Wind Integration: Status, Issues, and Studies

MIT Wind Integration Workshop:

Current Status and Future of Wind and the Grid

Cambridge, MA
January, 2011

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Utility Wind Integration Group

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UWIG

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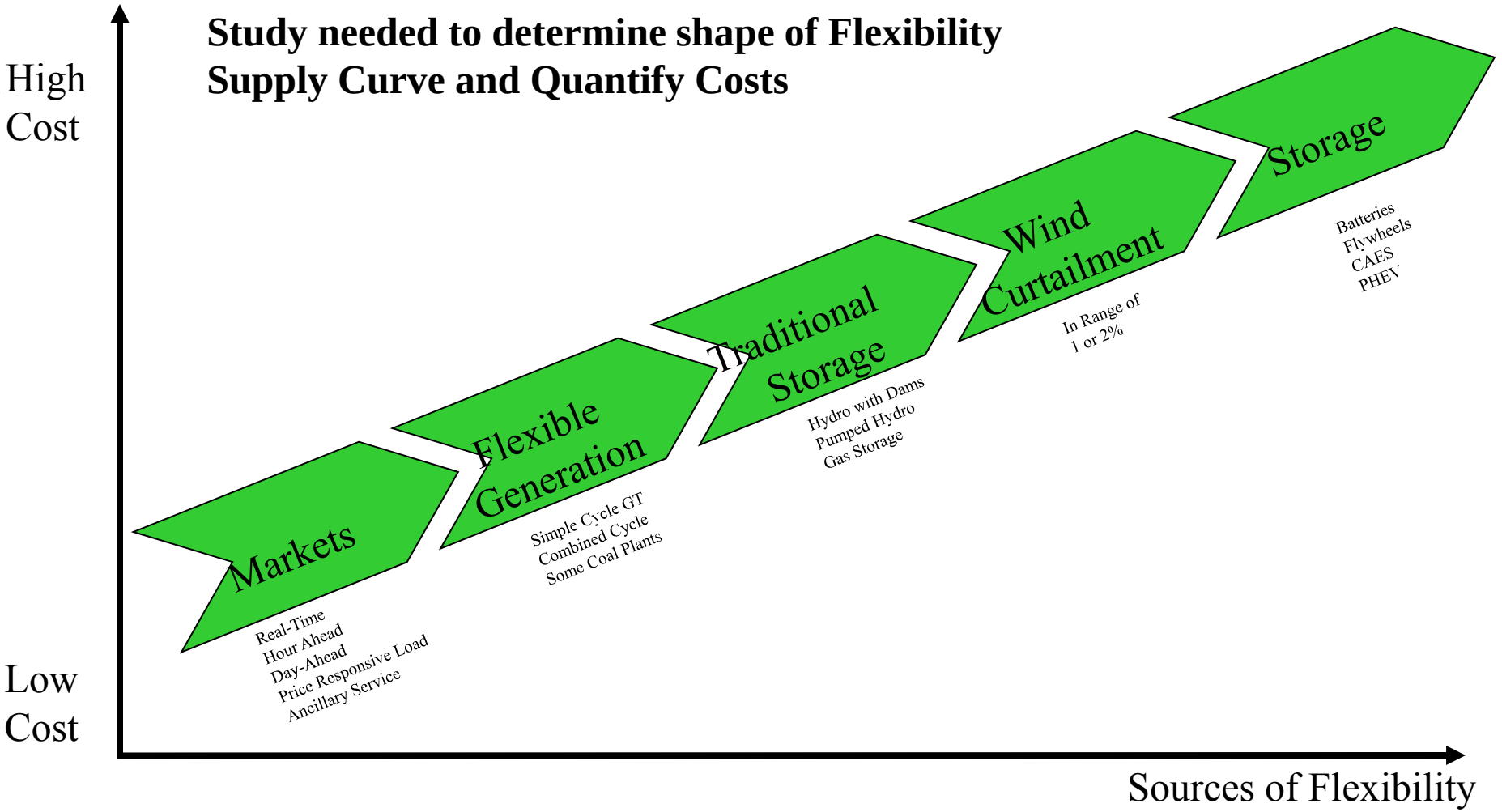
Outline of Topics

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

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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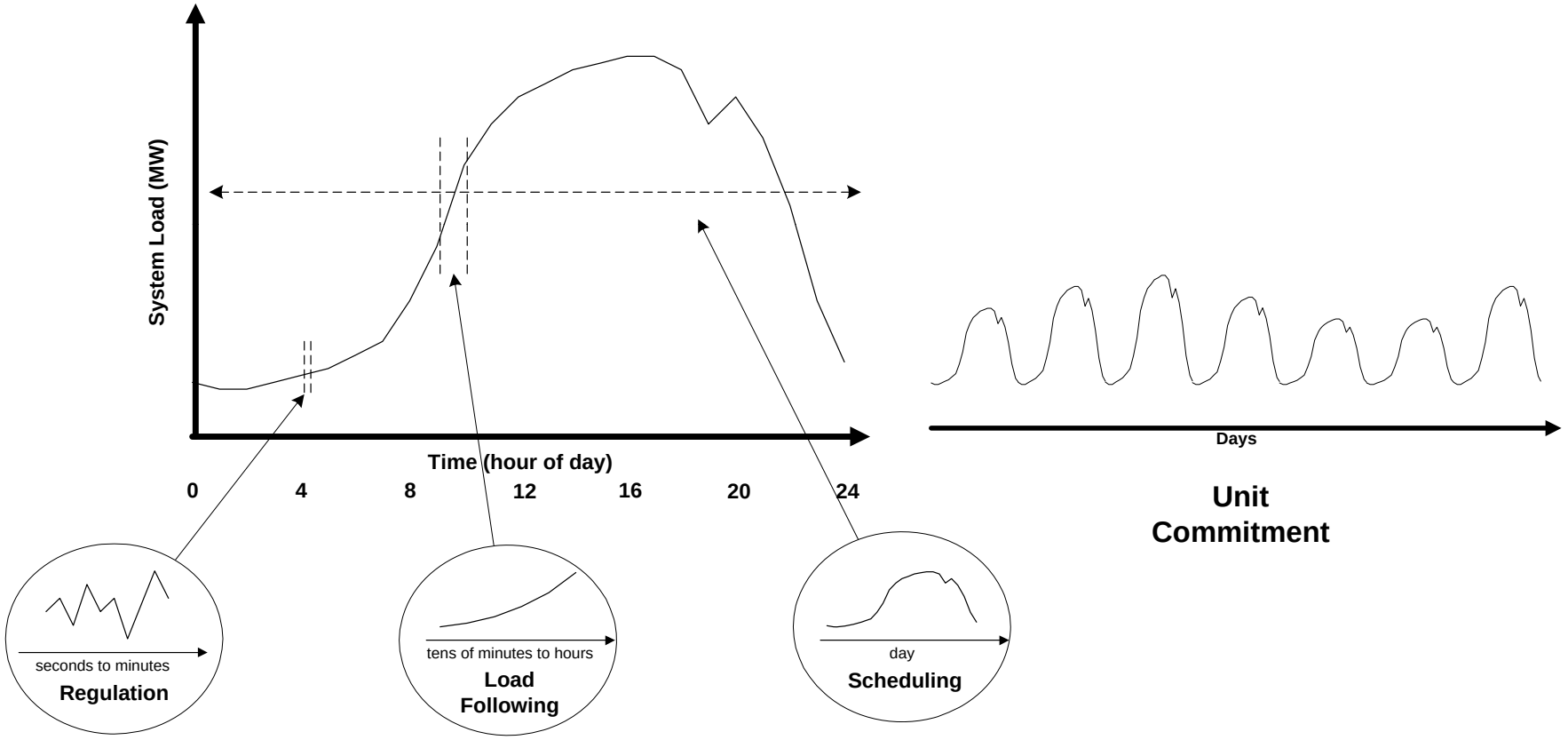
Time Scales of Interest



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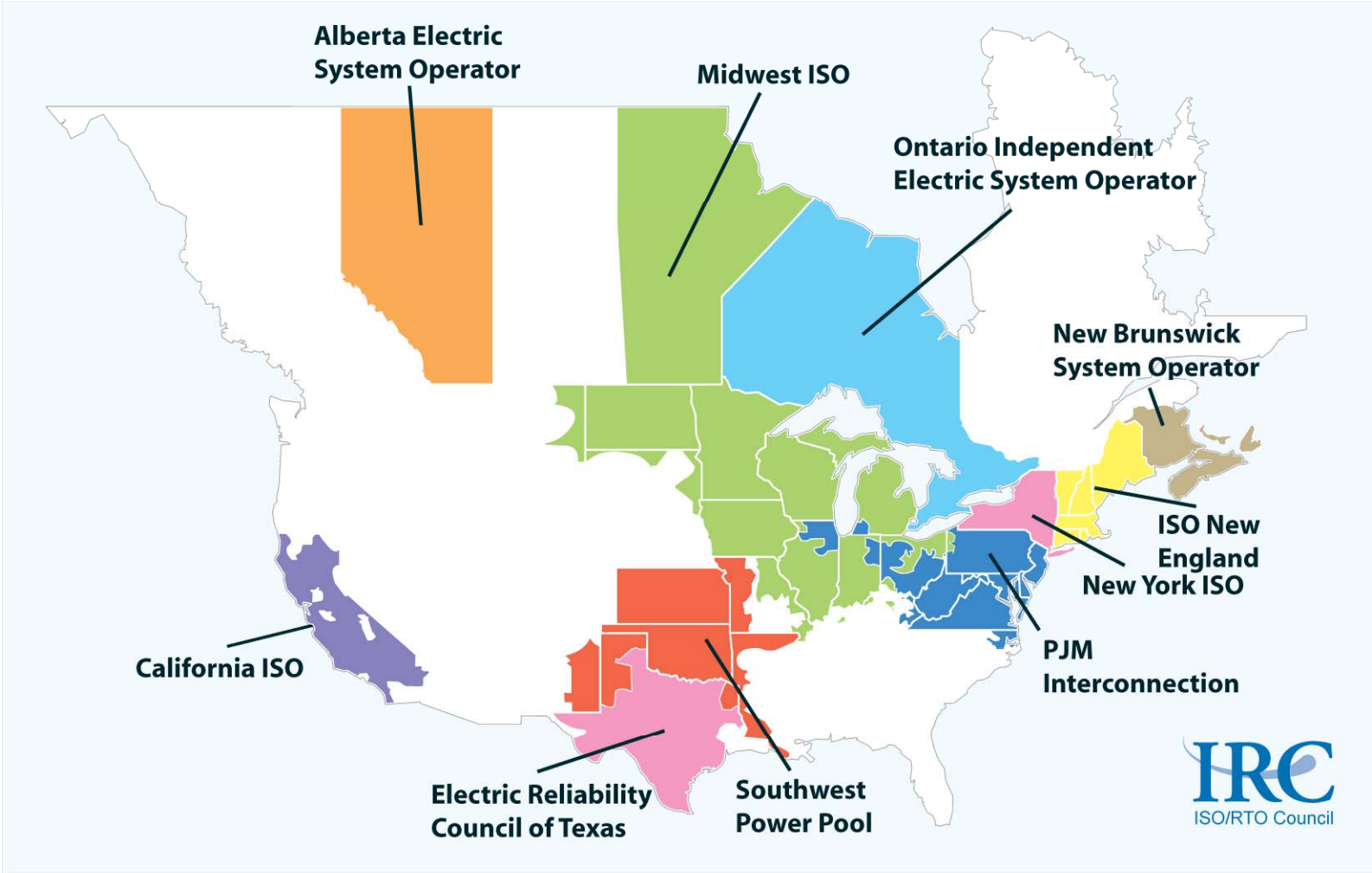
ISOs/RTOs in North America



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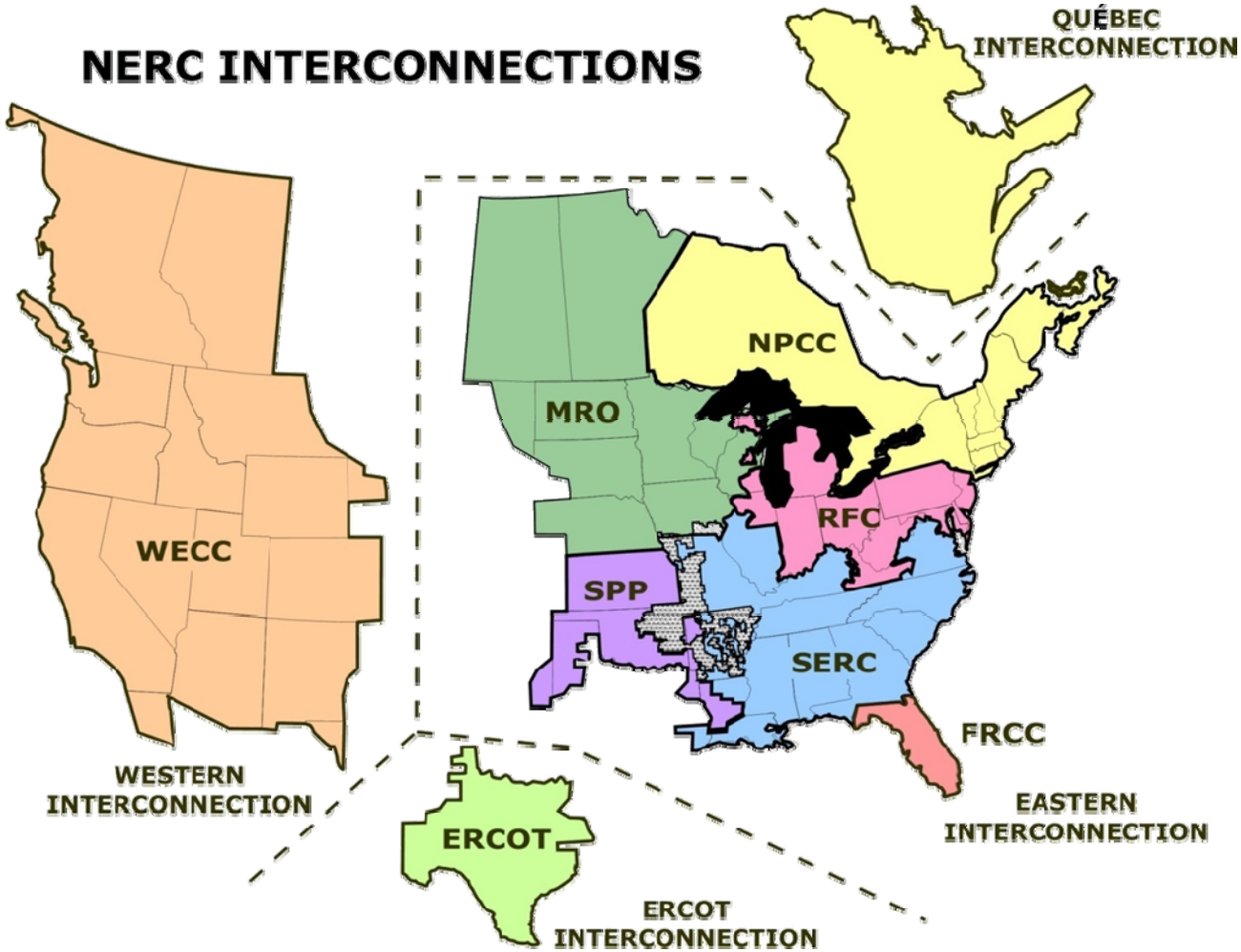
North American Interconnections



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

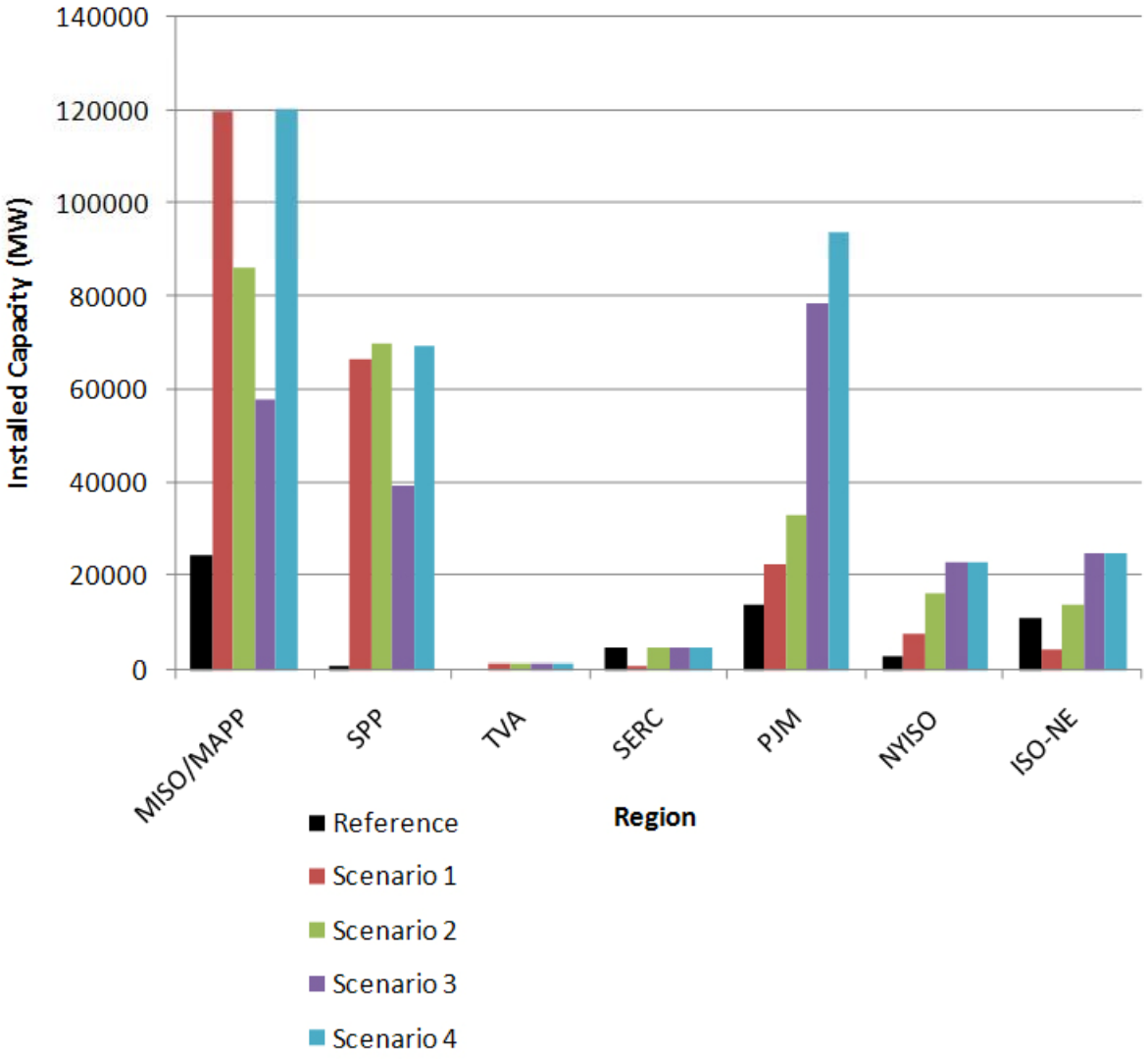
Source: Brendan Kirby, UWIG 2009 Spring Workshop

Variability is Expensive: Regulation Is The Most Expensive Ancillary Service

	2002	2003	2004	2005	2006	2007	2008
				Annual Average $/MW-hr			
			California (Reg = up + dn)				
Regulation	26.9	35.5	28.7	35.2	38.5	26.1	33.4
Spin	4.3	6.4	7.9	9.9	8.4	4.5	6.0
Non-Spin	1.8	3.6	4.7	3.2	2.5	2.8	1.3
Replacement	0.90	2.9	2.5	1.9	1.5	2.0	1.4
			ERCOT (Reg = up + dn)				
Regulation		16.9	22.6	38.6	25.2	21.4	43.1
Responsive		7.3	8.3	16.6	14.6	12.6	27.2
Non-Spin		3.2	1.9	6.1	4.2	3.0	4.4
			New York				
Regulation	18.6	28.3	22.6	39.6	55.7	56.3	59.5
Spin	3.0	4.3	2.4	7.6	8.4	6.8	10.1
Non Spin	1.5	1.0	0.3	1.5	2.3	2.7	3.1
30 Minute	1.2	1.0	0.3	0.4	0.6	0.9	1.1
			New England (Reg +"mileage")				
Regulation			54.64	30.22	22.26	12.65	13.75
Spin					0.27	0.41	1.67
10 Minute					0.13	0.34	1.21
30 Minute					0.01	0.09	0.06

Source: Brendan Kirby, UWIG 2009 Spring Workshop

Eastern Wind Integration and Transmission Study (EWITS) Scenarios



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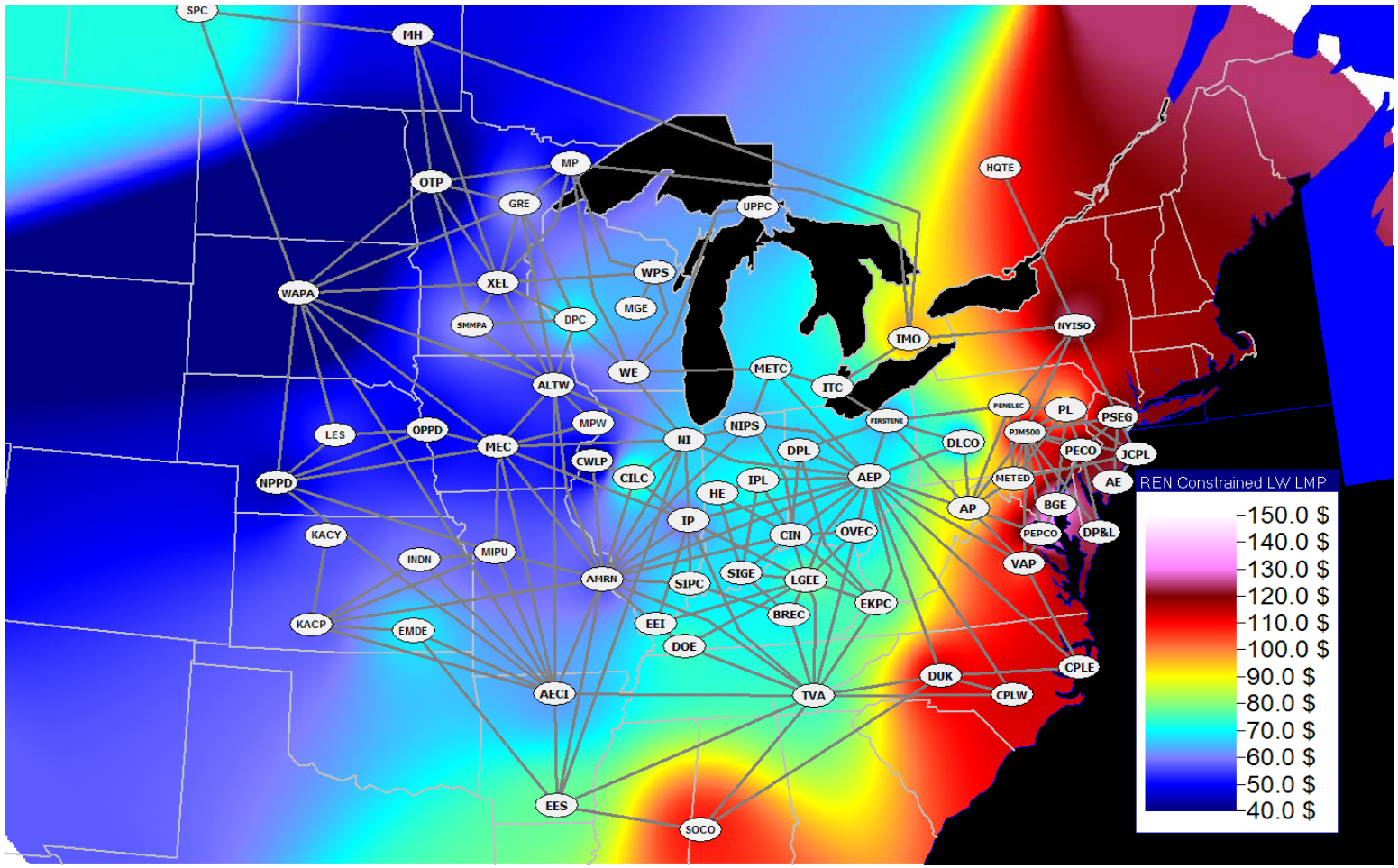
Full Constrained Case
Annual Load Weighted LMP



Source: MISO

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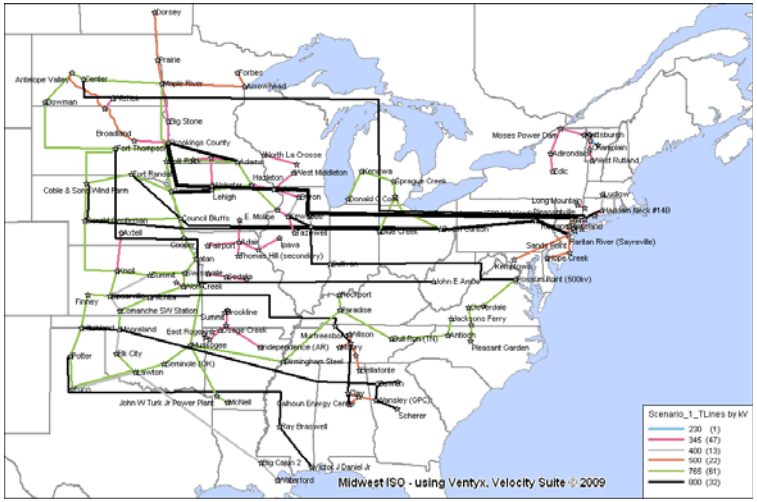
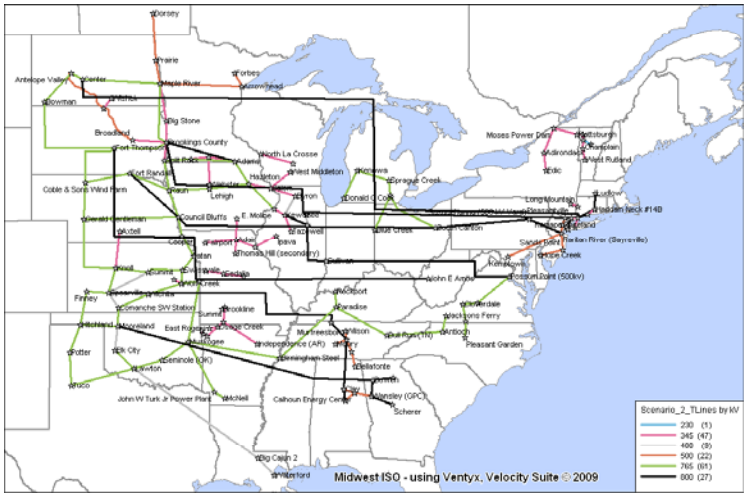
Overlays for 4 Scenarios

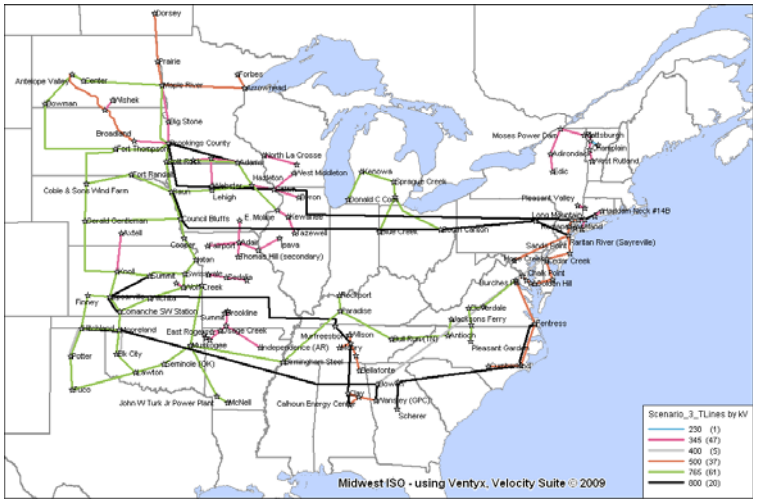
Scenario 1



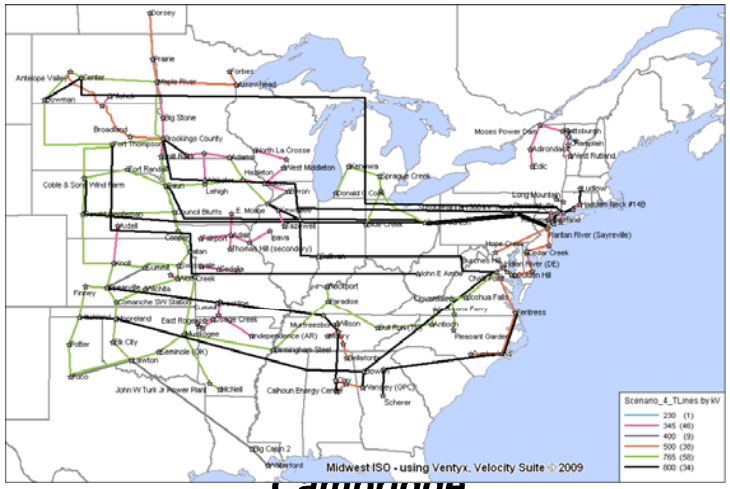
Scenario 2



Scenario 3

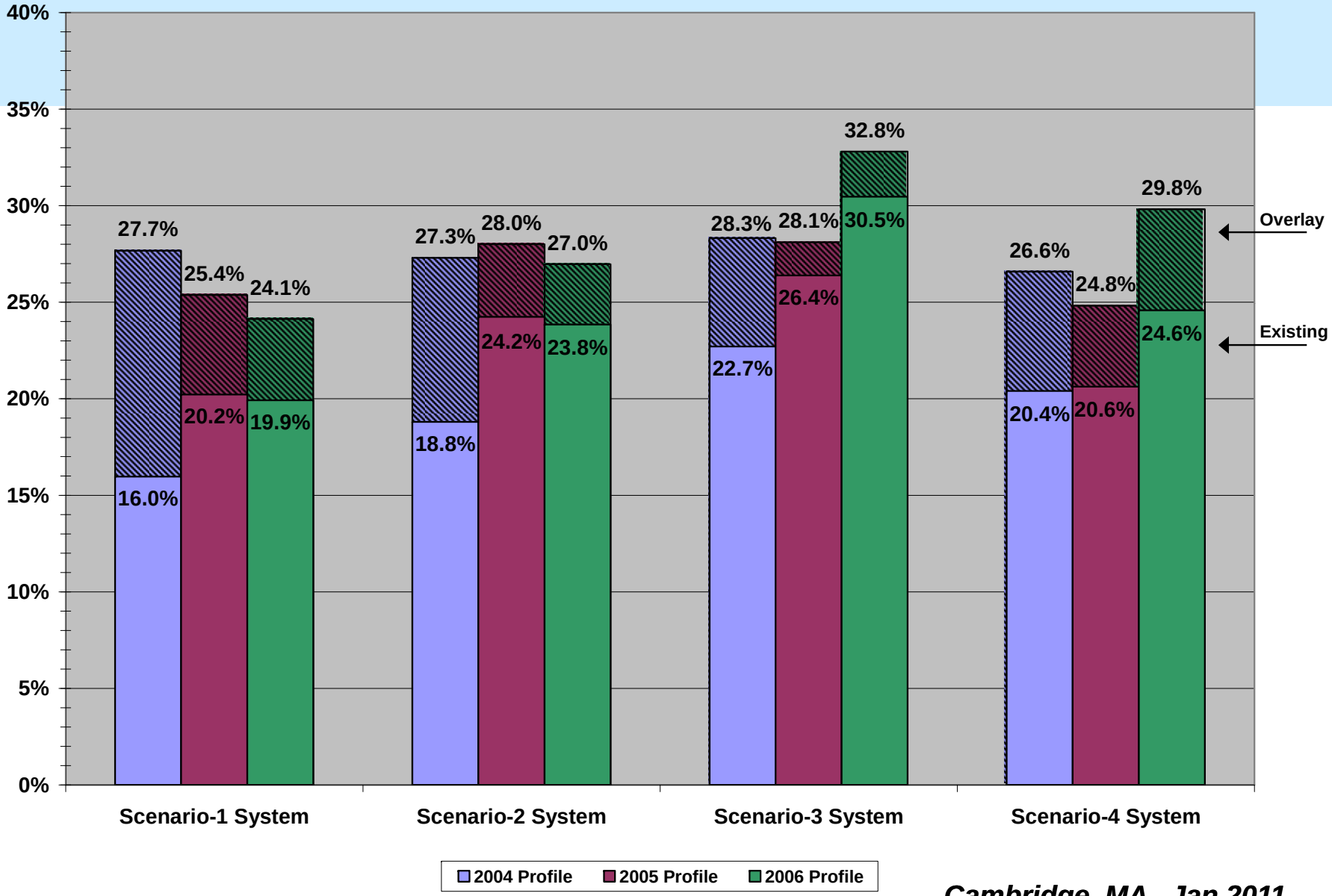


Scenario 4

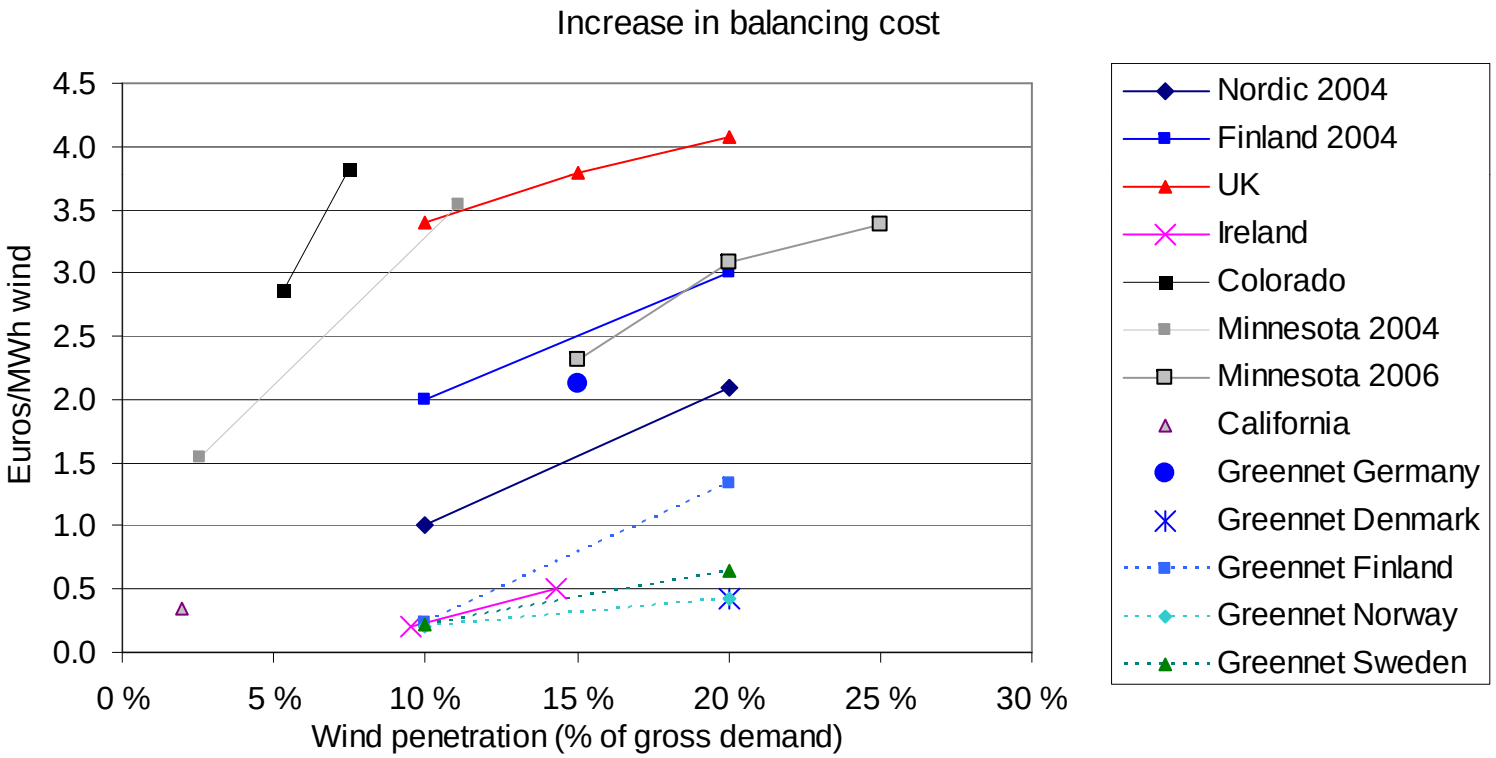


Study System ELCC Scenarios (1 - 4)

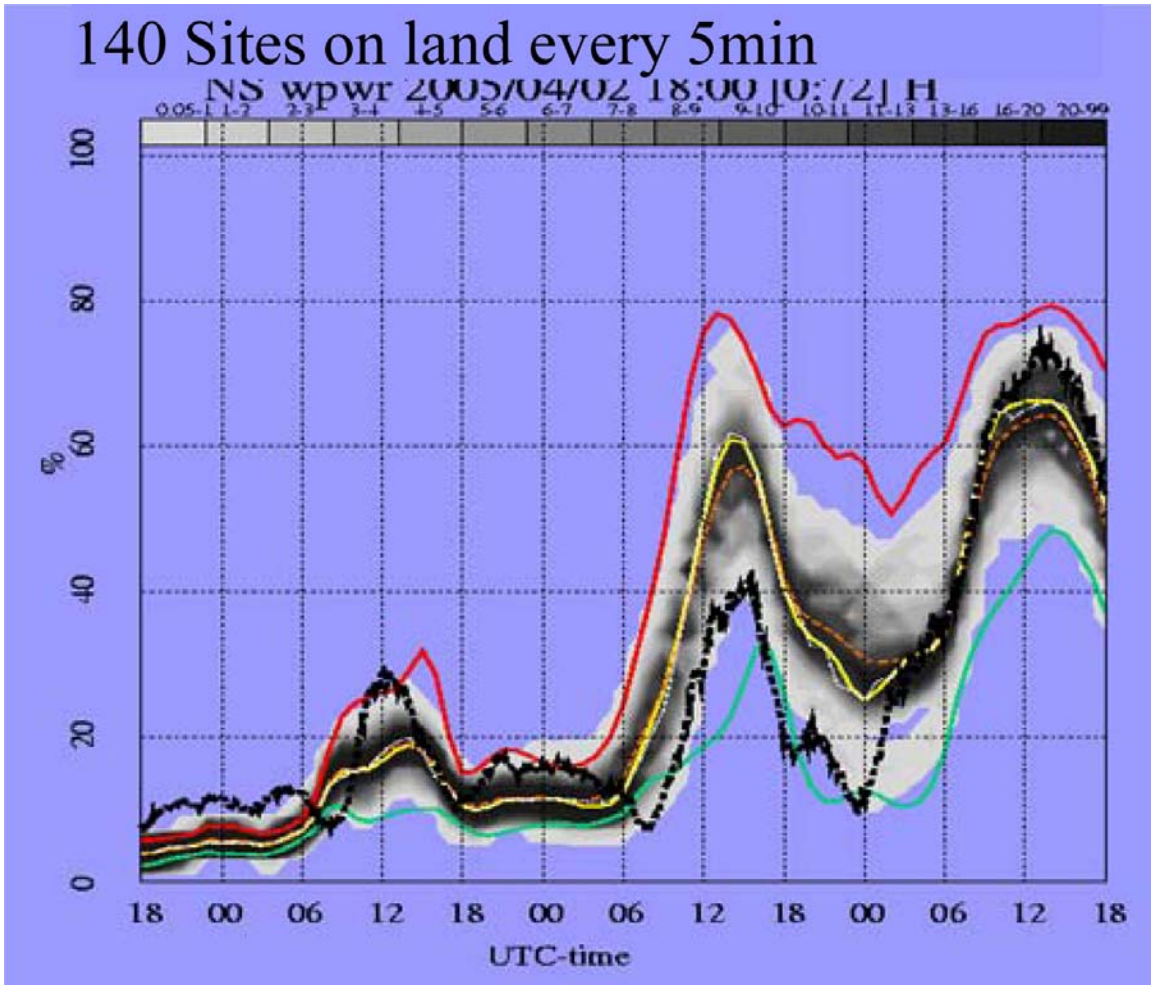
Existing & Overlay Transmission Tie Limits - ELCC (%) {Shaded Area shows Increased ELCC of Overlay}



Increased Balancing Cost



Forecasting and Balancing Markets Reduce Impacts



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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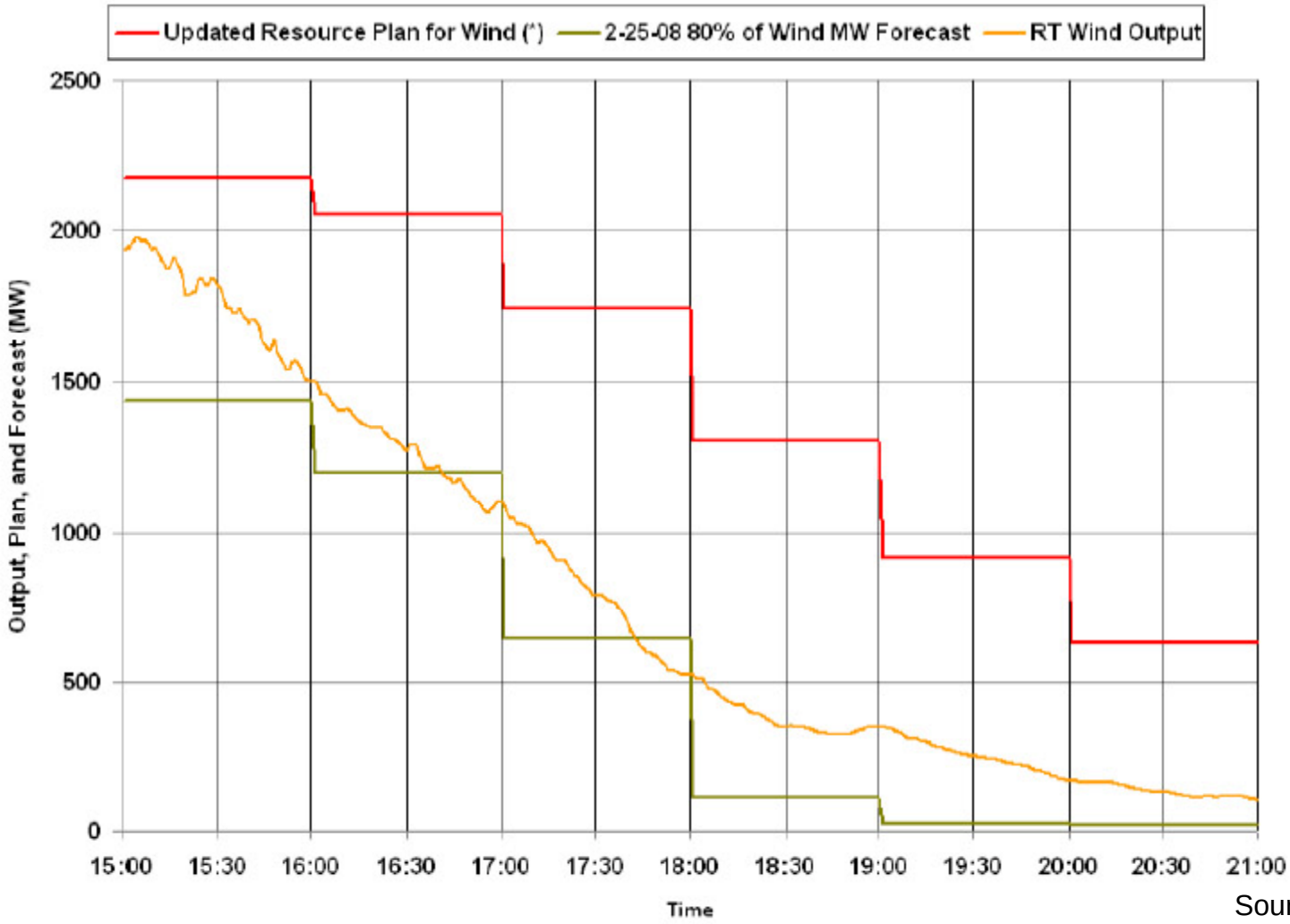
ERCOT Wind Generation – Feb. 26, 2008



Source: ERCOT

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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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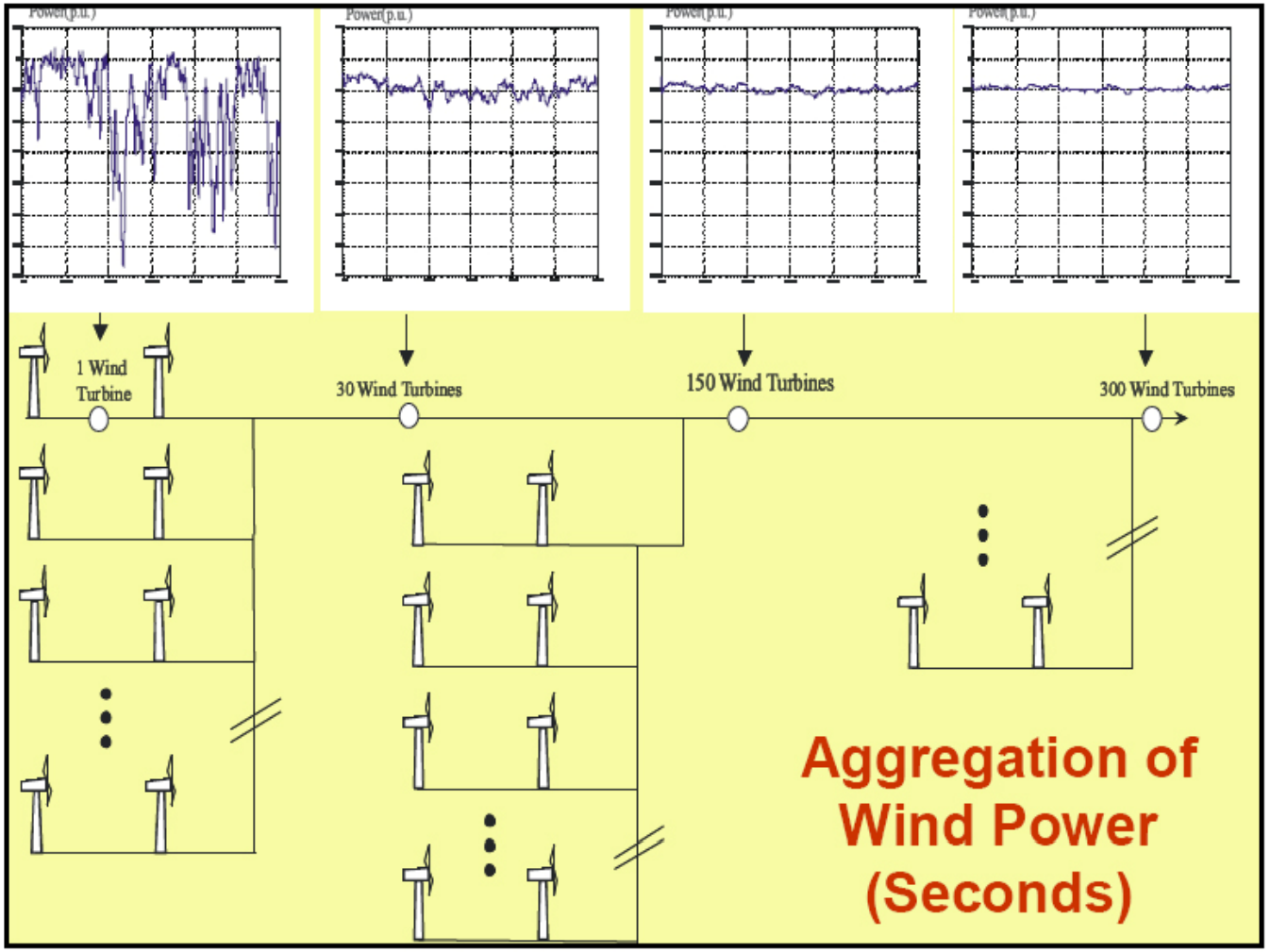
The Power of Aggregation



Source: Thomas Ackermann, Energynautics

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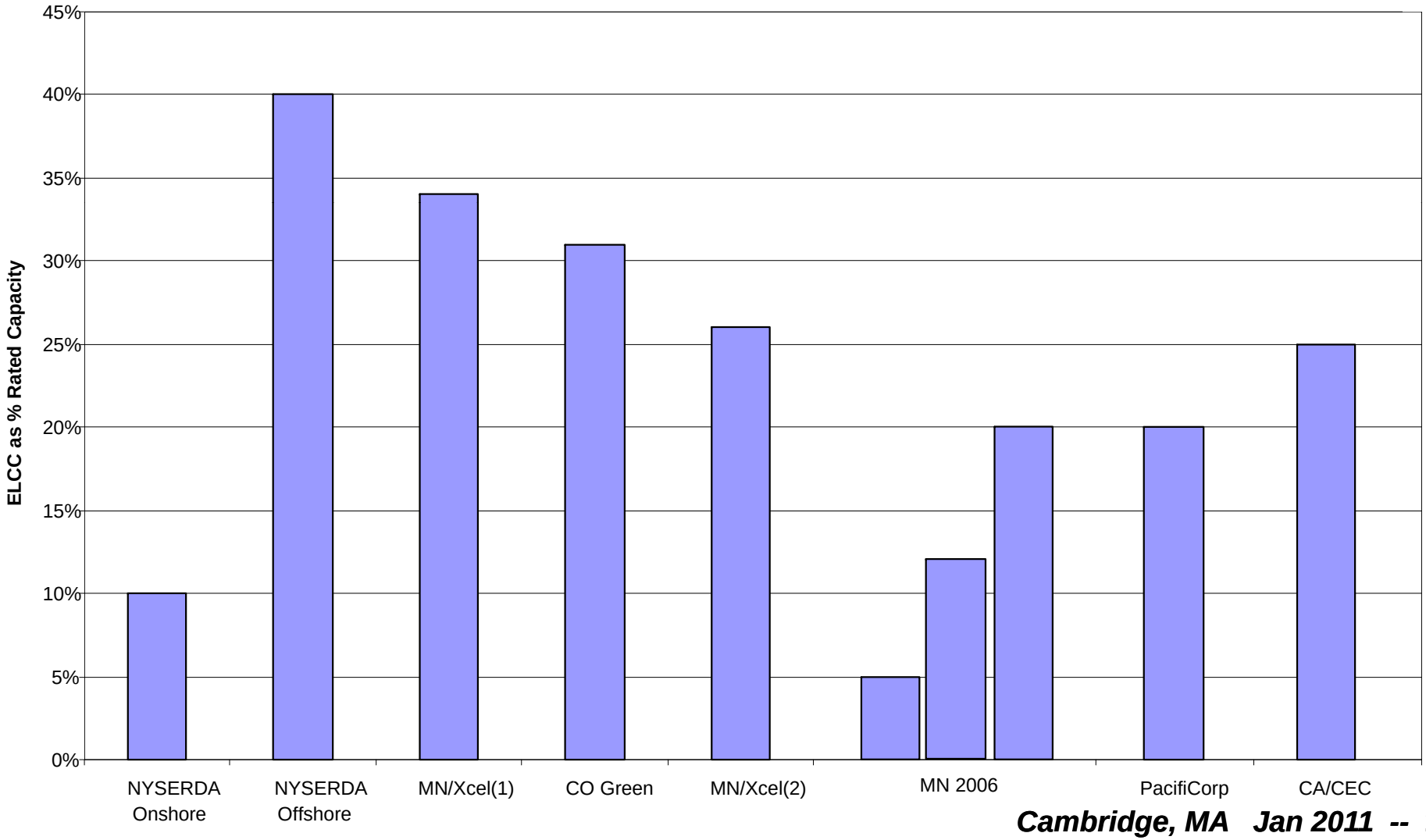
What To Do When the Wind Doesn't Blow

- 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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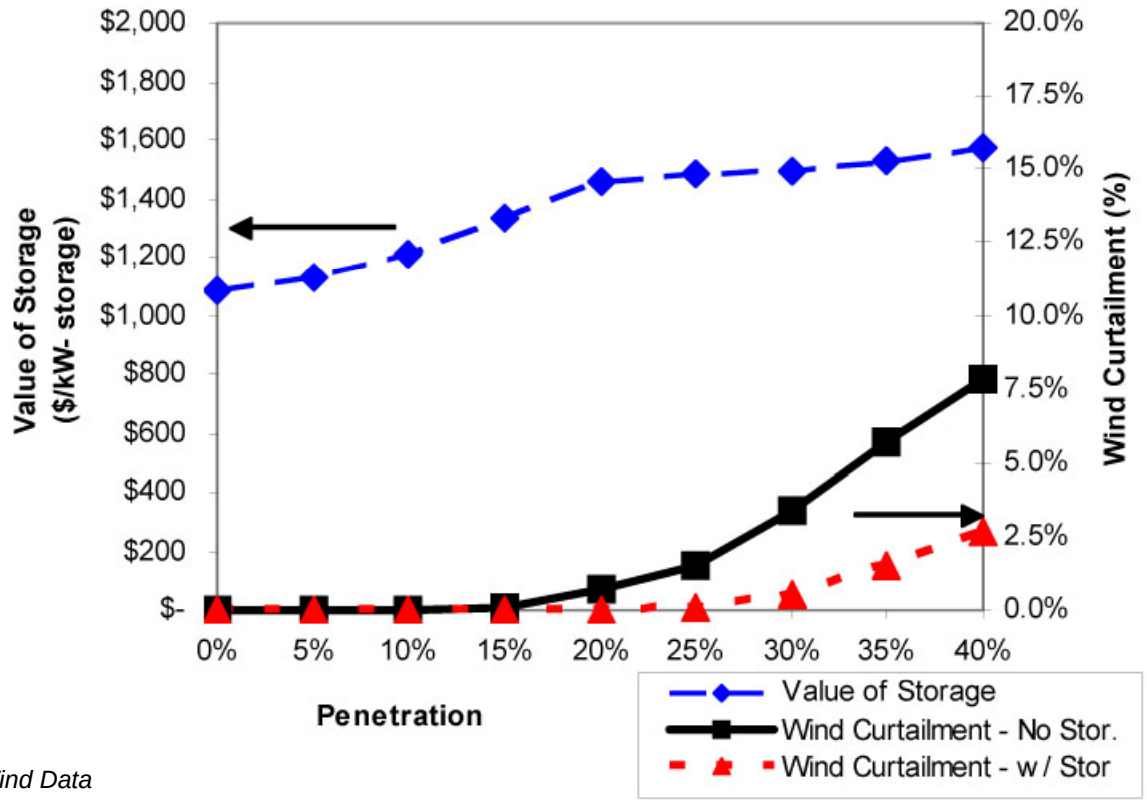
What About Energy Storage?

- 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

Value of Electrical Storage - Wind

- "Medium run" ~ 80% Incumbent Generation



High Diversity Wind Data
Source: LBNL

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

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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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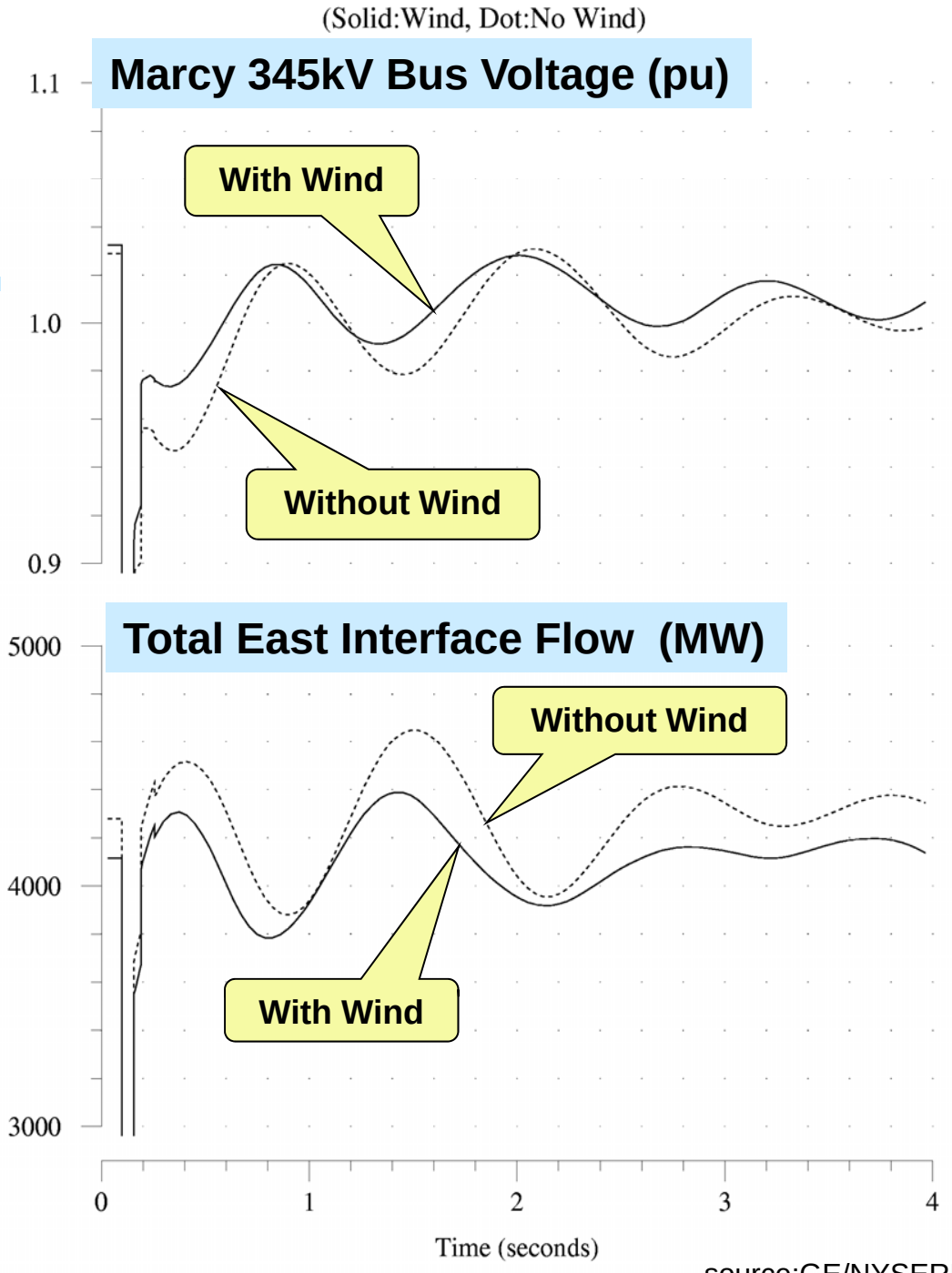
Impact of Wind Generation on System Dynamic Performance

- 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

Conclusions from a Recent GE Case Study

- WECC 20% Electricity from Wind Scenario
  - Systems with high wind penetration can exhibit superior frequency performance
  - Presently available wind plant controls can contribute positively to system frequency performance
  - "It is *possible* for systems with wind generation to experience degraded frequency performance"
  - "Statements that wind generation *necessarily* results in degraded frequency performance are *incorrect*"

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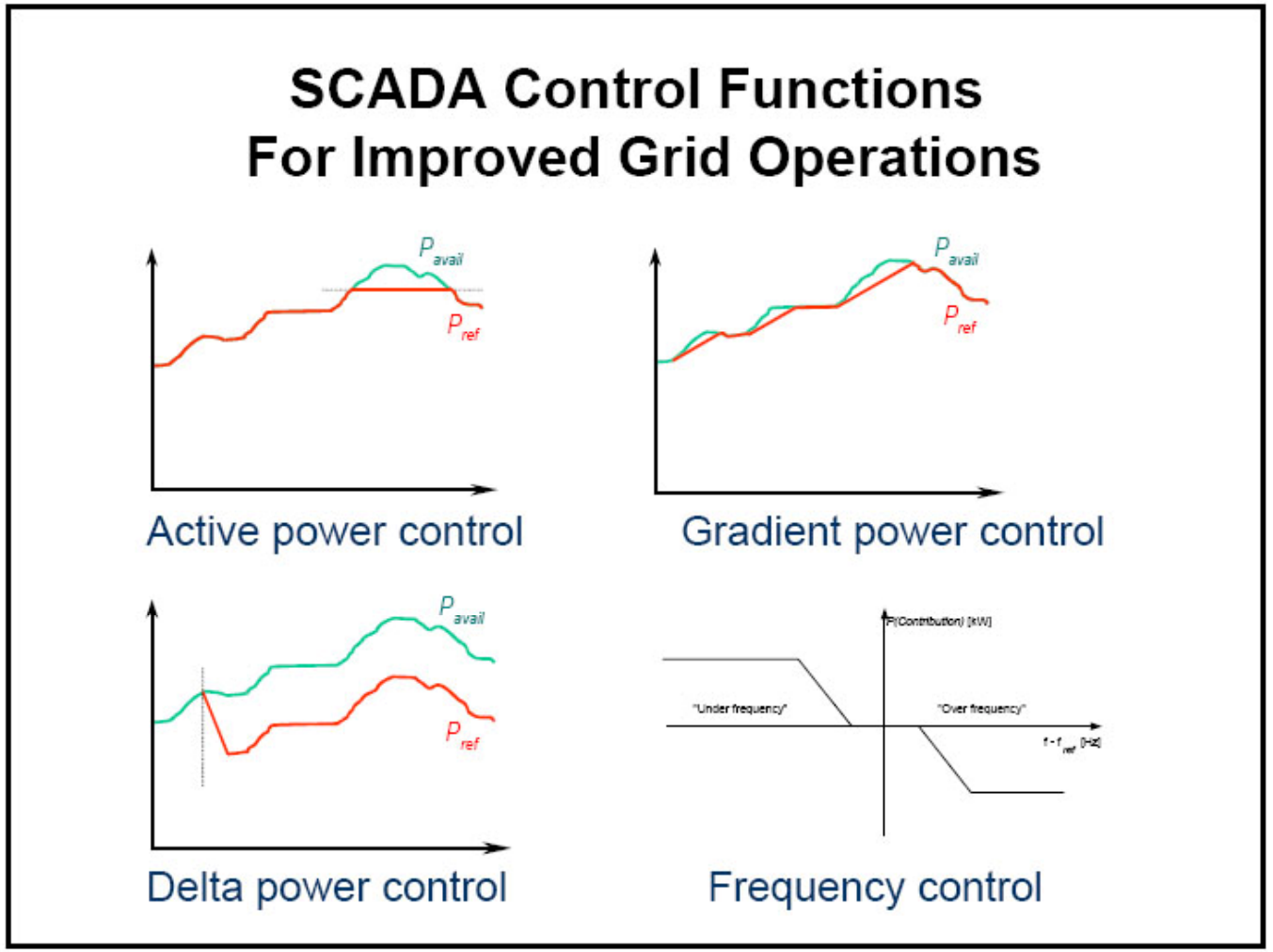
Turbine Technology Advances Reduce Impacts



Wind Plant Control Capability

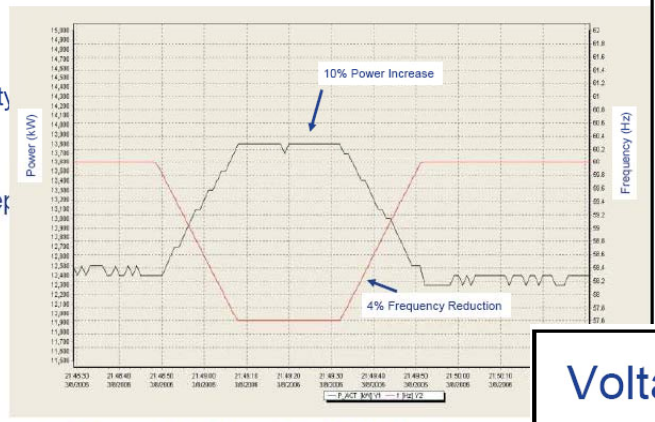
Under-Frequency Droop Response

Settings:

90% Wind Capacity

4% Droop

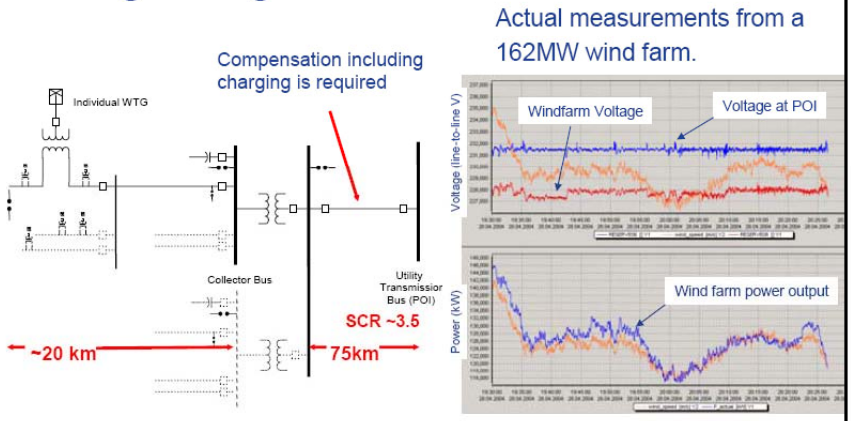
4% Frequency Step @0.125Hz/sec



10% Increase in Farm Watts with 4% Under-Frequency

Voltage Regulation

Actual measurements from a 162MW wind farm.



Windfarm Control Minimizes Grid Voltage Fluctuations With Varying Wind Conditions

GE imagination at work

Source: GE Energy

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National Transmission Policy

- National policy debate stimulated by two activities:
  - Success of Texas CREZ process
  - Growing recognition that RPS goals cannot be met without significant transmission build-out
- Three major transmission bills proposed in US Senate in 2009
- All different, but all have three common elements:
  - Interconnection-wide transmission planning
  - High voltage backbone with broad cost allocation
  - Federal backstop siting authority
- Growing recognition of critical need for transmission

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NERC IVGTF Report Recommendations

- Broad based industry effort with participation of utilities, ISOs, turbine manufacturers, project developers, research organizations, consultants, trade associations
- Requested by OC/PC in recognition of the increasing large role wind power will play
- Chaired by Warren Frost, AESO with NERC staaff support provided by Mark Lauby
- Just released report, which will lead to a review and likely update of NERC standards

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The Big Enchaladas

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

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and the conclusion is…

- There are no fundamental technical barriers to the integration of 20% 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 policy and market development for this to be achieved.

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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