Wind Integration: Status and Prospects

CMU Data-Driven Sustainable Energy Systems Seminar:

Wind Integration: Status and Prospects

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Utility Wind Integration Group

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Outline of Topics

- Overview
- Findings from Recent Studies
- Wind Forecasting
- Capacity Value
- Energy Storage
- System Stability
- Market Design
- Conclusions and Recommendations

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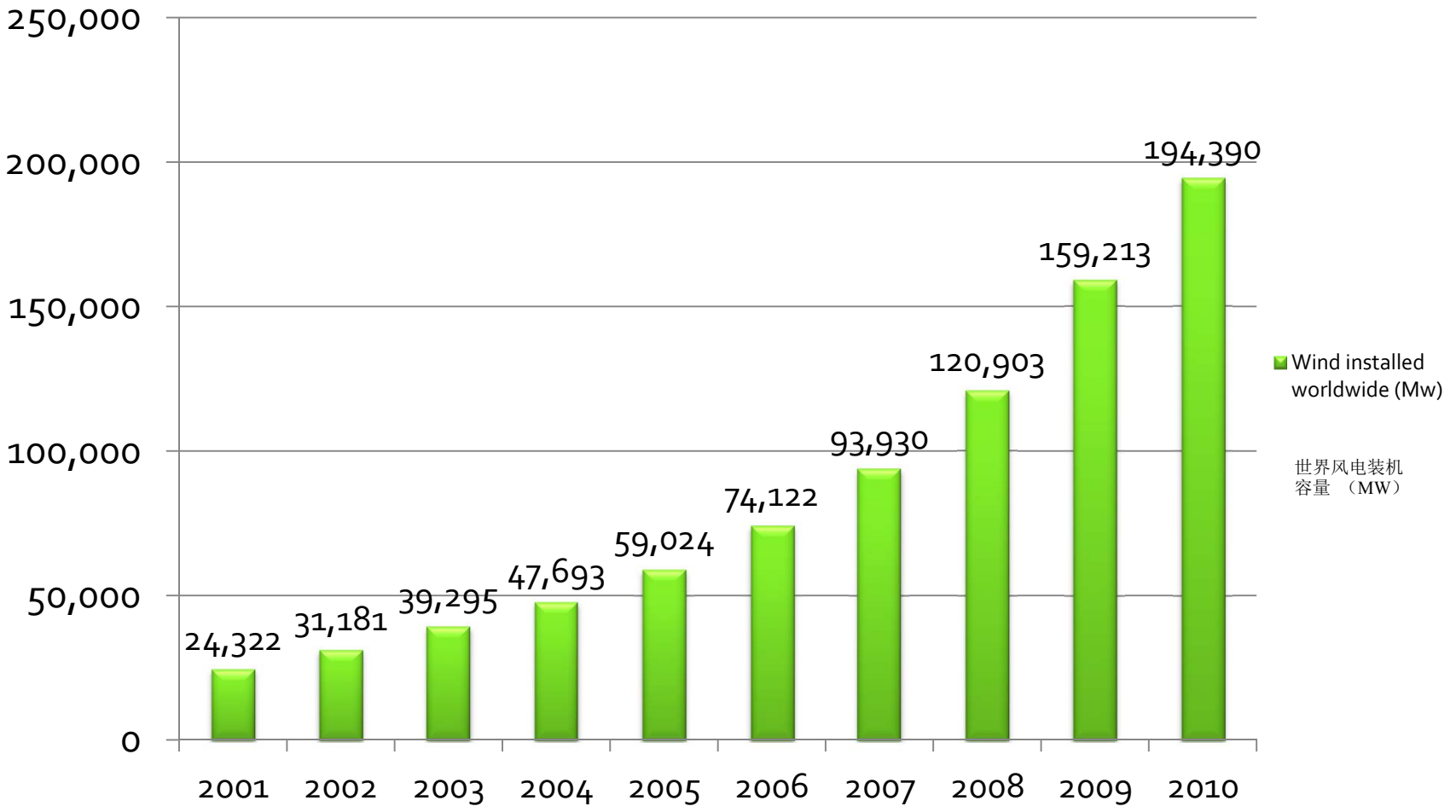
Wind Installed Worldwide
世界风电装机容量



Source: GWEC, 2010

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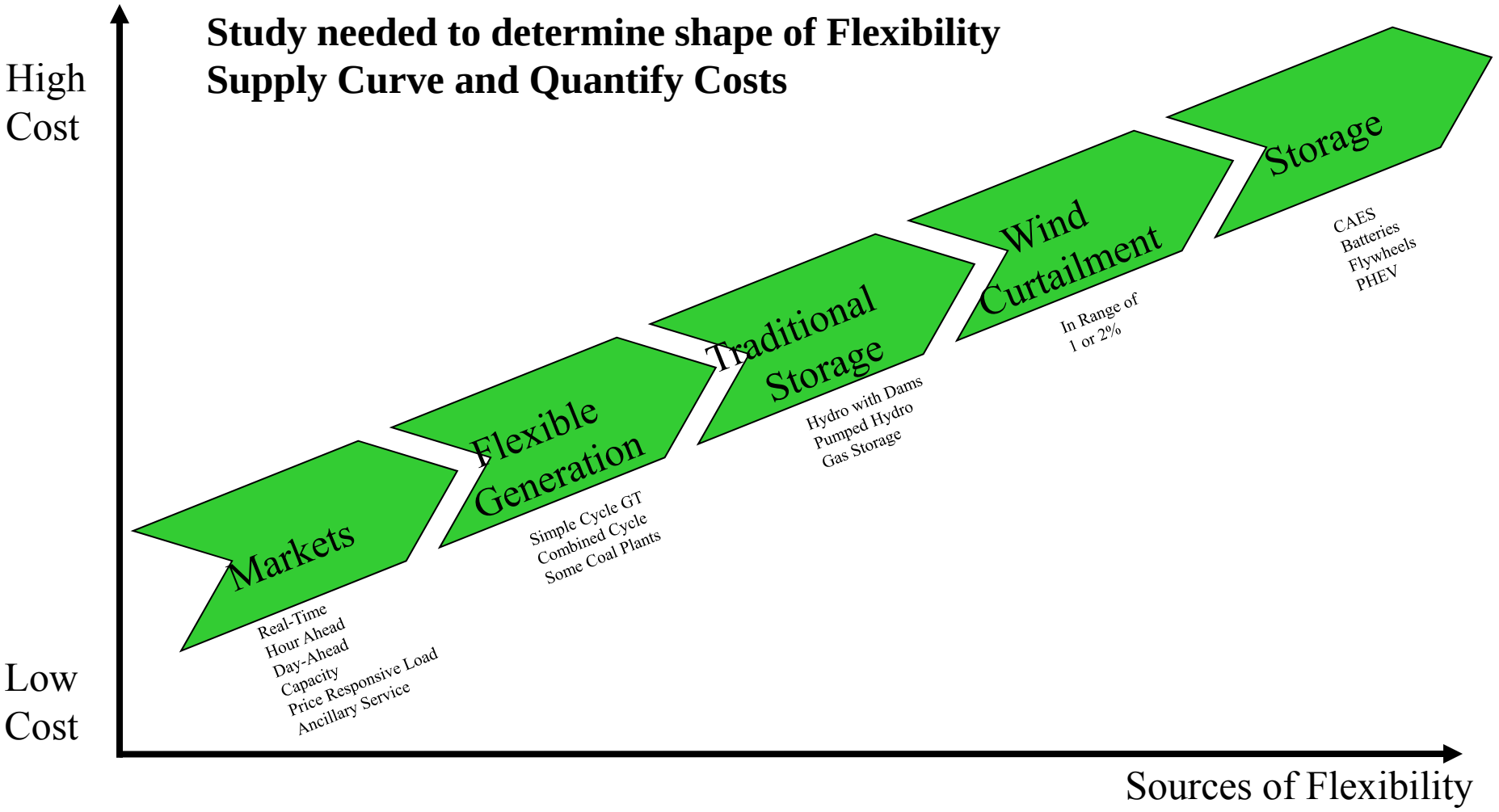
It's All About Dealing with Variability and Uncertainty

- Variability
  - Load varies by seconds, minutes, hours, by day type, and with weather
  - Supply resources may not be available or limited in capacity due to partial outages
  - Prices for power purchases or sales exhibit fluctuations
- Uncertainty
  - Operational plans are made on basis of best available forecasts of needs; some error is inherent
  - Supply side resource available with some probability (usually high)
- Key questions
  - How does wind generation affect existing variability and uncertainty
  - What are the costs associated with the changes
  - What does the future hold

Flexibility Supply Curve



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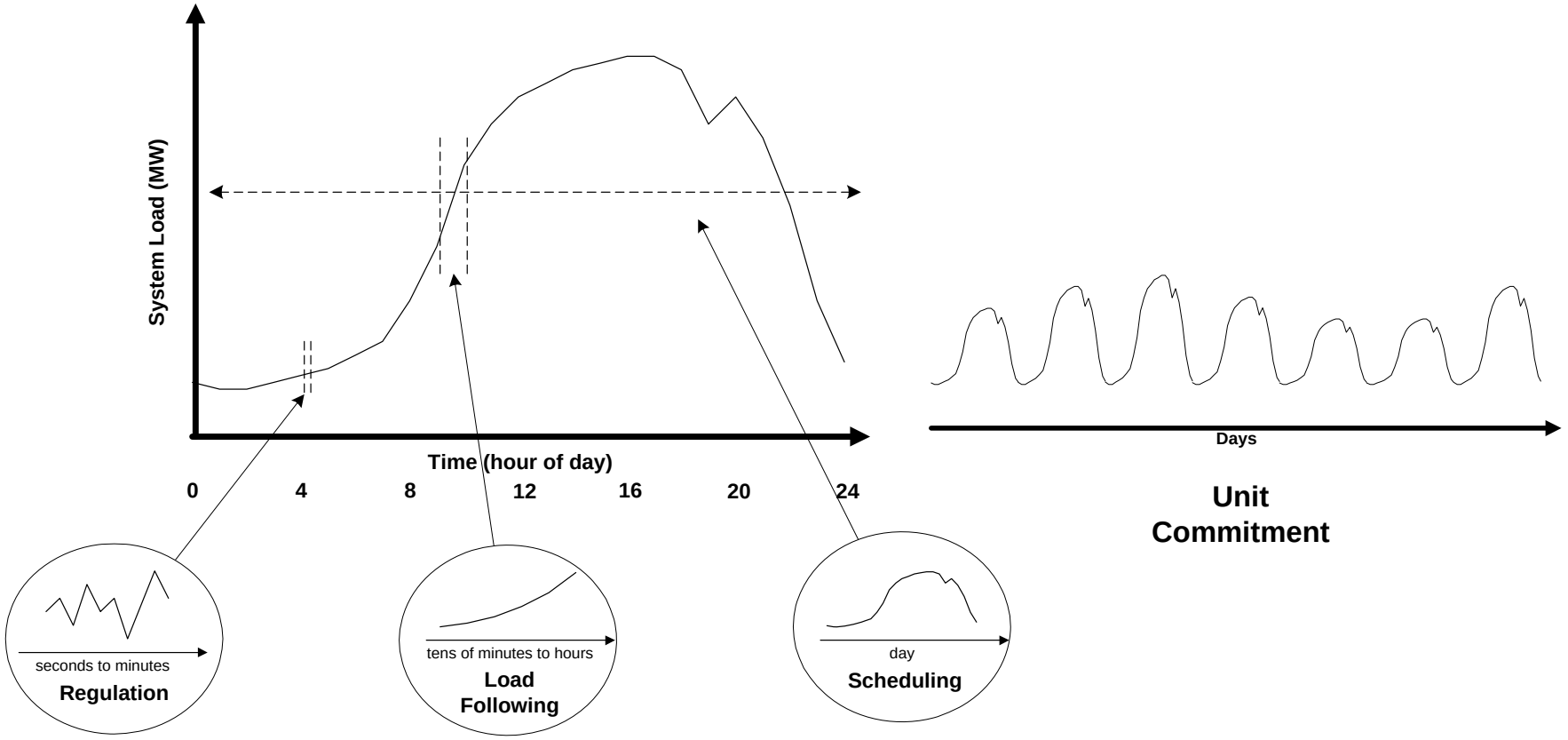
Time Scales of Interest



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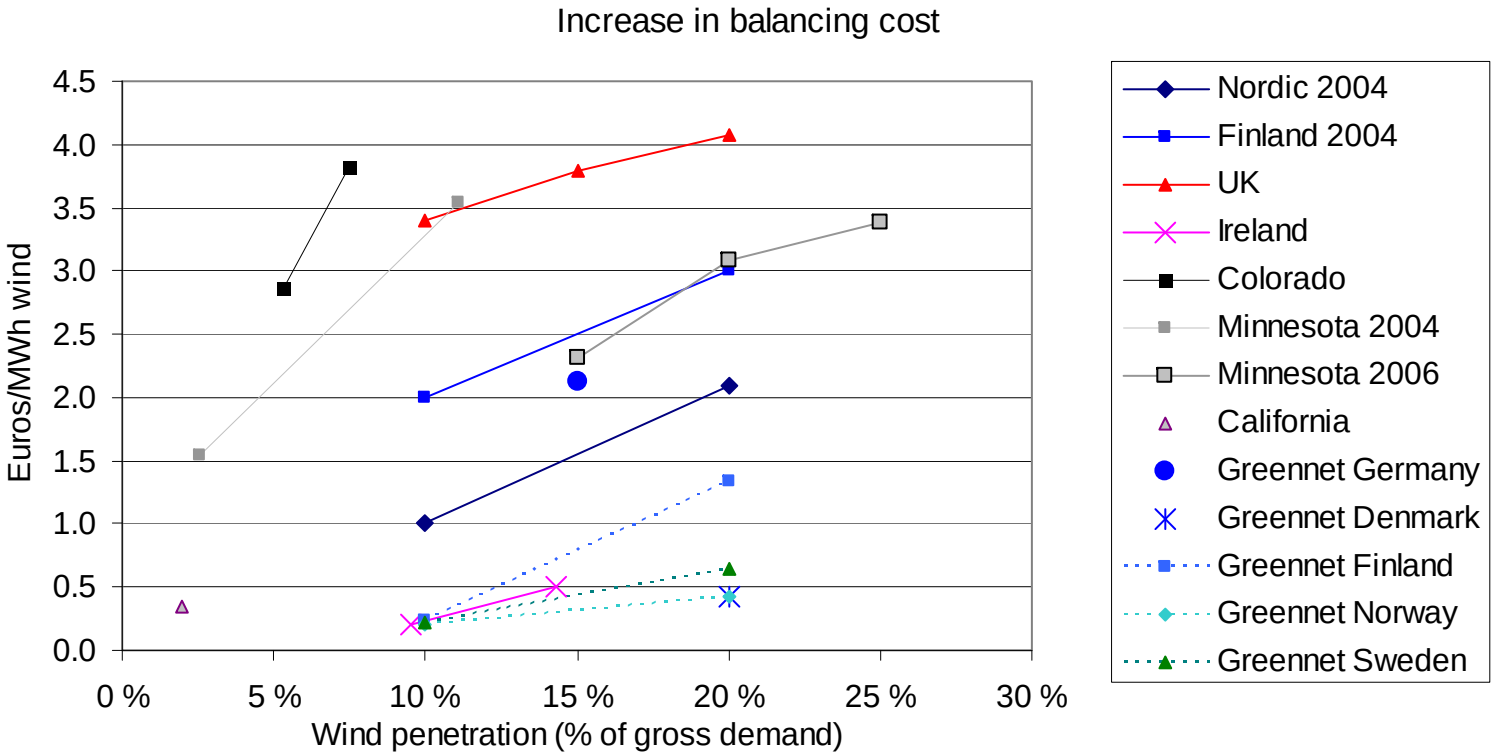
Increased Balancing Cost



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Wind Power Forecasting – Why Is it Important

- Economics
  - Better forecasts mean lower operating reserves
  - Lower operating reserves mean lower operating costs
  - Avoid penalties for bad forecasts
- Reliability
  - Situational awareness for operators
  - System positioning for ramping events
  - Preparation for extreme events
- Market Operation
  - Understand need for and provide incentives for the right market products with high VG penetration
  - Align market rules with forecasting capabilities

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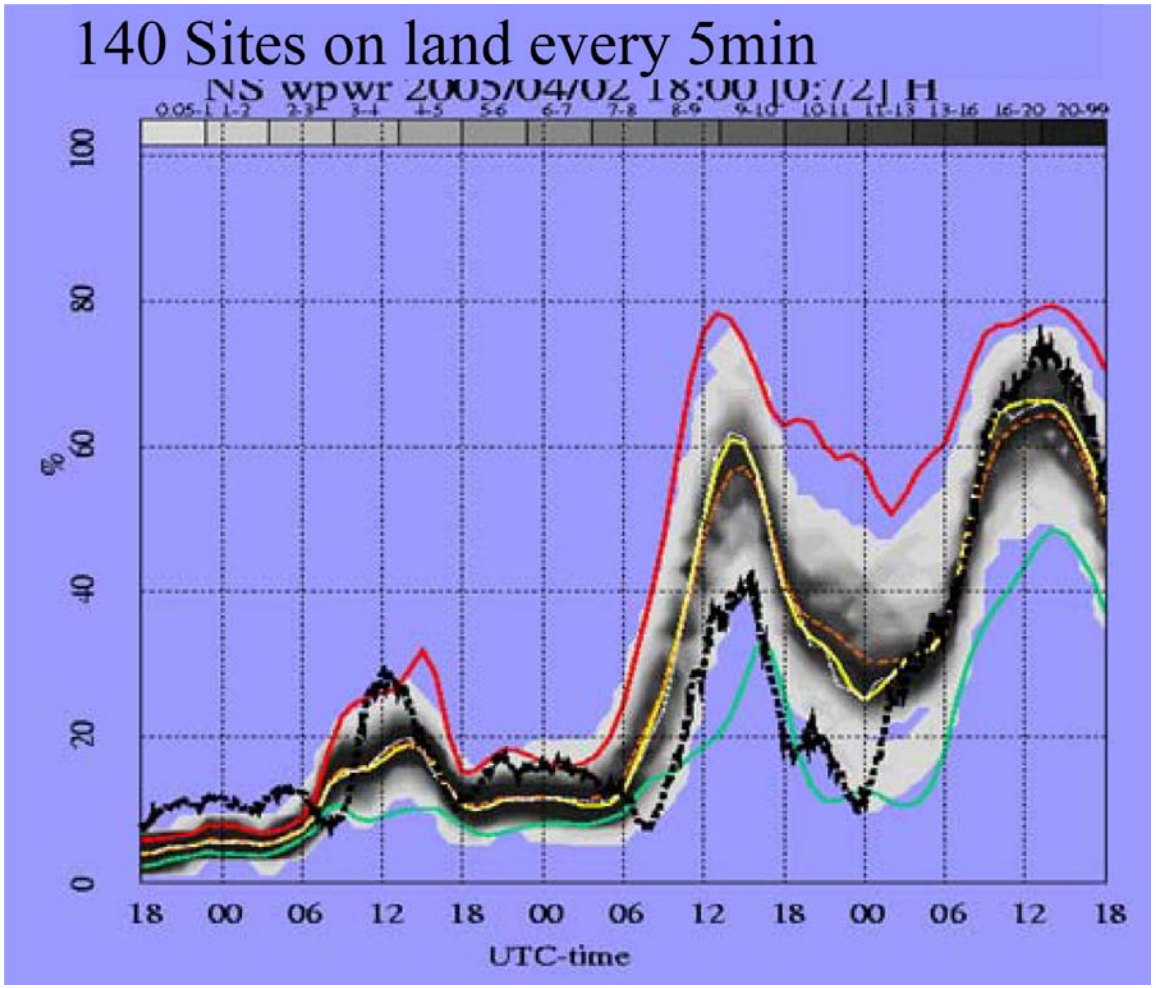
Forecasting and Balancing Markets Reduce Impacts



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Different Forecasts for Different Time Periods

- Situational awareness forecast: used for severe weather events (real-time)
- Hour ahead forecast: uses rapid update cycle to produce 10 min forecasts 4-6 hrs ahead, updated every hour
- Day ahead forecast: Hourly forecasts 2-4 days ahead, updated every 12 hours, uses national weather service models
- Nodal forecast: hourly forecast of transmission system nodal injections for managing transmission congestion
- Different performance metrics for different forecasts

How Good is the Forecast?

- Wind plant output can be forecast within some margin of error, and forecasts are getting better

	Forecast Error	
	Single Plant	Large Region
Hour Ahead		
Energy (% actual)	10-15%	6-11%
Capacity (% rated)	4-6%	3-6%
Day Ahead		
Hourly Energy (% Actual)	25-30%	15-18%
Hourly Capacity (% Rated)	10-12%	6-8%

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What If the Wind Stops Blowing Everywhere at the Same Time?

- Meso-scale wind forecasting techniques provide the answer
- Significant benefit to geographical dispersion
  - Dispersion provides smoothing in the long term
  - Aggregation provides smoothing in the short term
- Extensive modeling studies have shown no credible single contingency leading to simultaneous loss of capacity in a broad geographical region

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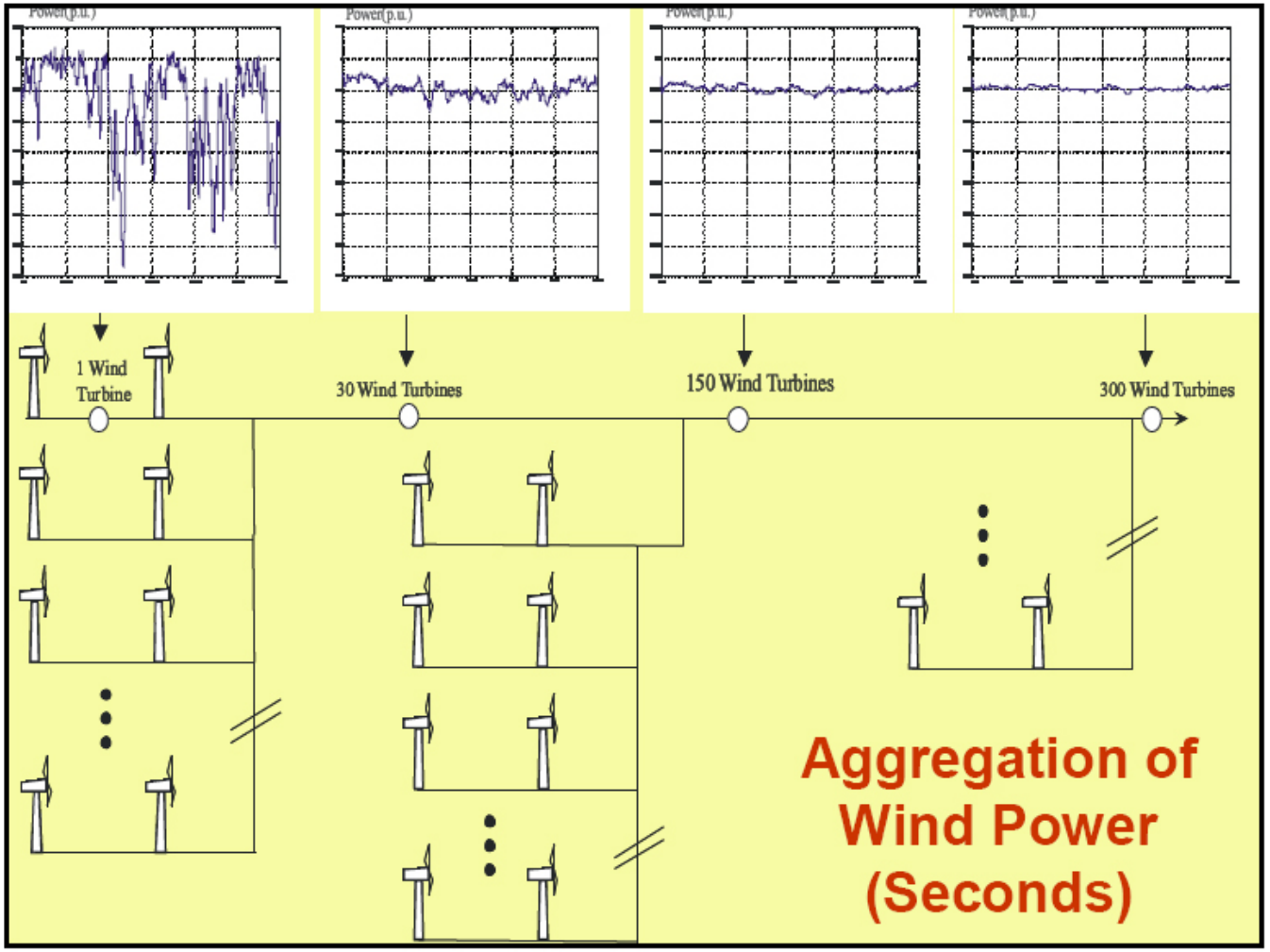
The Power of Aggregation



Source: Thomas Ackermann, Energynautics

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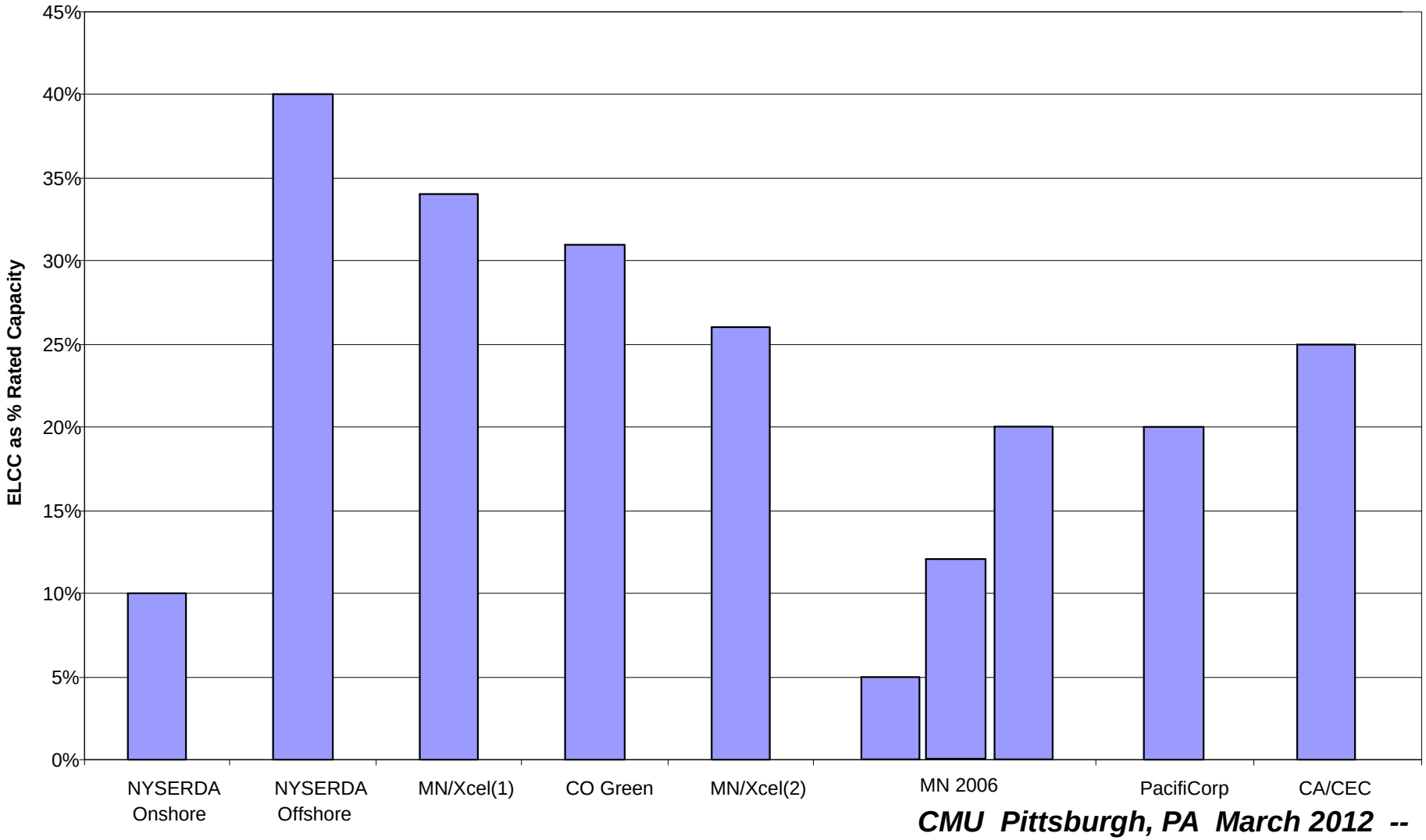
What To Do When the Wind Doesn't Blow

- Good question!
- Must deal with energy resource in a capacity world
- Dealt with through probabilistic reliability methods used to calculate Effective Load Carrying Capability (ELCC)
- Contribution may be large (40%) or small (<5%)
- Once the ELCC is determined, get on with the job of designing a reliable system
- And that means adding more flexible capacity in the future!

An Energy Resource in a Capacity World



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What About Energy Storage?

- Valuable component of a power system, can provide many benefits
- Greatest value when operated for benefit of entire system, not dedicated to a single resource
- One of many sources of flexibility available to the system
- Expensive, and benefits accrue to different parties, i.e. generation owner, trans. system operator, power marketer
- Seldom sufficient value in revenue stream for any single party to justify the investment
- Integration studies do not show need for storage at 20% wind except possibly on small, isolated systems

Won't Too Much Wind Power Cause the System to Collapse?

- Often comes up as a question after a system disturbance resulting in a blackout
- Related questions about system stability are driving world-wide wind turbine and wind plant model development and verification efforts (IEEE, UWIG, WECC, manufacturers, TSOs, utilities)
- Detailed simulations of DFIGs shows that wind plants can actually aid system stability by providing LVRT and dynamic var support to reduce voltage excursions and dampen swings

System Stability Case Study

- Wind integration and interconnection study conducted by GE for NYISO, supported by NYSERDA
- Looked at impacts of 3,300 MW of wind generation on 33,000 MW peak load system (10%)
- Stability case study investigated differences in behavior with 3,300 MW of wind plant with generic doubly fed induction machines, distributed throughout the state, replacing 3,300 MW of conventional plant

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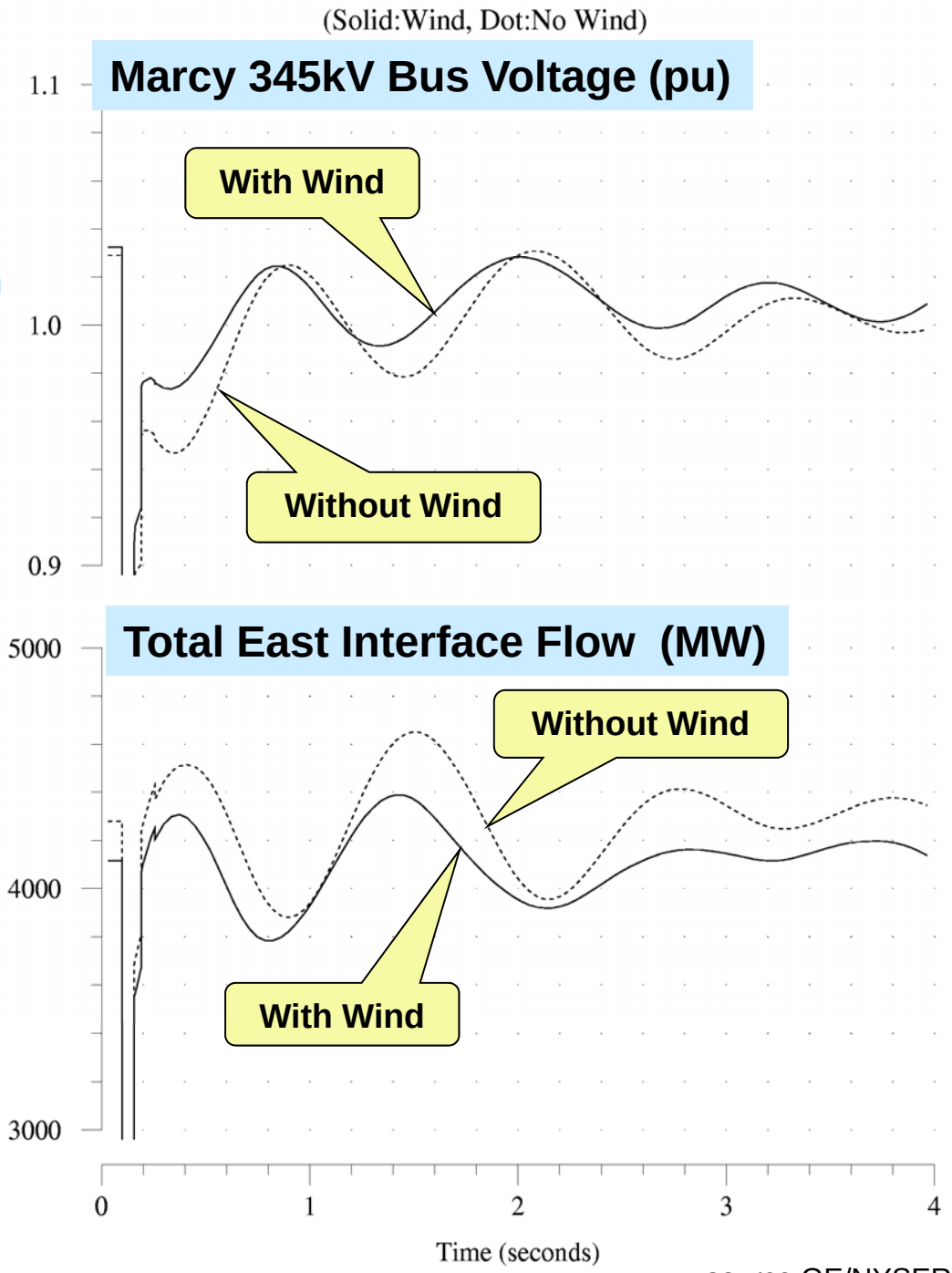
Impact of Wind Generation on System Dynamic Performance

- Fault at Marcy 345 kV bus
- Severe contingency for overall system stability
- Simulation assumes vector-controlled wind turbines
- Wind generation improves post-fault response of interconnected power grid



Source: GE/NYSERDA

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Market Design

- Today's markets not designed with VG in mind
  - *Energy markets*
  - Capacity markets
  - Ancillary service markets
  - Price responsive load markets
- Market shortcomings must be identified and corrected
  - Energy market price volatility
  - *Capacity adequacy concerns*
  - Ramping products for flexibility
  - Slow reserve products

Importance of Policy

- Align market rules with forecast capability
  - Motivate wind generators to be in the market and to do a better job of forecasting
    - » Look at the MISO Dispatchable Intermittent Resource (DIR) policy with a 15 min schedule adjustment
    - » If the forecast cannot be used to adjust schedules to improve market operation and reduce cost by enabling imbalances to be traded in short-term forward markets, what good is it
    - » Adjust output schedules in a time frame meaningful to wind forecasts – 1.5 to 2.5 hours ahead is a "no man's land" between persistence and short term forecasts

Interestingly – Generators Do Not Appear To Command A Premium For Sub-Hourly Response

ISO	Day-Ahead $/MWH	Hour-Ahead $/MWH	5-Minute $/MWH	Average Within-Hour 5-Minute Range $/MWH
NYISO	$67.70	$64.93	$63.31	**$91.18**
ISO-NE	$81.38	$80.76	$81.22	**$24.40**
CAISO		$69.78	$68.32	**$59.87**
ERCOT[1]			$71.69	**$40.00**
MISO	$49.99	$48.62	$48.71	**$67.75**

[1]ERCOT currently operate a 15 minute sub-hourly market rather than a 5 minute market.

- *Average* day-ahead, hour-ahead, and 5-minute prices are nearly equal
  - 5-minute price is often slightly lower
  - No premium for flexible generation
- *Within hour* 5-minute price *range* is very large
  - Marginal generators receive a strong signal to move within the hour

Source: Brendan Kirby, UWIG 2009 Spring Workshop

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The NERC IVGTF Big Enchiladas

- Large balancing areas
- Faster markets
- Need for forecasting
- Remove barriers to transmission
- Probabilistic planning
- Incorporating need for flexibility in G&T planning
- PHEV and DSM as sources of flexibility
- Grid codes
- Dynamic models

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and the conclusion is…

- There are no fundamental technical barriers to the integration of 20-30% wind energy into the electrical system, but…
- It will not be accomplished with a business as usual scenario.
- There needs to be a continuing evolution of transmission planning policy, system operation practices and market development for this to be achieved.

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As they say in Texas …

- If all you ever do
  is all you ever done,
  then all you'll ever get
  is all you ever got!

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Outreach Activities

- IEEE *Power & Energy* magazine special issue on wind – 2005, 2007, 2009, 2011
- IEEE PES *Transactions on Sustainable Energy* special issue on wind energy
- Participation in Cigré wind activities
- Participation in IEEE
  - Wind Power Coordinating Committee
- NERC Wind Generator Task Force
- NERC Integration of Variable Gen TF

For More Information

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