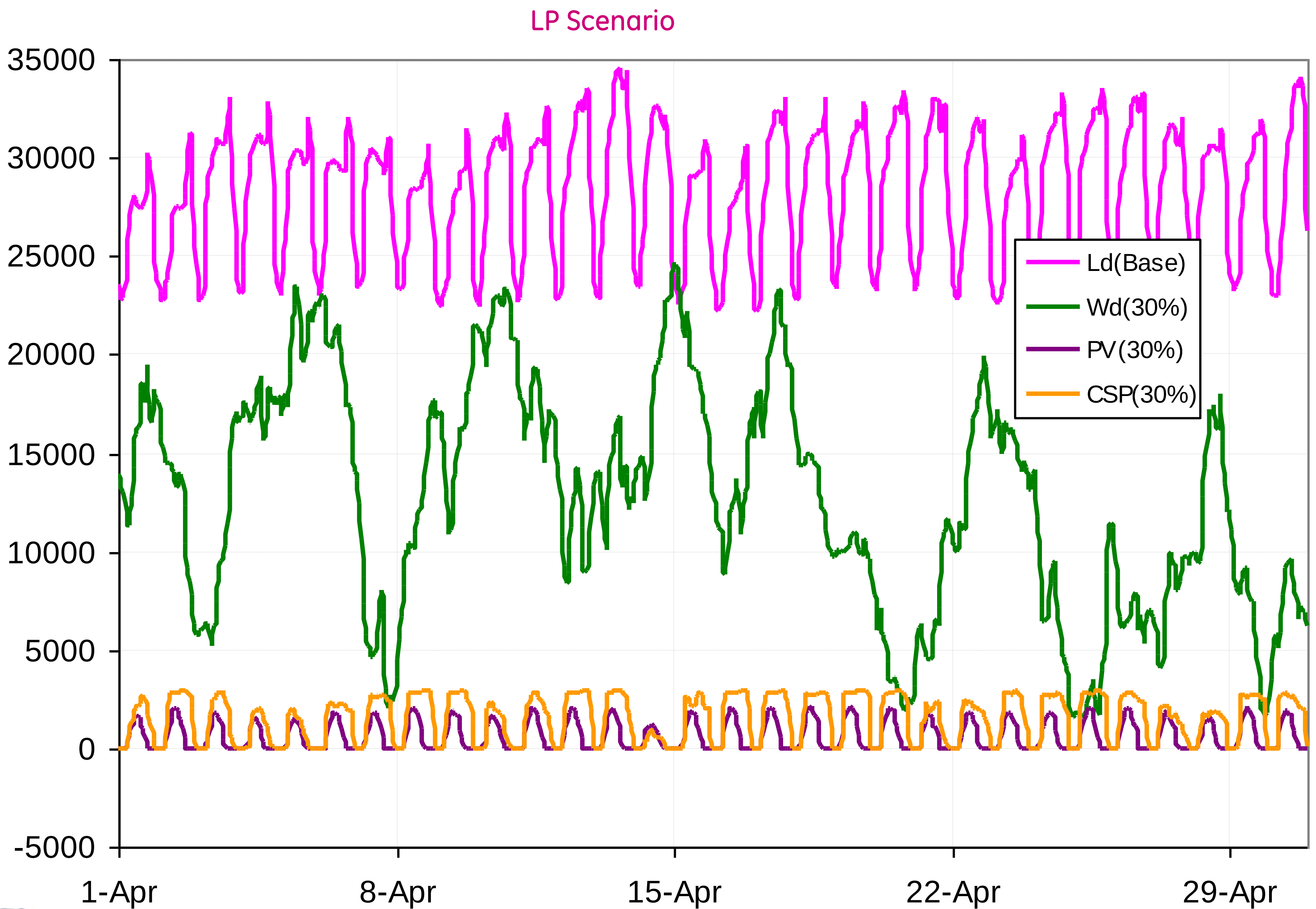
Study Footprint Total Load, Wind and Solar Variation Over Month of April
(30% Wind Energy in Footprint)



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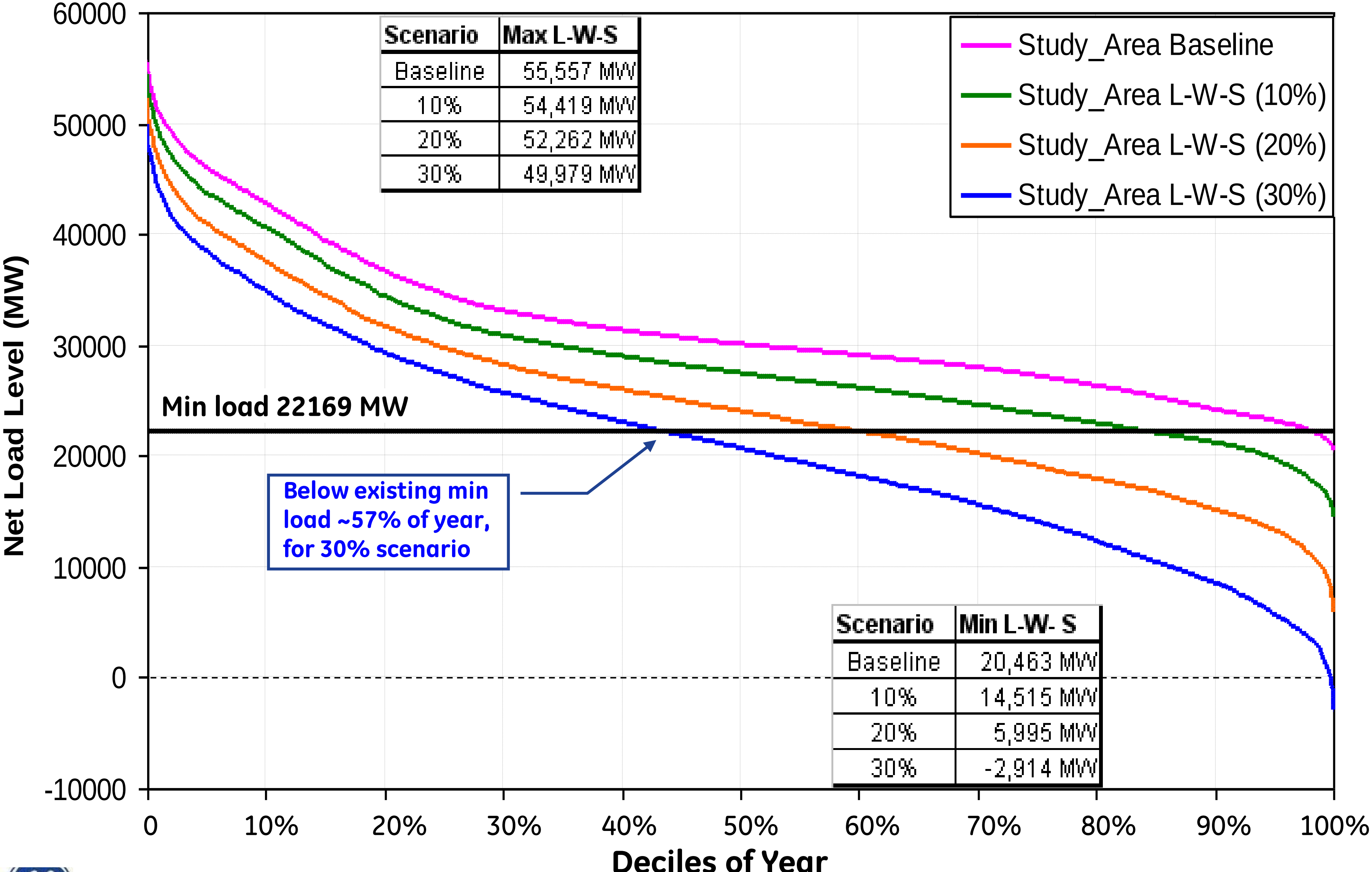
Study Footprint 2006 Net Load Duration – In Area Scenario



Scenario	Max L-W-S
Baseline	55,557 MW
10%	54,419 MW
20%	52,262 MW
30%	49,979 MW

Scenario	Min L-W- S
Baseline	20,463 MW
10%	14,515 MW
20%	5,995 MW
30%	-2,914 MW

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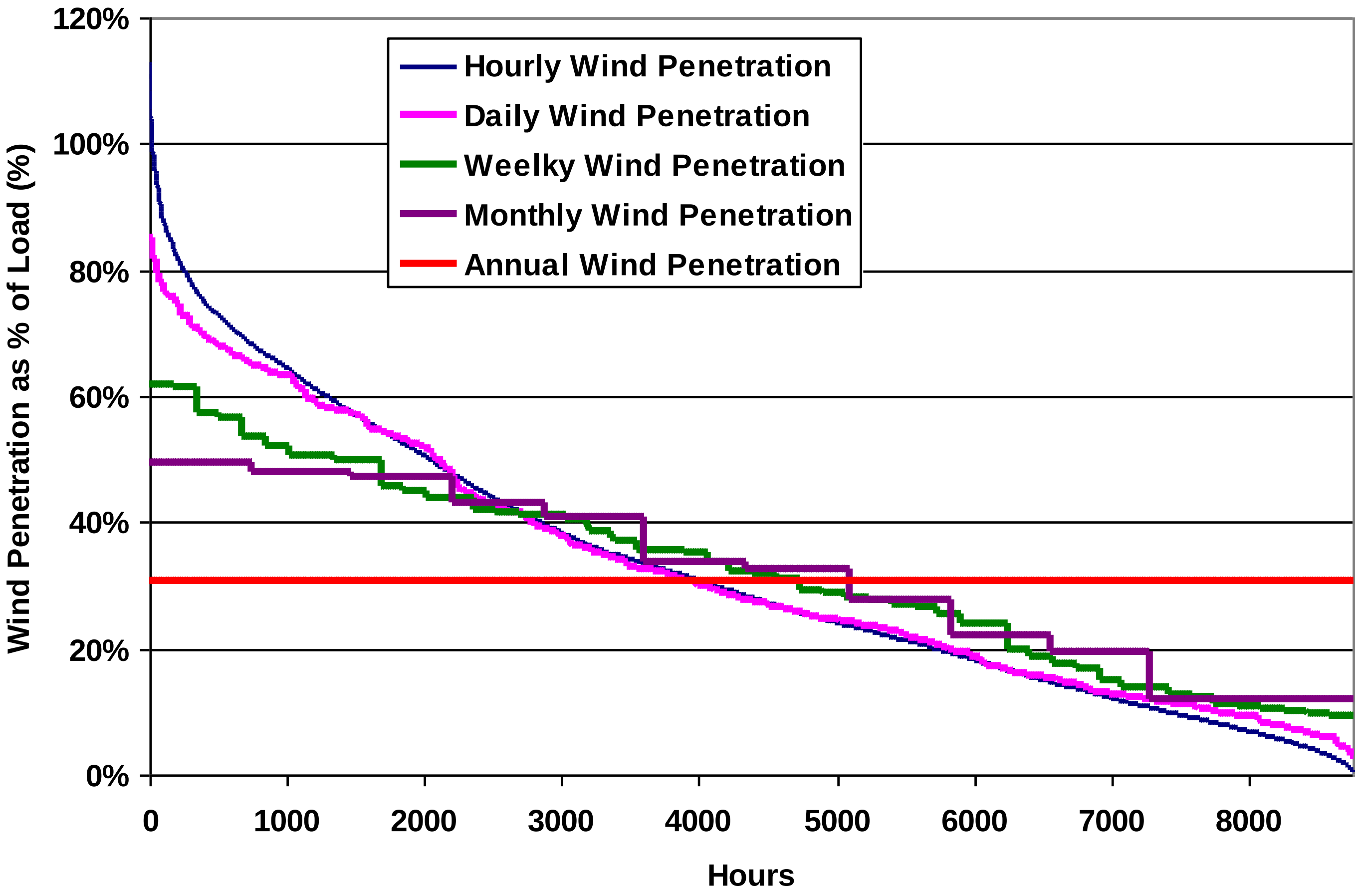
What Does 30% Penetration Mean?



Overview

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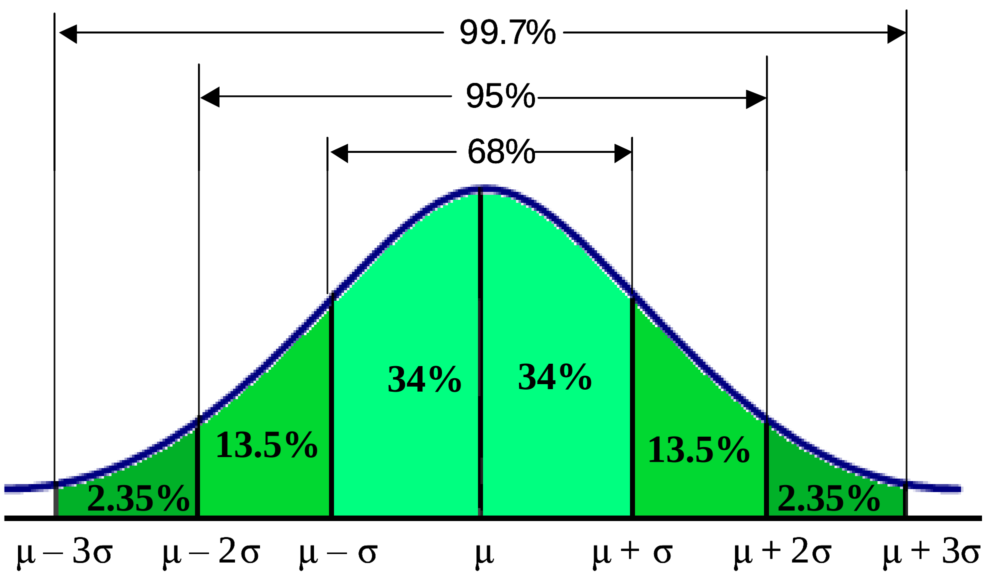
Variability Analysis - Deltas

Statistics used to characterize variability:

- Delta (Δ) – The difference between successive data points in a series, or period-to-period ramp rate.
  - Positive delta is a rise or up-ramp
  - Negative delta is a drop or down-ramp
- Mean (μ) – The average of the deltas (typically zero within a diurnal cycle)
- Sigma (σ) – The standard deviation of the deltas; measures spread about the mean

For a normal distribution of deltas, σ is related to the percentage of deltas within a certain distance of the mean



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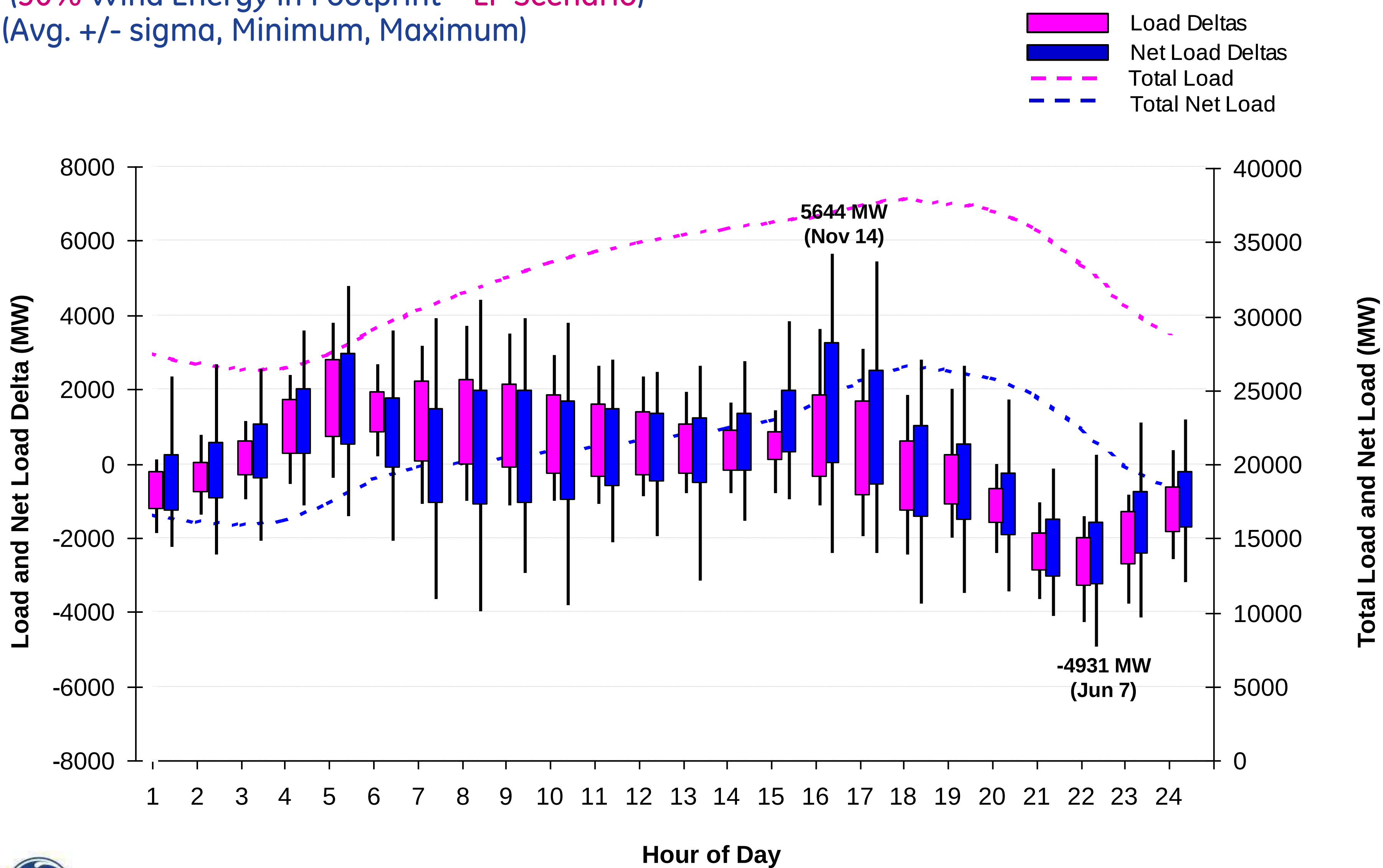
Average Daily Profile of Deltas Over Year 2006

(30% Wind Energy in Footprint – LP Scenario)
(Avg. +/- sigma, Minimum, Maximum)



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Overview

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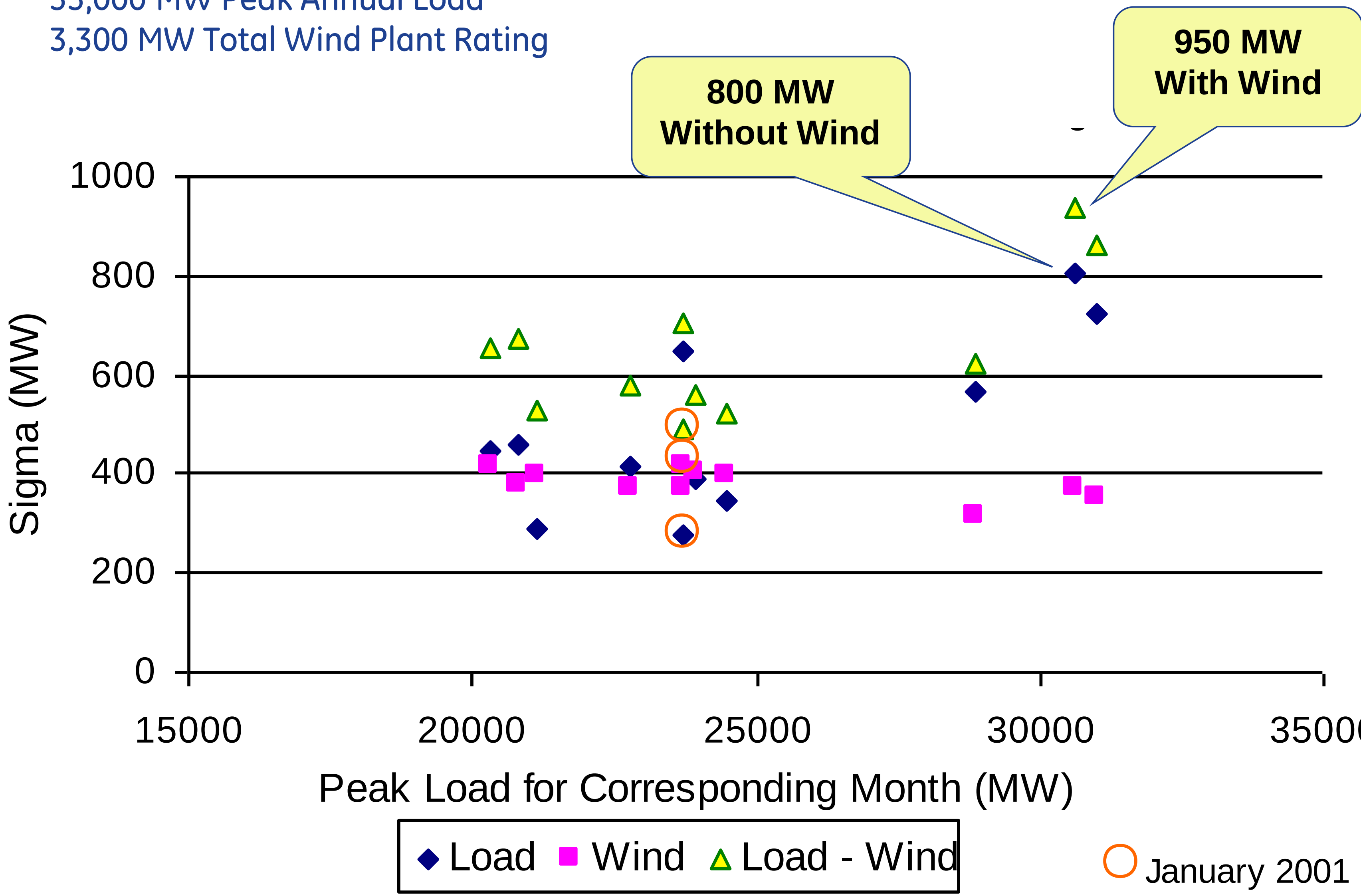
Standard Deviations of Day-Ahead Forecast Errors

33,000 MW Peak Annual Load
3,300 MW Total Wind Plant Rating



Overview

- Temporal/Spatial Patterns
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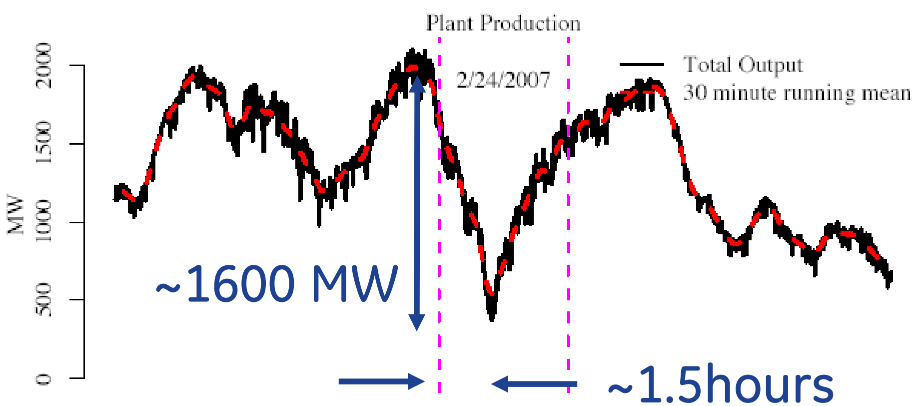
Forecasting

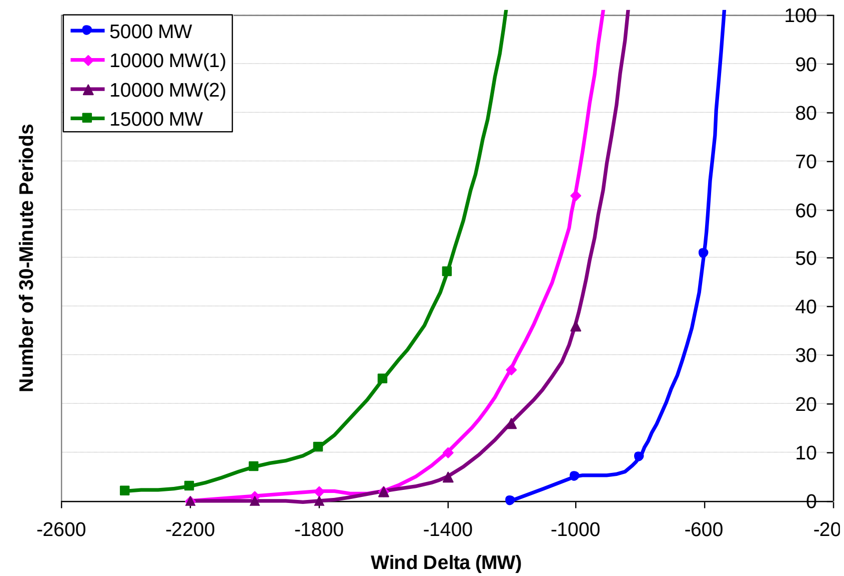
- Wind forecasting is absolutely essential
  - Forecasting increases economic value of wind power by >25% or more
  - Wide-spread extreme wind events are predictable (e.g. widely publicized Texas events were predicted)

Texas February 24, 2007 event



Arrival of such fronts is generally forecastable, several hours ahead within a 30-minute window

Extreme Thirty-Minute Wind Drops

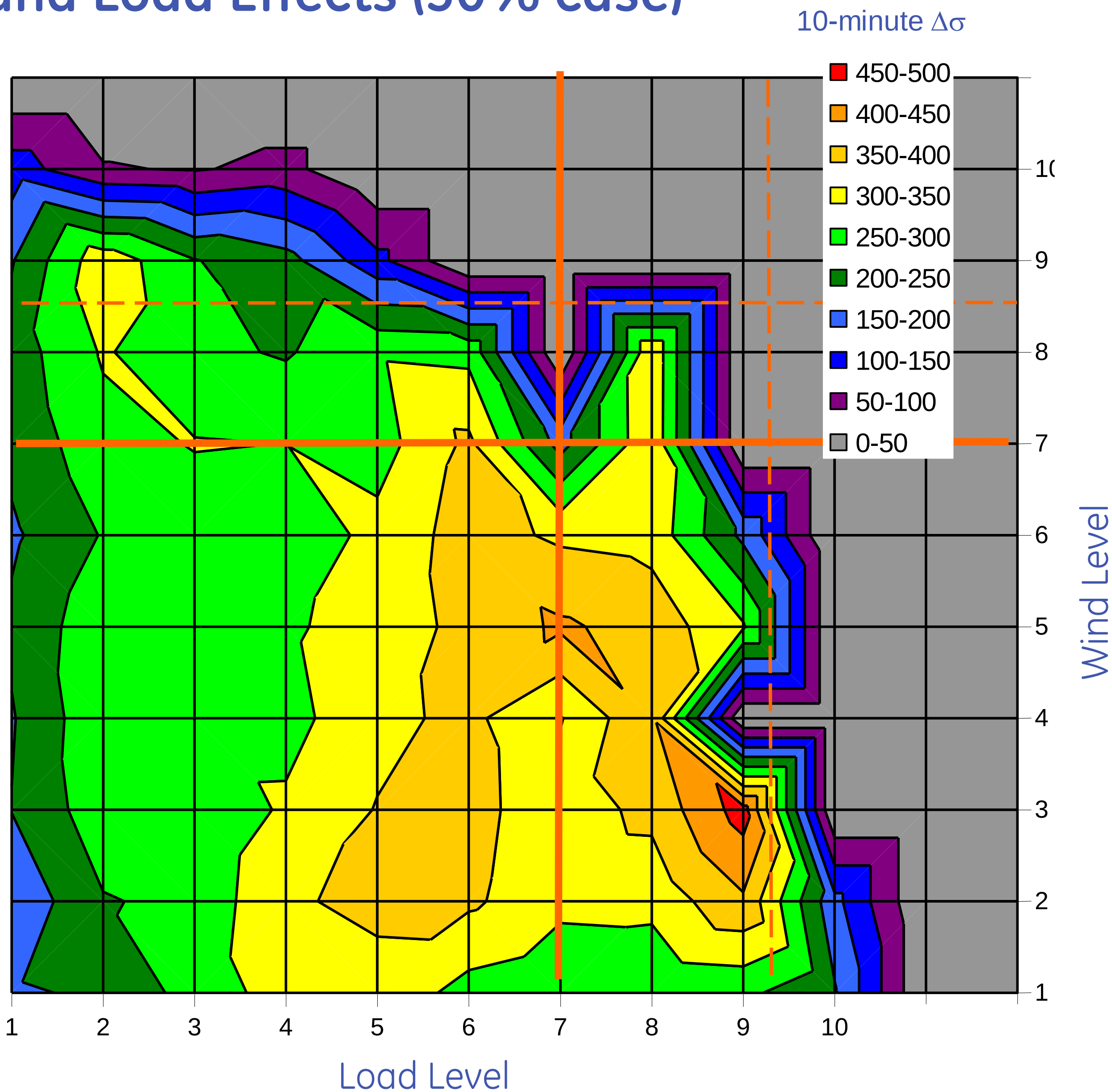


Reserve Requirements

Large System Net Load Variability : Separating Wind and Load Effects (30% case)

- Net load variability increases with wind
- Implied reserve requirement is 3 x $\Delta\sigma$
- Requirement is a function of both load level and wind level

Distillation of $3\Delta\sigma$ to Simple Rule: X% of Load plus Y% of Wind *Production with a max*



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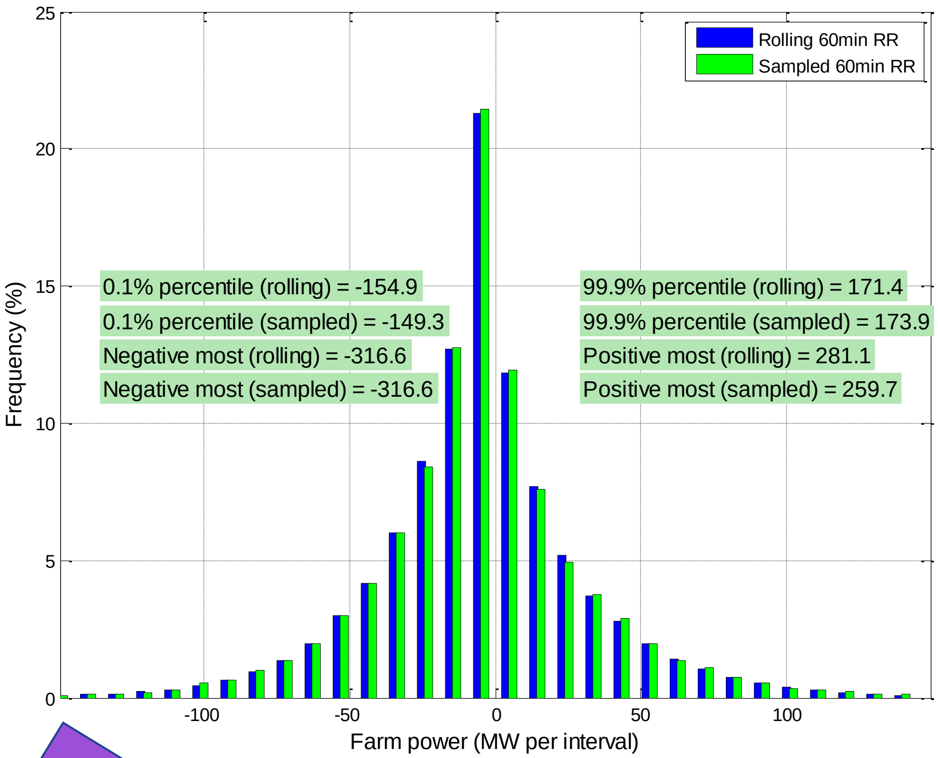
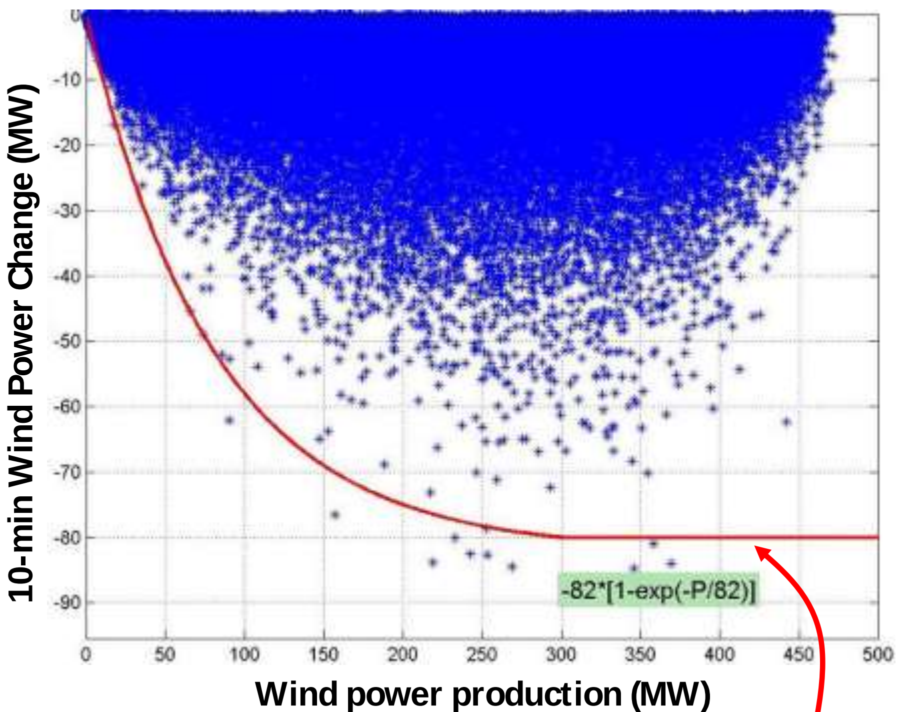
Wind Power Data: Extrema More Important in Small Systems

Provided by AWS Truewind (2 years of 10-min for each plant)

500 MW Wind case (inc 2 x 200MW remote island plants

Can't lean on the Neighbors





New Reserve = Spin + Up Regulation = 185MW + f (Wind)

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Flexible Generation

Dealing with Variability

- Balance of generation portfolio (dispatchable generation) must have the capability to respond to variations in net load
  - Net load = (Load MW) – (Wind MW)
- Generators must have room to maneuver up or down
  - Ramp RANGE up and down
- Generators must be capable to maneuver fast enough to follow changes in net load
  - Ramp RATE (MW/minute)

The following slides show how Ramp Range and Ramp Rate for an operating area are affected by increasing penetration of wind generation

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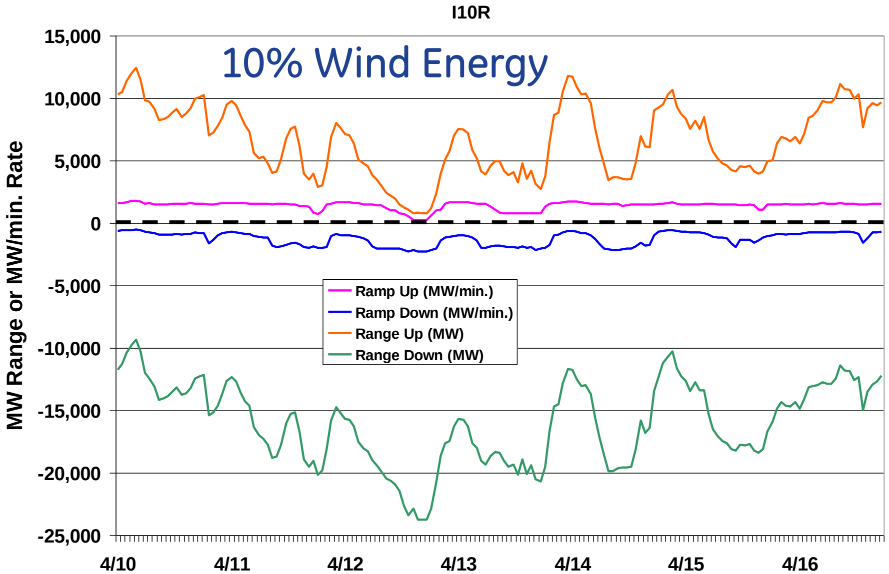
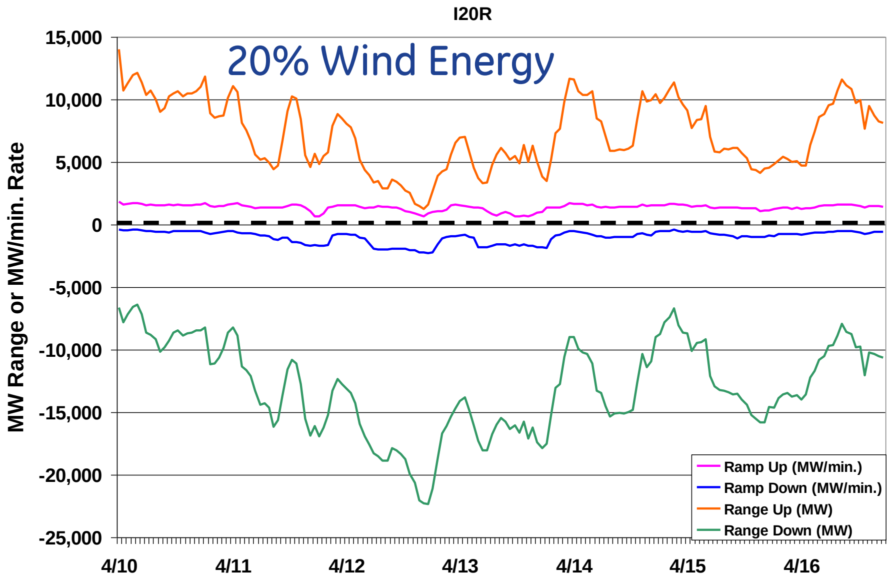
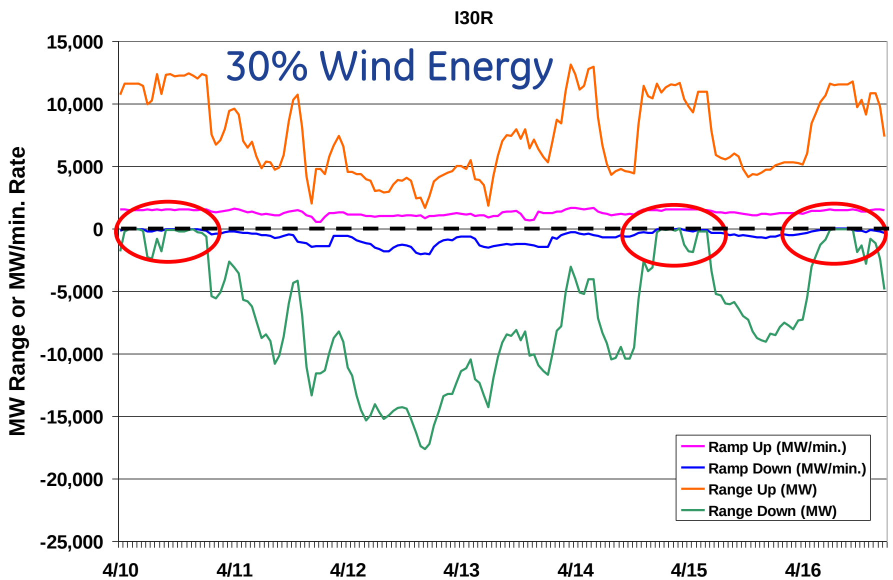
Grid maneuverability decreases as wind penetration increases





Week of April 10, Spring Season

- Load levels are typically low
- Wind generation is typically higher in spring than other seasons
- Wind plant output is typically greater at night
- Grid has difficulty operating at "minimum load"



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Subhourly Time Simulations

QSS (Quasi Steady-State) Simulations

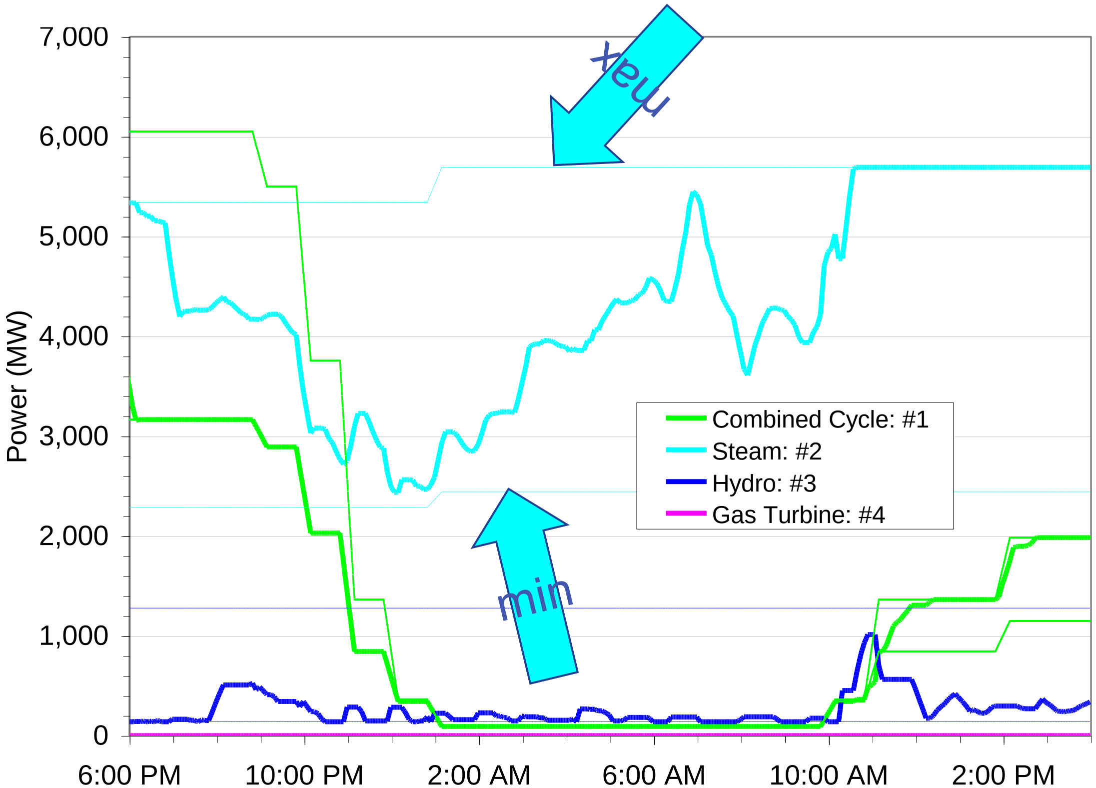
vs.

LTDS (Long-term Dynamic Simulations)

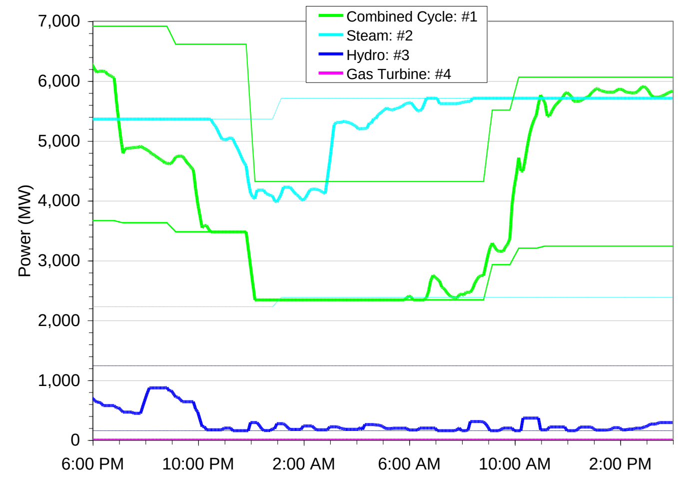
- Provide Validation and Context for Operational and Statistical Analysis
  - Cases Selected from Statistical Analysis
  - Boundary Conditions Set by Operational Analysis
- Evaluate Impact of Significant Wind Generation
  - Load Following & Ramp Rate Requirements
  - Regulation/AGC Requirements
- Illustrate Performance Issues
- Illustrate Mitigation Measures

Unit-Type Dispatch

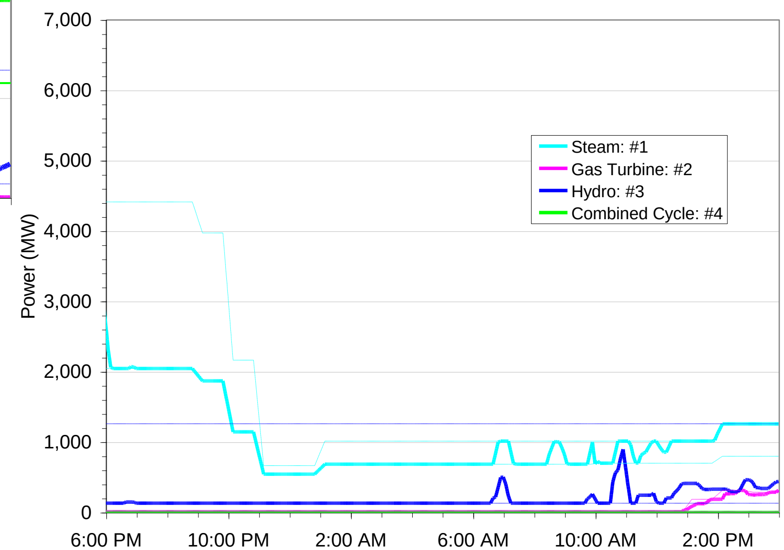
20% Wind



10% Wind



30% Wind



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Dealing with Uncertainty

- Basic options are increased reserves or demand response
- Increasing reserves
  - Commit additional generation so that load will never be interrupted
  - Need to do it 100% of the time, because you do not know the reserves will be required
- Demand response
  - Interrupt or reduce load occasionally, as need arises
  - A paid ancillary service

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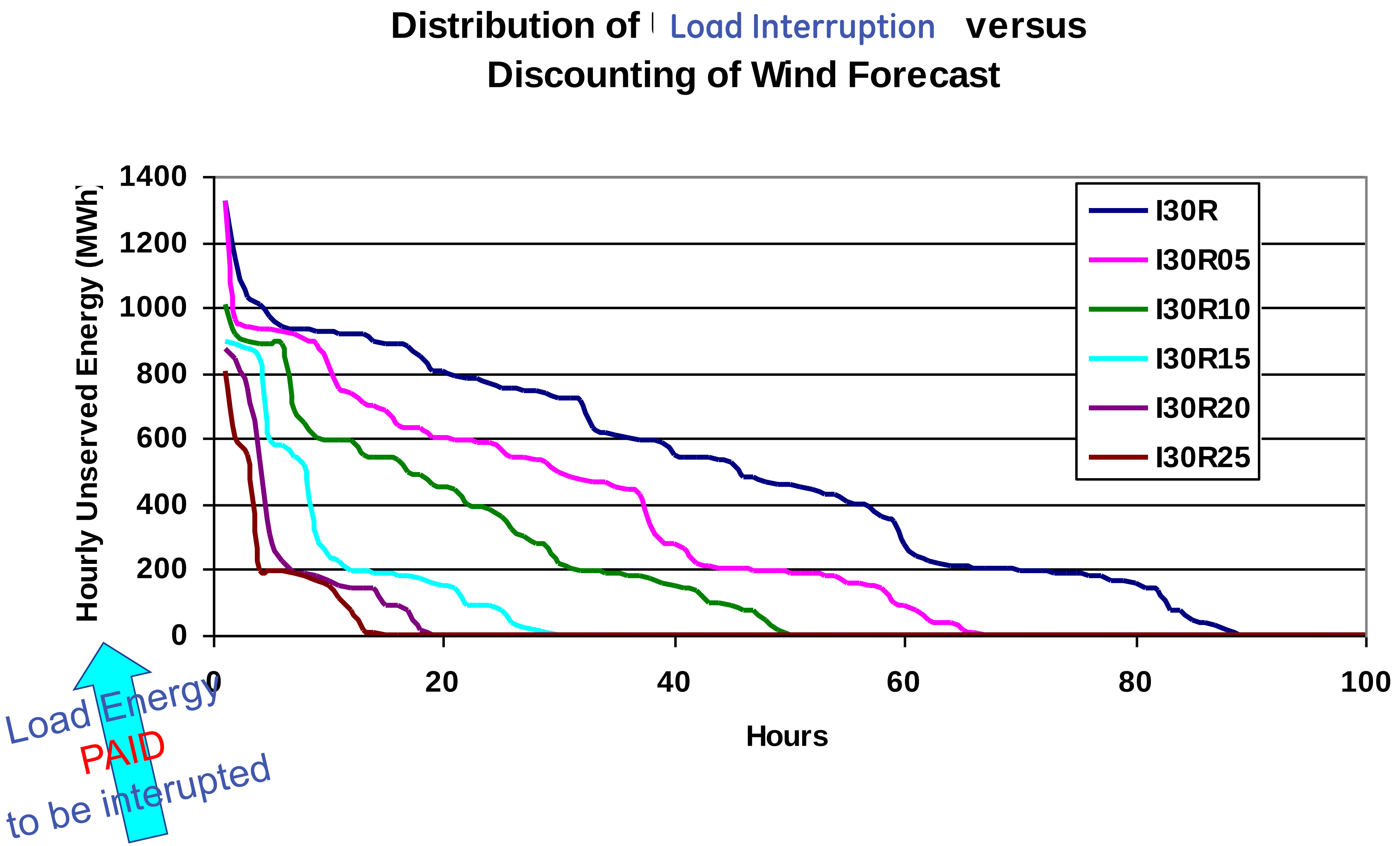
Using Load to Meet Occasional Extremes



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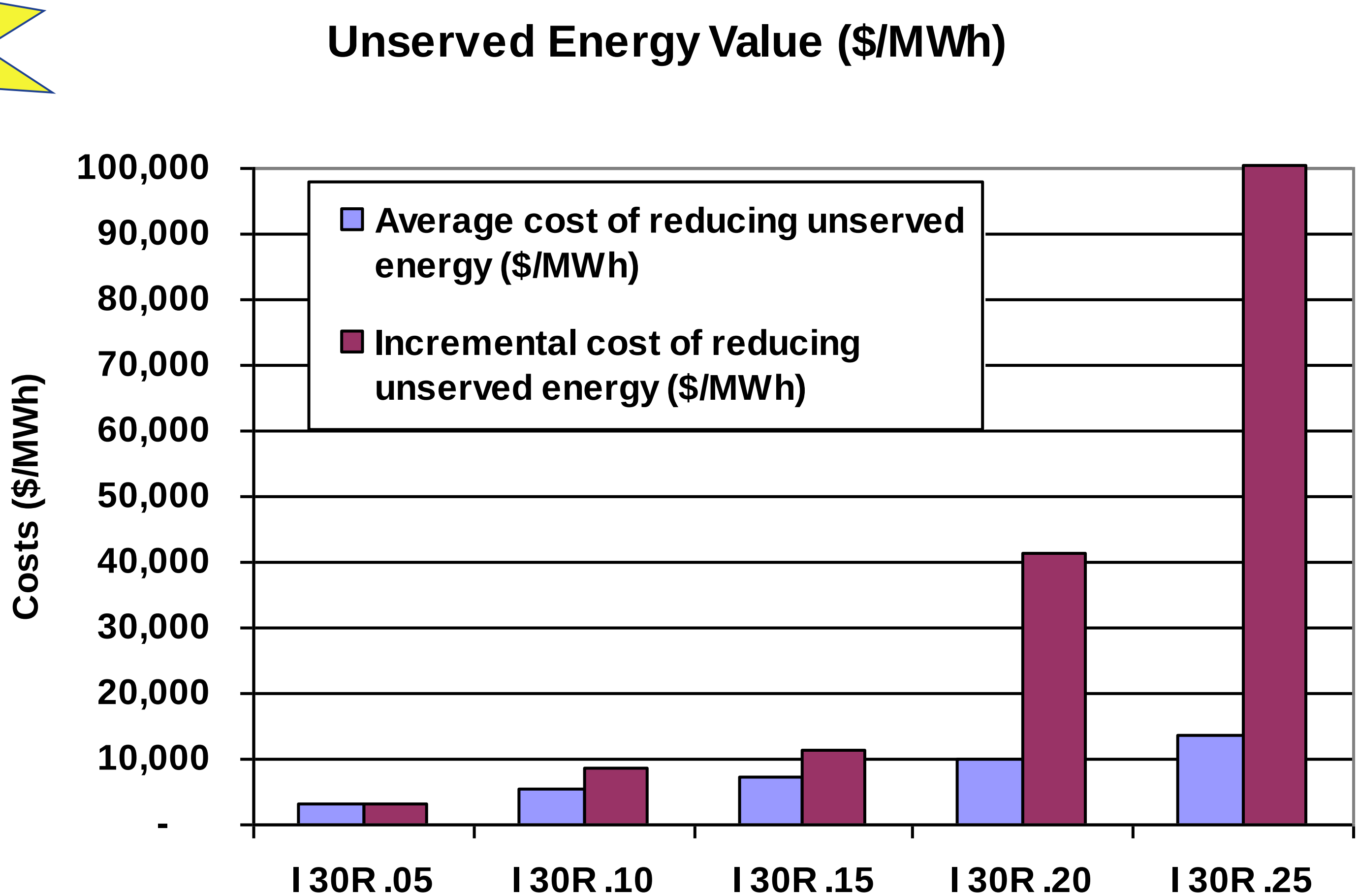
Interruptible loads are easily cost justified



Cost of reducing Unserved Energy by discounting wind generation forecasts.
(i.e., adding reserves in proportion to forecasted wind generation)

Costs are per MWh of energy reduced.

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Impact on the Existing Generation Fleet?

- Lower capacity factors for base and mid-merit generation
- Use of “peakers” at “unusual” times
- Pressure to increase hydro maneuverability
- Increased combined cycle cycling (today and growing rapidly)
- Increased coal cycling (growing rapidly in some places)
  - Increased O&M, higher outage rates, environmental performance impacts
- Credible quantitative data is limited; sensitive
- Claims of costs, loss of life, and physical capability are variable

Severity of impacts and the allocation of costs is a topic of intense debate

Capacity Value of Wind Generation

Effective Capacity
or Effective Load Carrying Capability (ELCC)

ELCC is a measure of long-term adequacy

- Ability of a plant to serve load
- Avoid loss of load by the power grid

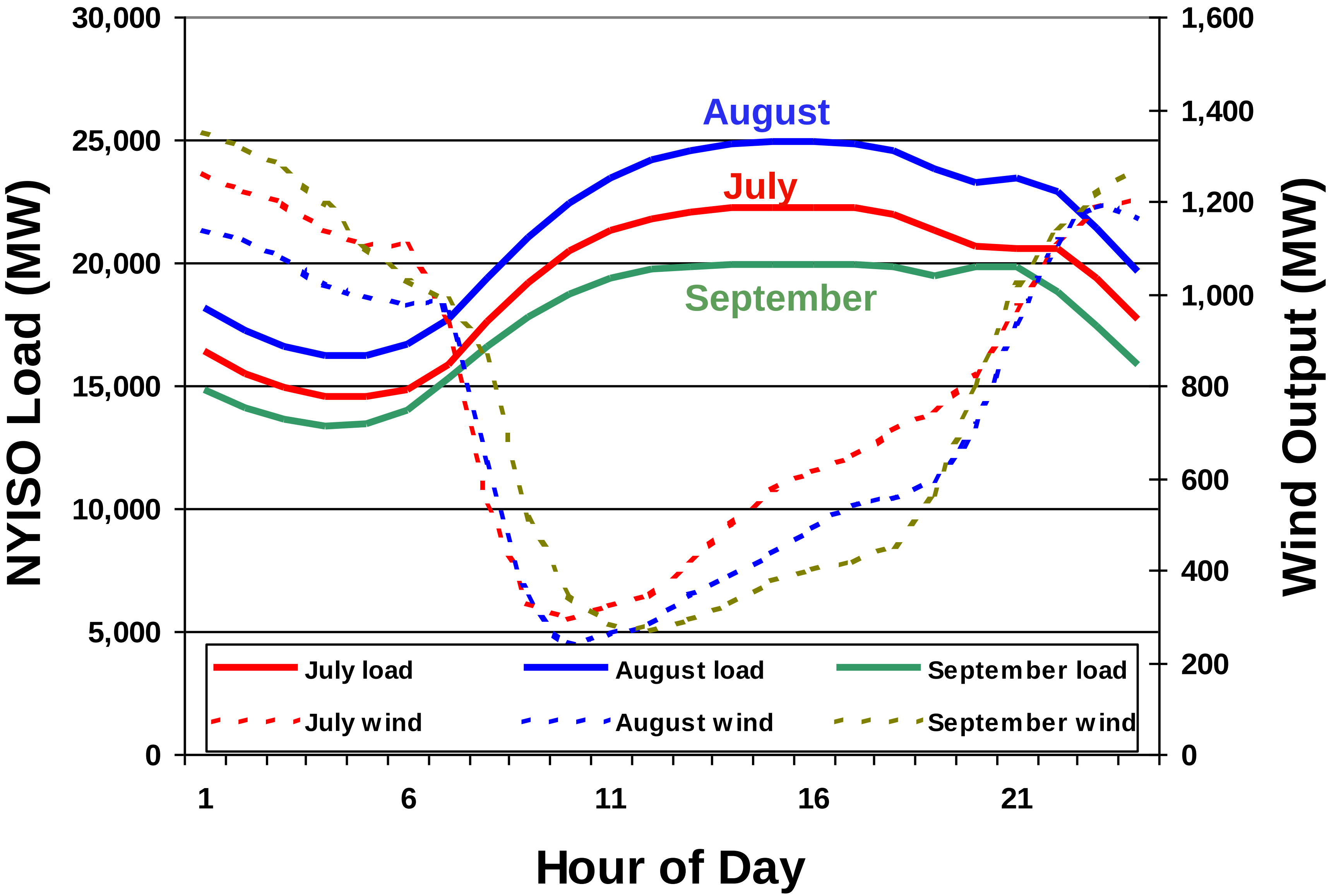
Example of a 100 MW thermal plant

- If forced outage rate is 10%, and
- If forced outages are equally probable at any time, then
- ELCC is 90%

How does this measure apply to wind power?

- Output of a wind plant is not dispatchable
- Wind plant output is a function of available wind, and it is time-dependent

2001 Average Load versus Average Wind



Effective Capacity

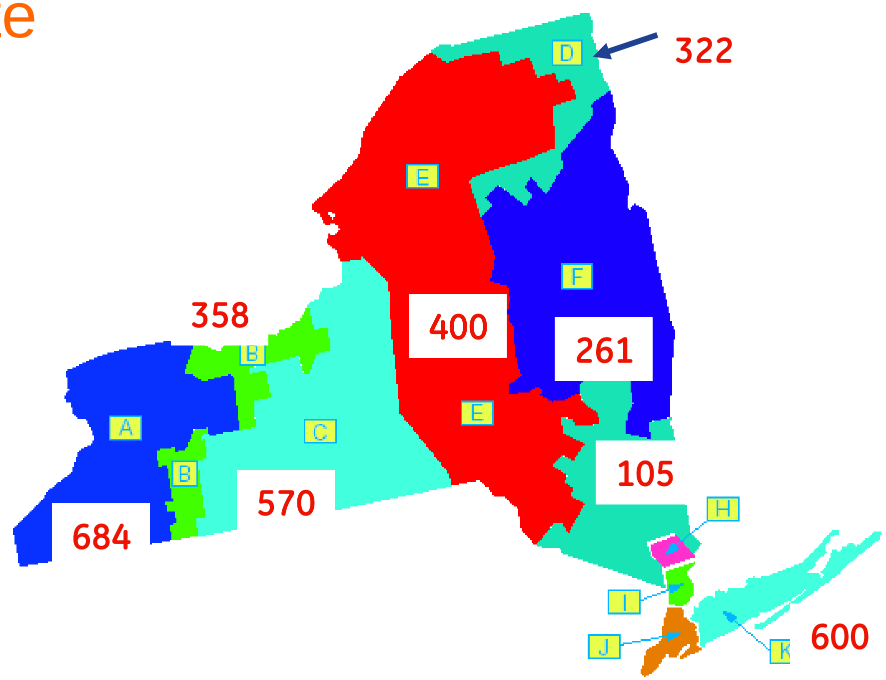
Based on rigorous LOLP calculations using 2001 - 2003 load and wind profiles for NY State

Inland Wind Sites:

- Capacity factors ~ 30%
- Effective capacity, UCAP ~ 10%

Offshore Wind Site:

- Capacity factors ~ 40%
- Effective capacity, UCAP ~ 39%



Developed approximate calculation method:

- UCAP ~ On-Peak Capacity Factor for 1:00-5:00pm, June-August

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Experience and Lessons Learned

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Major Study Results :

- **Large interconnected power systems can accommodate variable generation (Wind + Solar) penetration levels exceeding 30% of peak loads**
- **But not by doing more of the same.....**

To reach higher levels of wind generation and other renewables:

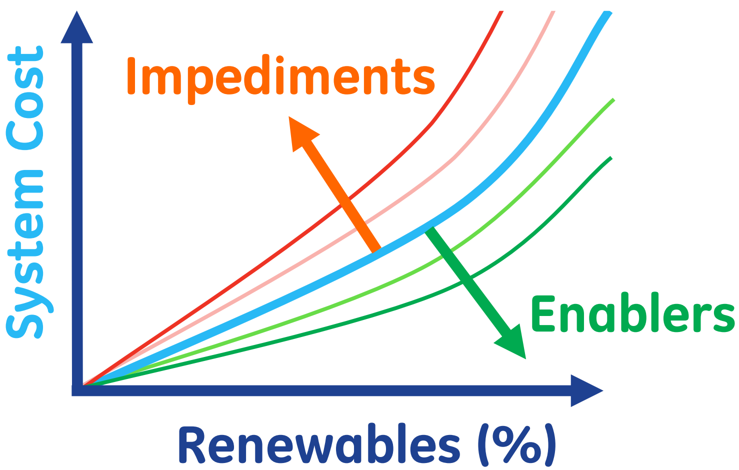
- Get the infrastructure right
- And use it better

The debate has changed:
No longer: “Is it possible?”
Now: “How do we get there?”

Lessons Learned

System Cost

Unserved Energy
Missing Wind/Solar Target
Higher Cost of Electricity



Impediments

- Lack of transmission
- Lack of control area cooperation
- Market rules / contracts constraints
- Unobservable DG – "behind the fence"
- Inflexible operation strategies during light load & high risk periods

Enablers

- Wind Forecasting
- Flexible Thermal fleet
  - Faster quick starts
  - Deeper turn-down
  - Faster ramps
- More spatial diversity of wind/solar
- Grid-friendly wind and solar
- Demand response ancillary services

All grid can accommodate substantial levels of wind and solar power … There is never a hard limit

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