Lessons Learned in Wind Integration

Dan Woodfin

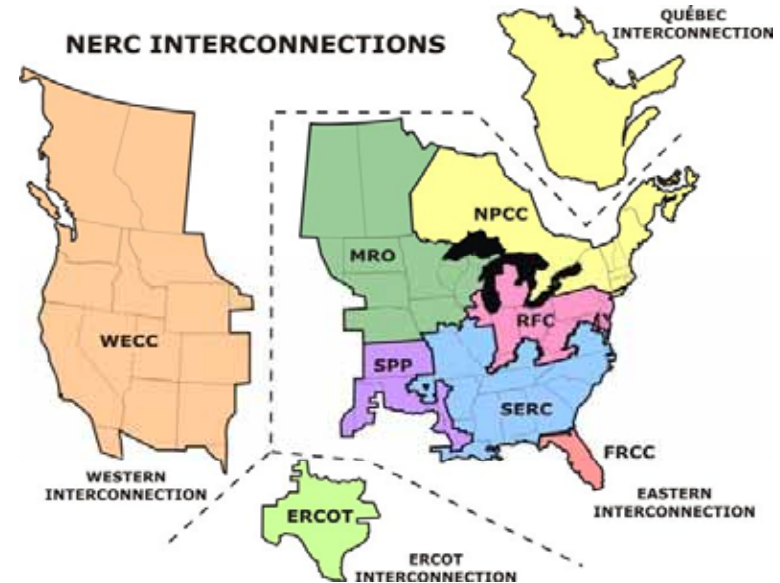**Director, System Operations**

NECPUC Symposium

May 21, 2012

The ERCOT Region

The interconnected electrical system serving most of Texas, with limited external connections

- 75% of Texas land; 85% of Texas load
- 68,294 MW peak demand (set August 3, 2011)
- More than 40,000 miles of transmission lines
- 2 DC ties with SPP; 3 DC ties with Mexico; 1106 MW total
- 550+ generation units

NERC INTERCONNECTIONS

QUÉBEC INTERCONNECTION

NPCC
MRO
WECC
RFC
SPP
SERC
FRCC

WESTERN INTERCONNECTION
ERCOT
EASTERN INTERCONNECTION
ERCOT INTERCONNECTION

Markets

- Fully unbundled Wholesale market
    - ERCOT operates a single Control Area with ancillary services markets
    - Generators are paid Locational Marginal Prices (LMPs) at their node
    - Load-serving entities pay averaged load-zone prices
- Full Retail competition except in municipal & co-op utility areas

Transmission Service

- All transmission costs are rolled-in to single postage-stamp rate paid by load
- All generators have, essentially, "network service"
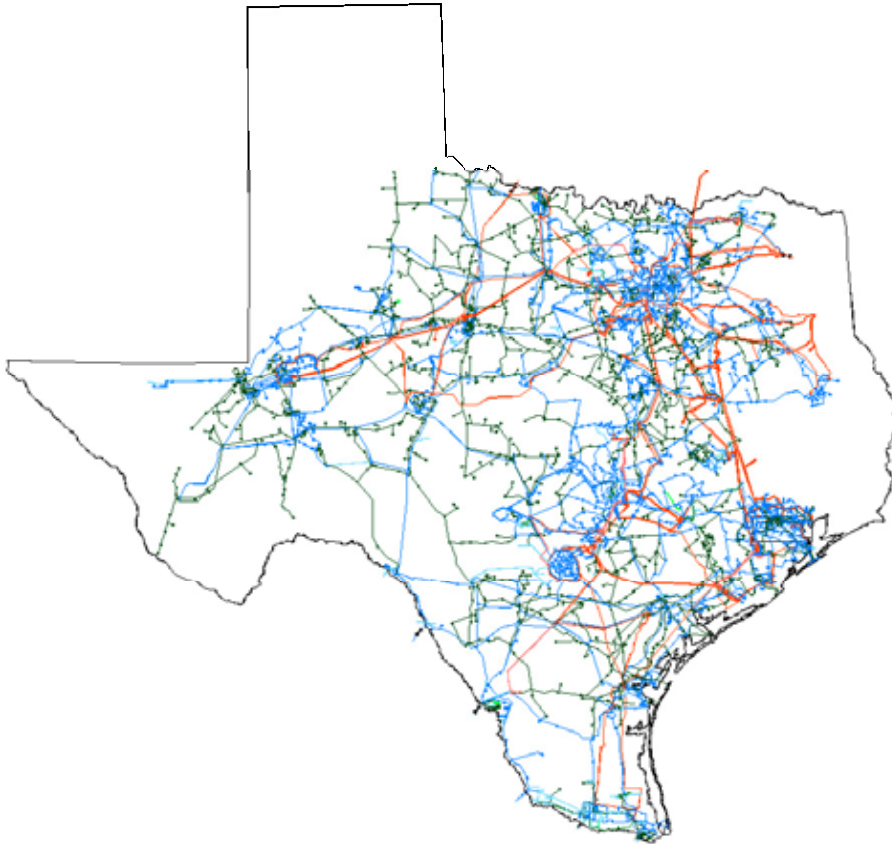
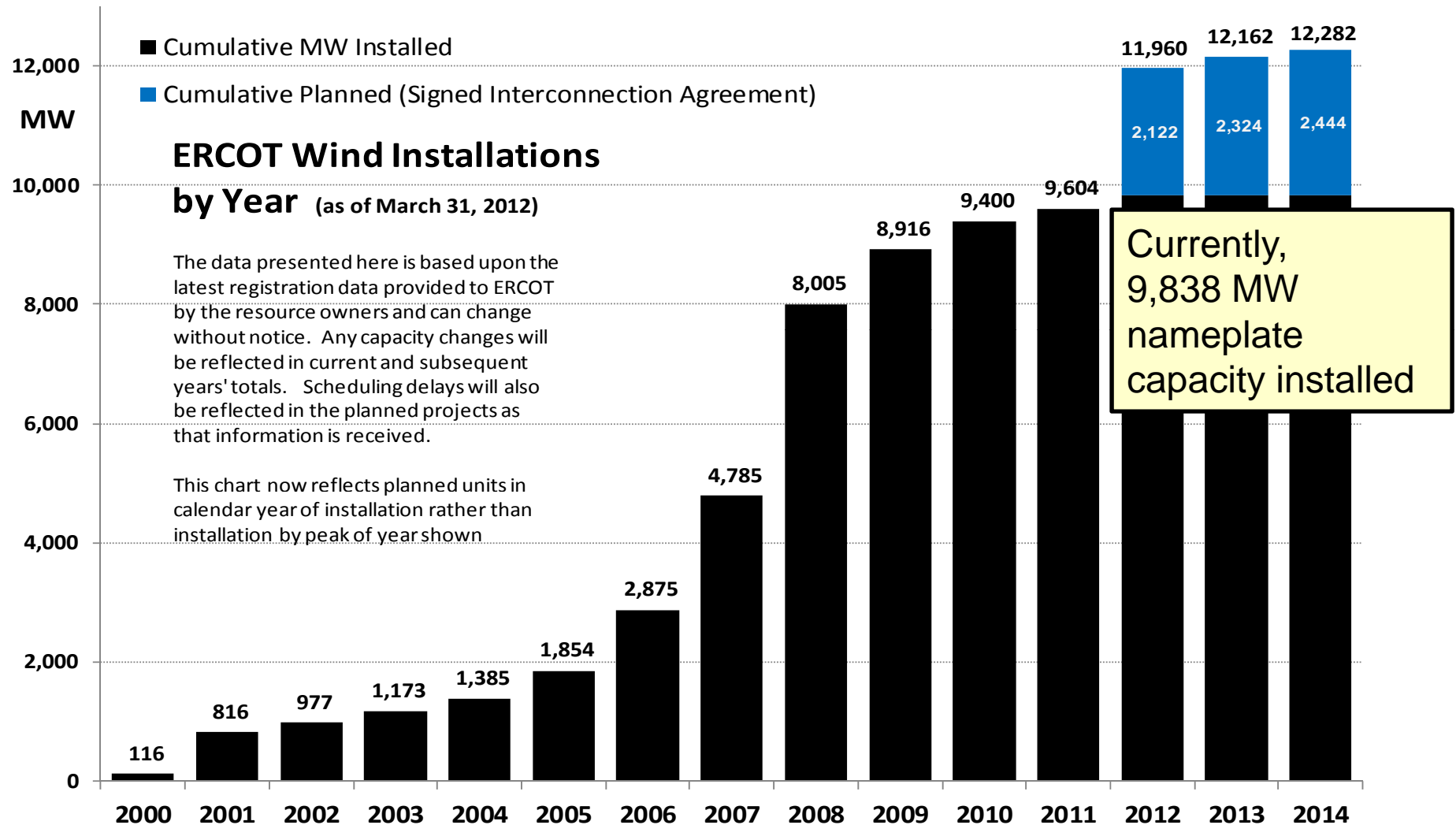# ERCOT ISO

ERCOT Inc.:

A non-profit corporation designated the "Independent Organization" under state law and assigned these responsibilities [Texas Public Utility Regulatory Act (PURA) 39.151]:

- Maintaining System Reliability
- Ensuring Open Access to Transmission
- Facilitating the Competitive Wholesale Market
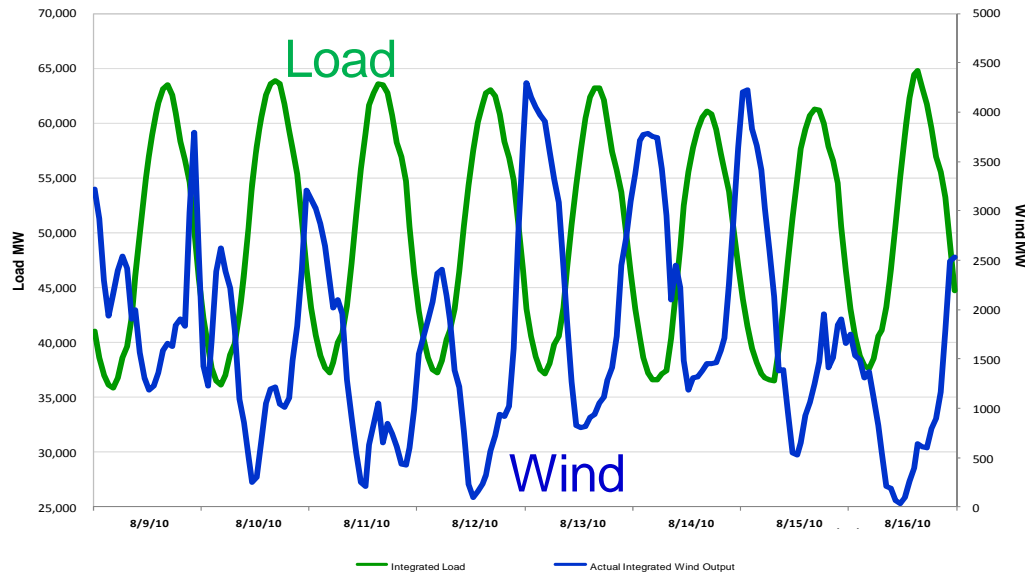- Facilitating the Competitive Retail Market

Regulatory Characteristics:

- ERCOT is regulated by the Texas Public Utility Commission with oversight by the Texas Legislature
- ERCOT is not a market participant and does not own generation or transmission/distribution wires
- ERCOT is the sole Reliability Coordinator, Balancing Authority, Planning Authority, Interchange Authority, and Transmission Service Provider for the ERCOT Region

Installed Wind Generation in ERCOT

Chart: ERCOT Wind Installations by Year (as of March 31, 2012)

Legend:
- Cumulative MW Installed (black)
- Cumulative Planned (Signed Interconnection Agreement) (blue)

ERCOT Wind Installations by Year (as of March 31, 2012)

The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received.

This chart now reflects planned units in calendar year of installation rather than installation by peak of year shown

Currently, 9,838 MW nameplate capacity installed

Data values:
- 2000: 116
- 2001: 816
- 2002: 977
- 2003: 1,173
- 2004: 1,385
- 2005: 1,854
- 2006: 2,875
- 2007: 4,785
- 2008: 8,005
- 2009: 8,916
- 2010: 9,400
- 2011: 9,604
- 2012: 11,960 (planned 2,122)
- 2013: 12,162 (planned 2,324)
- 2014: 12,282 (planned 2,444)

Wind Output

- **Peak wind generation output on 7,925MW on 4/13/12**
  - 20.1% of Load at the time
- **Maximum Percent of Load Served by Wind was 28.2% on 3/6/12**
- **8.7% of Nameplate Capacity of wind counted towards reserve margin**

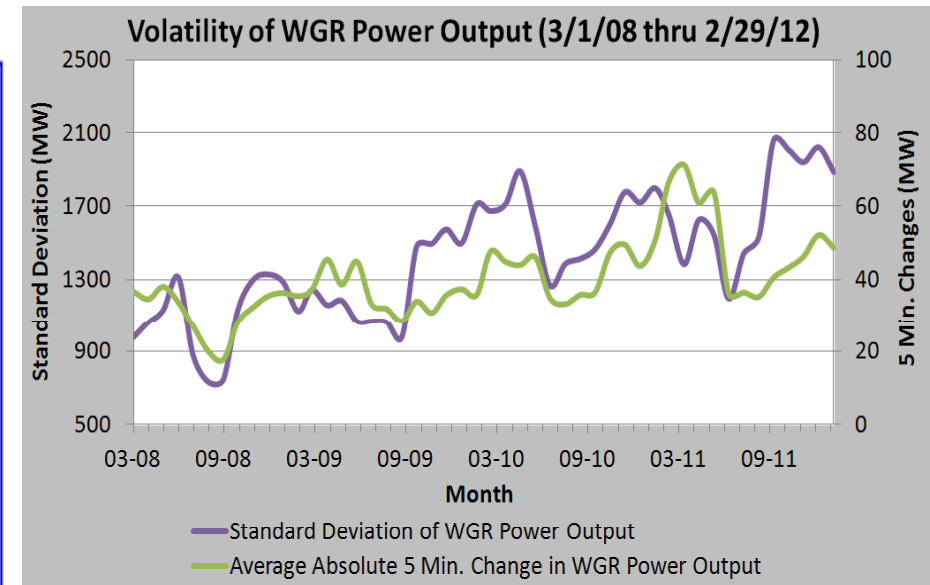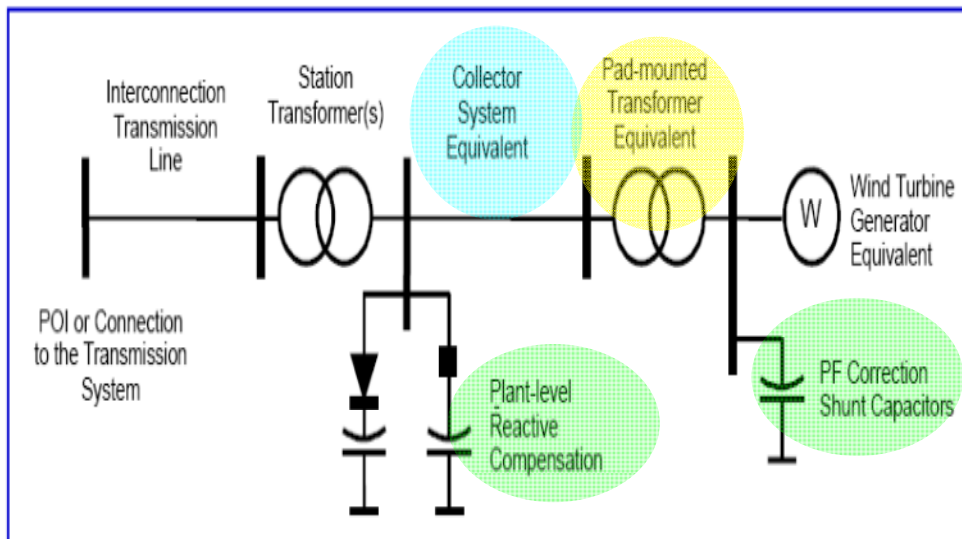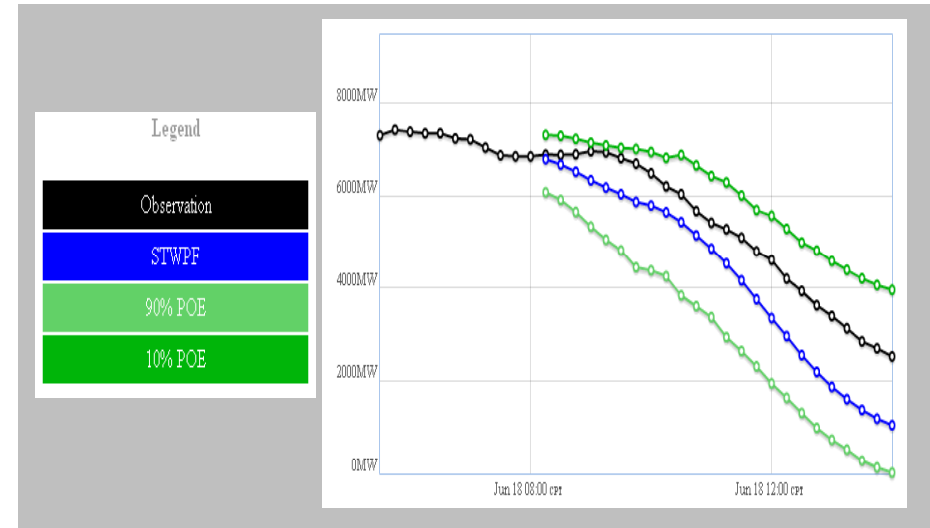% Energy Produced by Fuel Type 2011
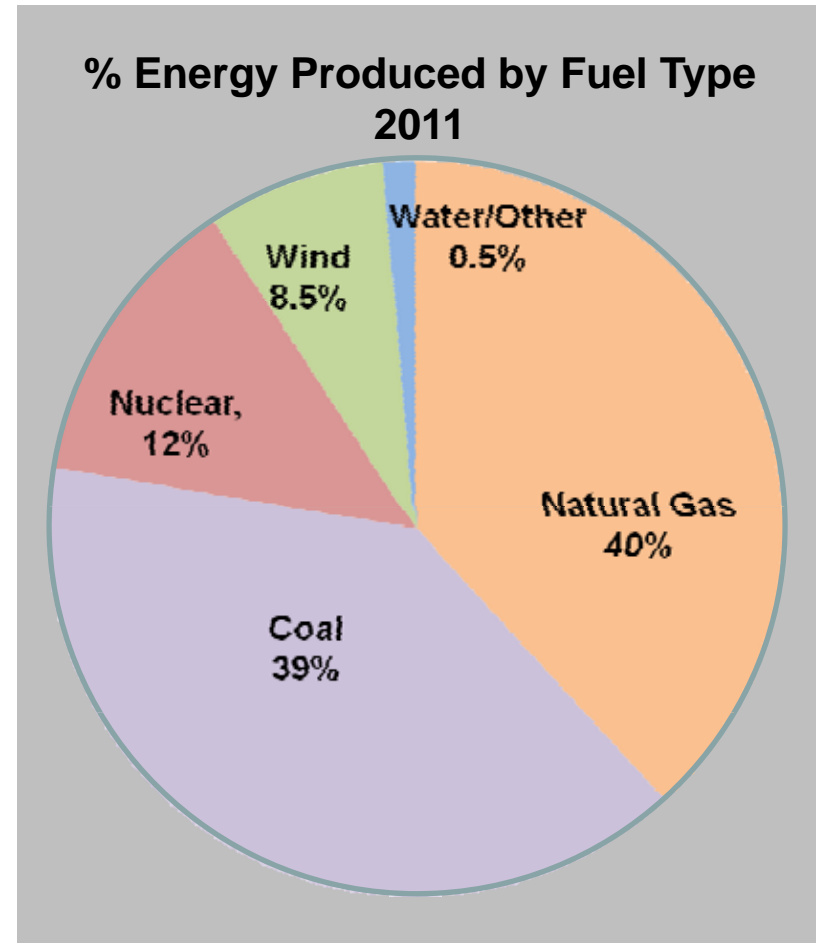
Competitive Renewable Energy Zones (CREZ)

- **Transmission Plan designed to serve approximately 18GW:**
  - ~4600 circuit miles of 345 kV
  - $6.7 billion project cost
- **All line certification cases completed**
  - Construction underway
  - All lines expected to be complete by end of 2013
- **Lines are open-access; use not limited to wind**

Competitive Renewable Energy Zones (CREZ)
Transmission Optimization Study
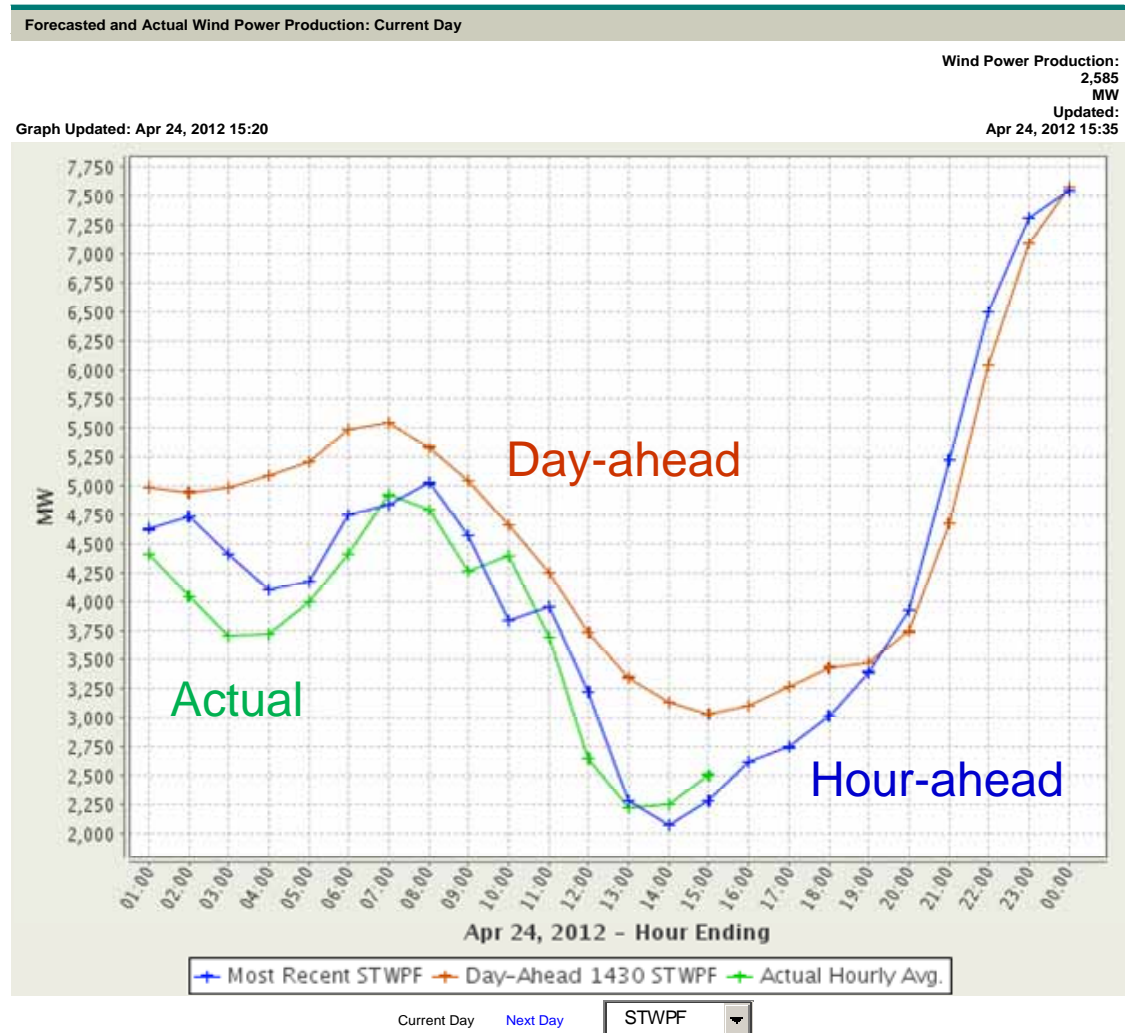Figure 5: Scenario 2

SCALE: 1" = 25 MILES
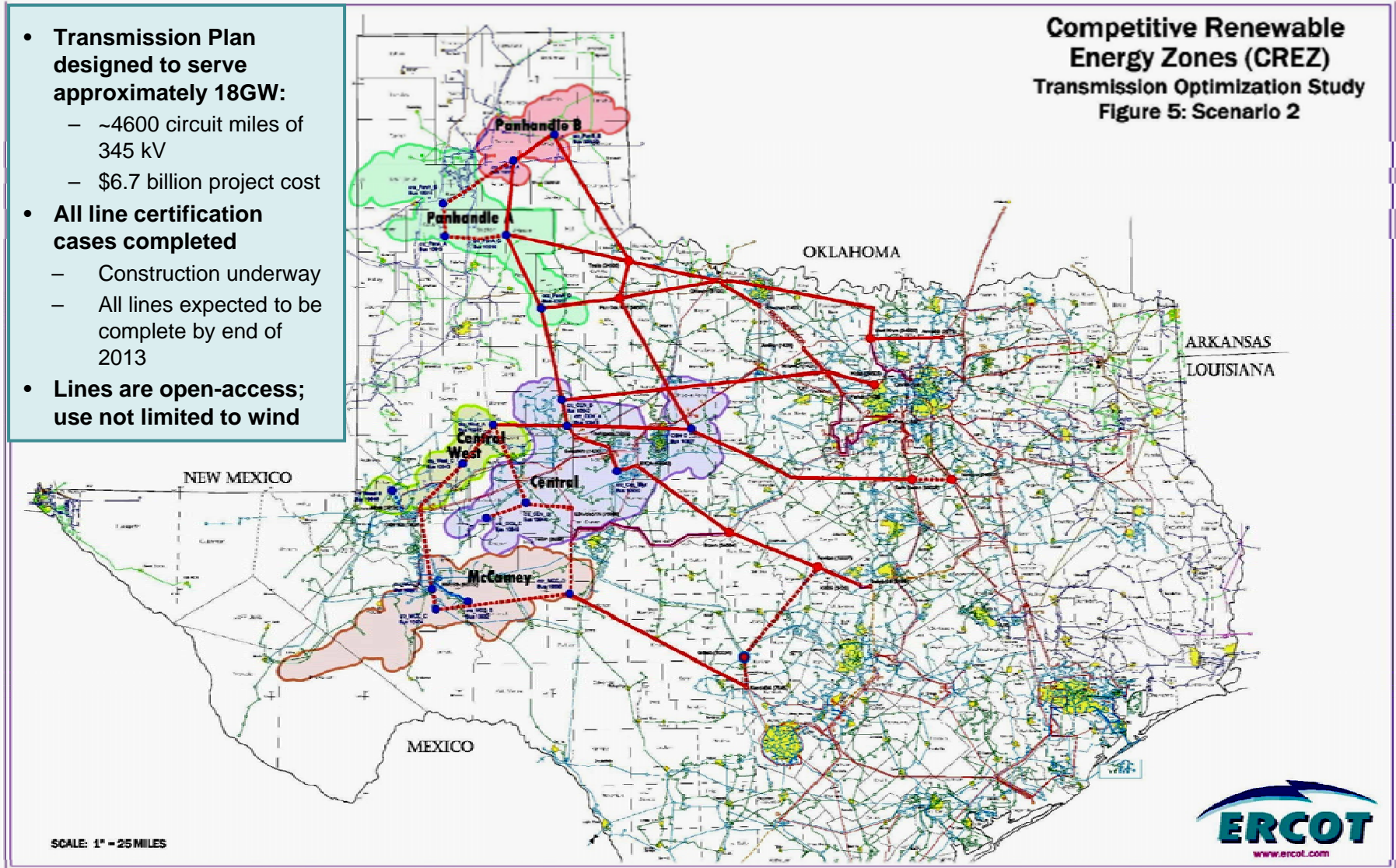
Operational Challenges for Wind Integration

- ## **Uncertainty**
- ## **Variability**
- ## **Interconnection**

Legend
- Observation (black)
- STWPF (blue)
- 90% POE (light green)
- 10% POE (green)

Volatility of WGR Power Output (3/1/08 thru 2/29/12)

— Standard Deviation of WGR Power Output
— Average Absolute 5 Min. Change in WGR Power Output

ERCOT

- ## Wind power production forecast

  – Hourly 50% probability of exceedance forecast for a rolling 48 hour period

  – Provided for each wind farm and total for system

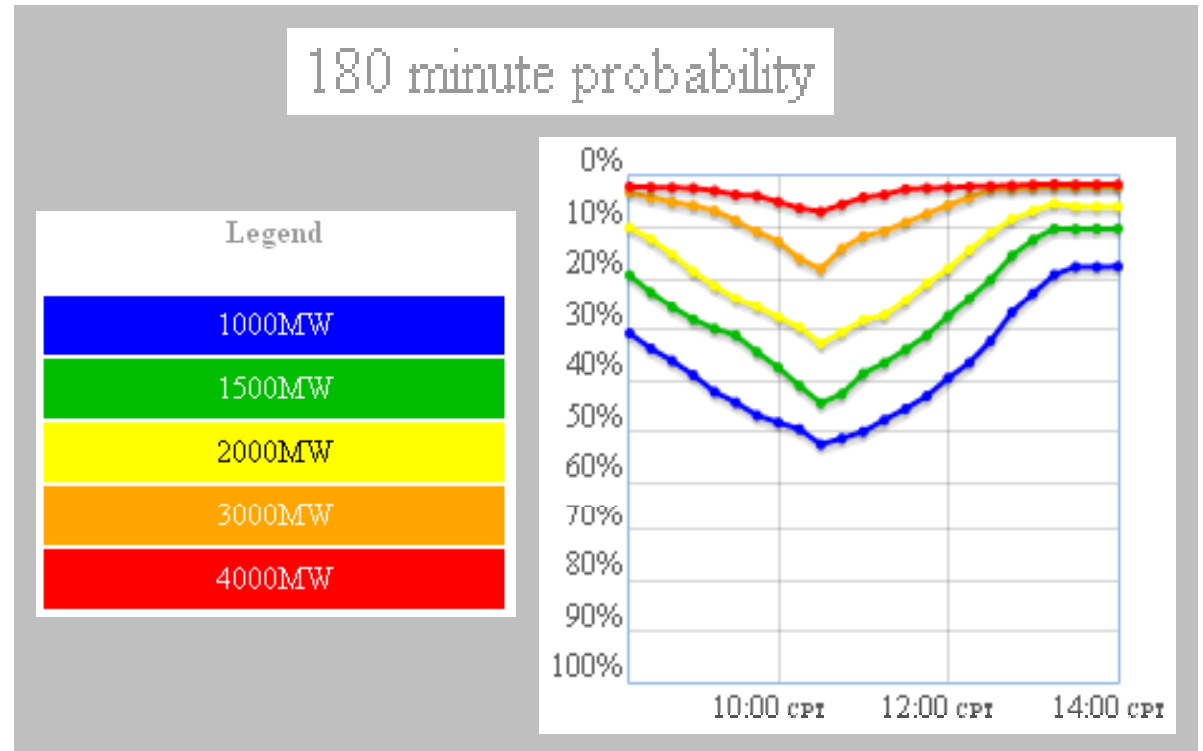- **Used to determine need for "residual" unit commitment**

Forecasted and Actual Wind Power Production: Current Day

Wind Power Production:
2,585
MW
Updated:
Apr 24, 2012 15:35

Graph Updated: Apr 24, 2012 15:20

Day-ahead

Actual

Hour-ahead

Apr 24, 2012 – Hour Ending

— Most Recent STWPF — Day-Ahead 1430 STWPF — Actual Hourly Avg.

Current Day   Next Day   STWPF

ERCOT

Wind Forecast Error

WIND POWER FORECAST
Mean Absolute Percent Error
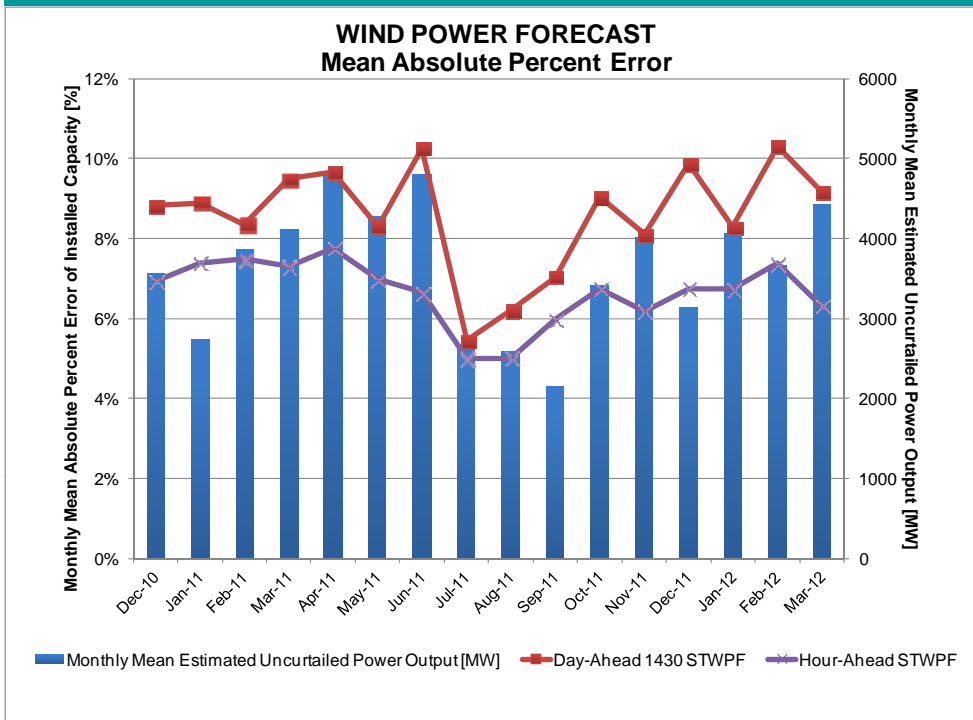
Average hour-ahead wind forecast error is significant (MAPE is ~7%)

MW errors may be high (>1000 MW; occasionally >2000 MW)

Histogram of Hour-Ahead MW Forecast Error
All Hours
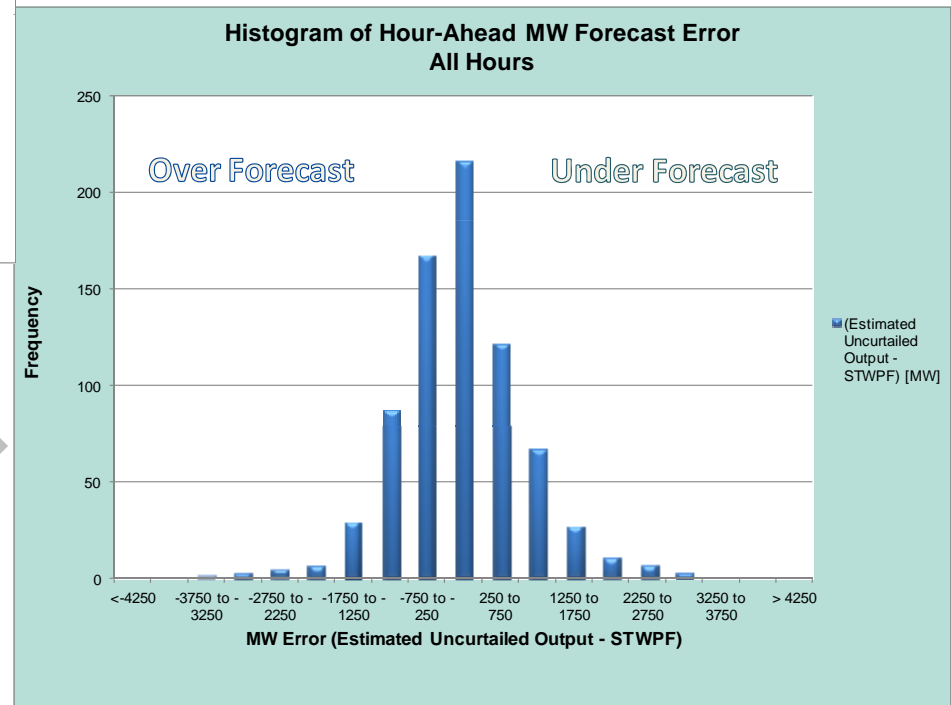
Over Forecast   Under Forecast

- ## ERCOT Large Ramp Alert System (ELRAS)

  - Probabilistic forecast which alerts Operators of ramps during the next 6 hours
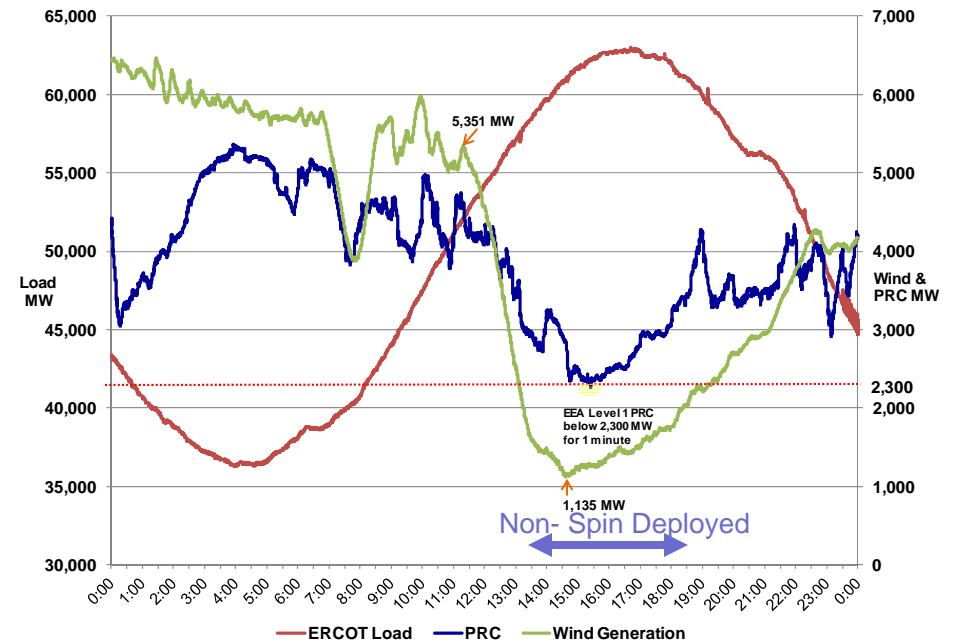
  - Provided on the system and regional level

180 minute probability

Legend

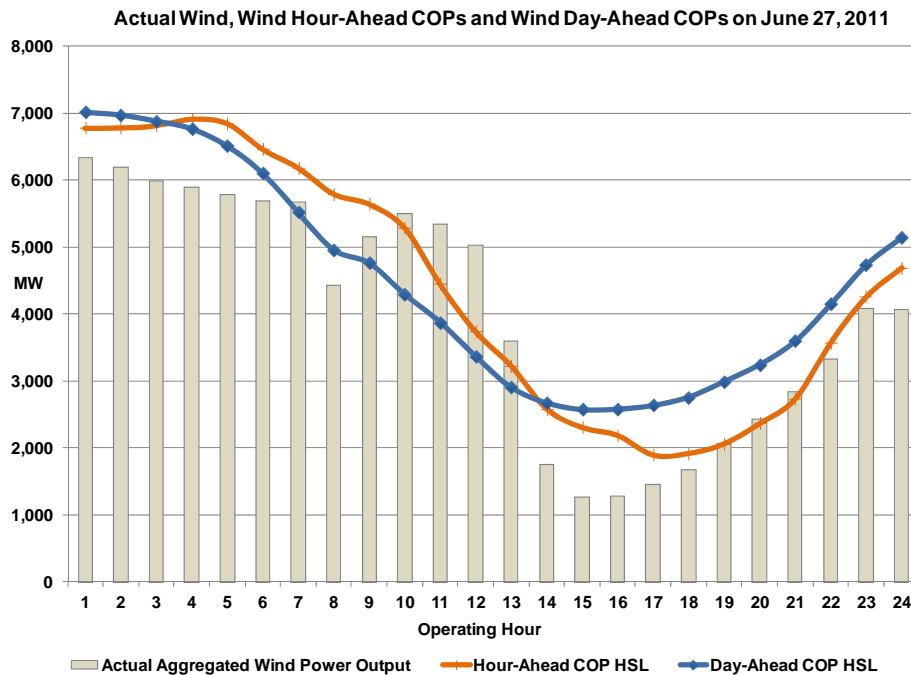| Color	MW
Blue	1000MW
Green	1500MW
Yellow	2000MW
Orange	3000MW
Red	4000MW

Ancillary Services - Regulation

- ERCOT typically dispatches generation each five minutes
- Regulation Service is used to balance the variation in load and generation between five-minute economic dispatch executions
- Primary driver for determining required amount of regulation is historical deployments
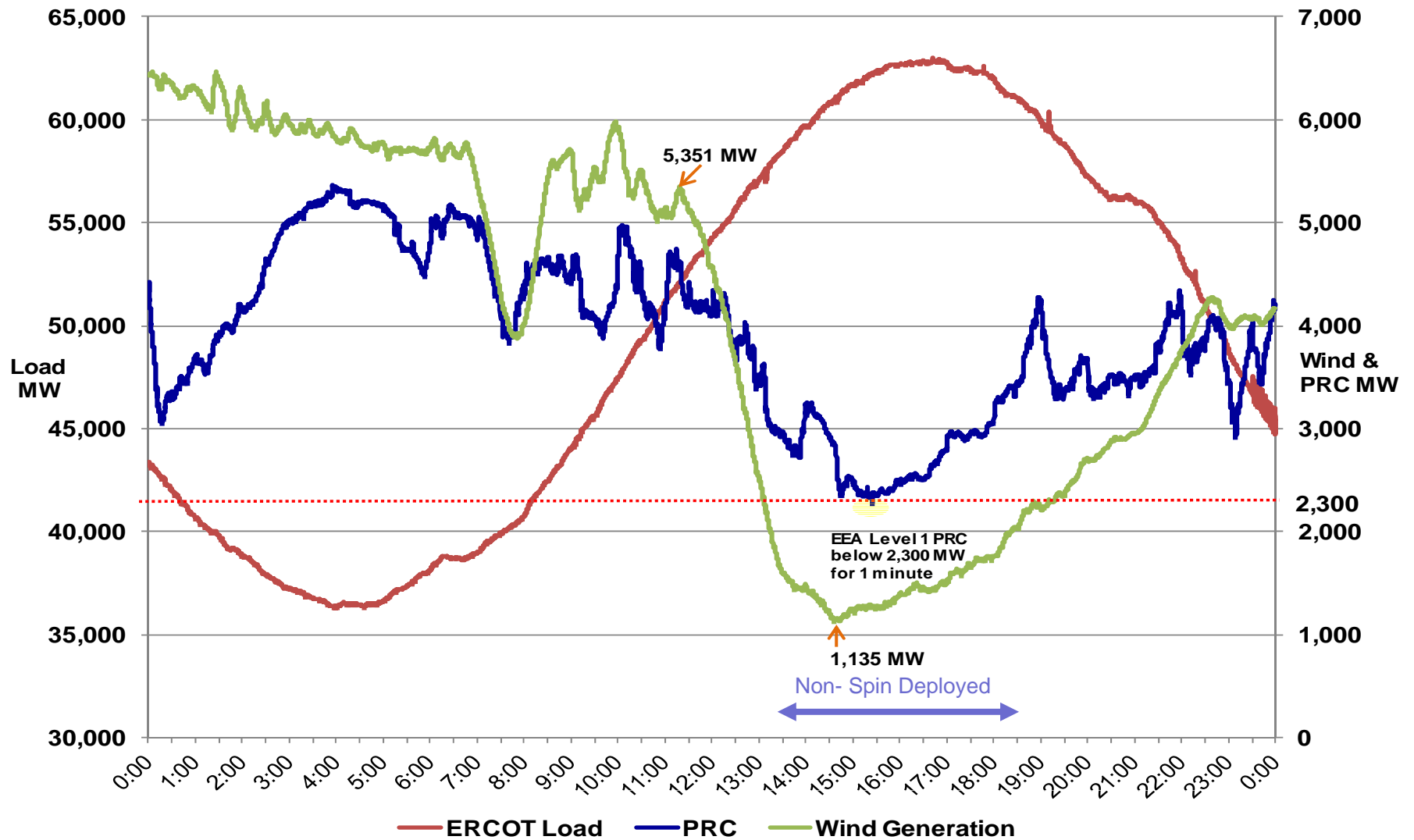 - Adjusted for increase in installed wind capacity

Load and Wind Power Output for 5 Minute Dispatch
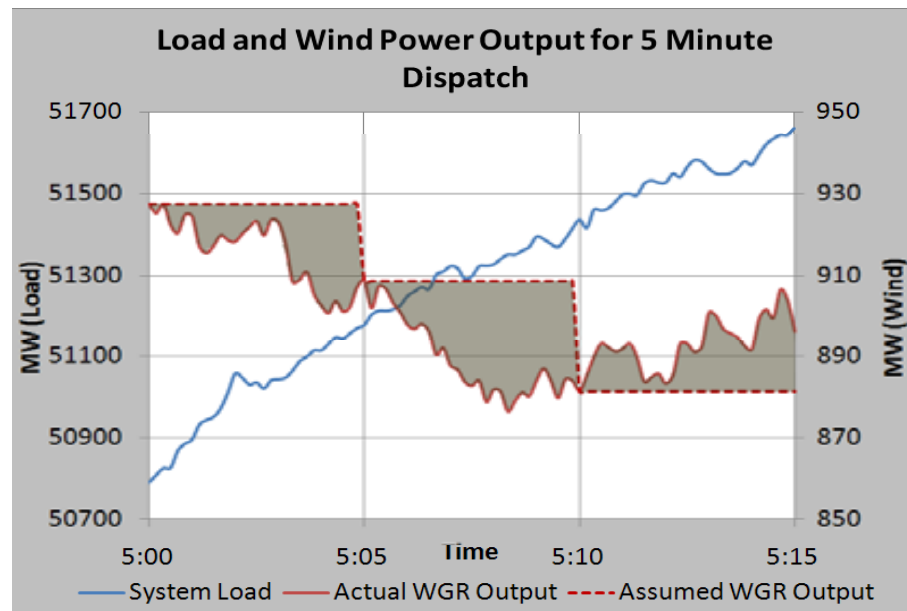
- ## **Non-spin Reserve Service**
  - 30 minute product that can be provided by unloaded capacity, offline Generators, and Load Resources
  - Wind power forecast error is one of the inputs used for calculating the requirement for this service

Actual Wind, Wind Hour-Ahead COPs and Wind Day-Ahead COPs on June 27, 2011

Legend: Actual Aggregated Wind Power Output | Hour-Ahead COP HSL | Day-Ahead COP HSL

5,351 MW

EEA Level 1 PRC below 2,300 MW for 1 minute

1,135 MW

Non- Spin Deployed

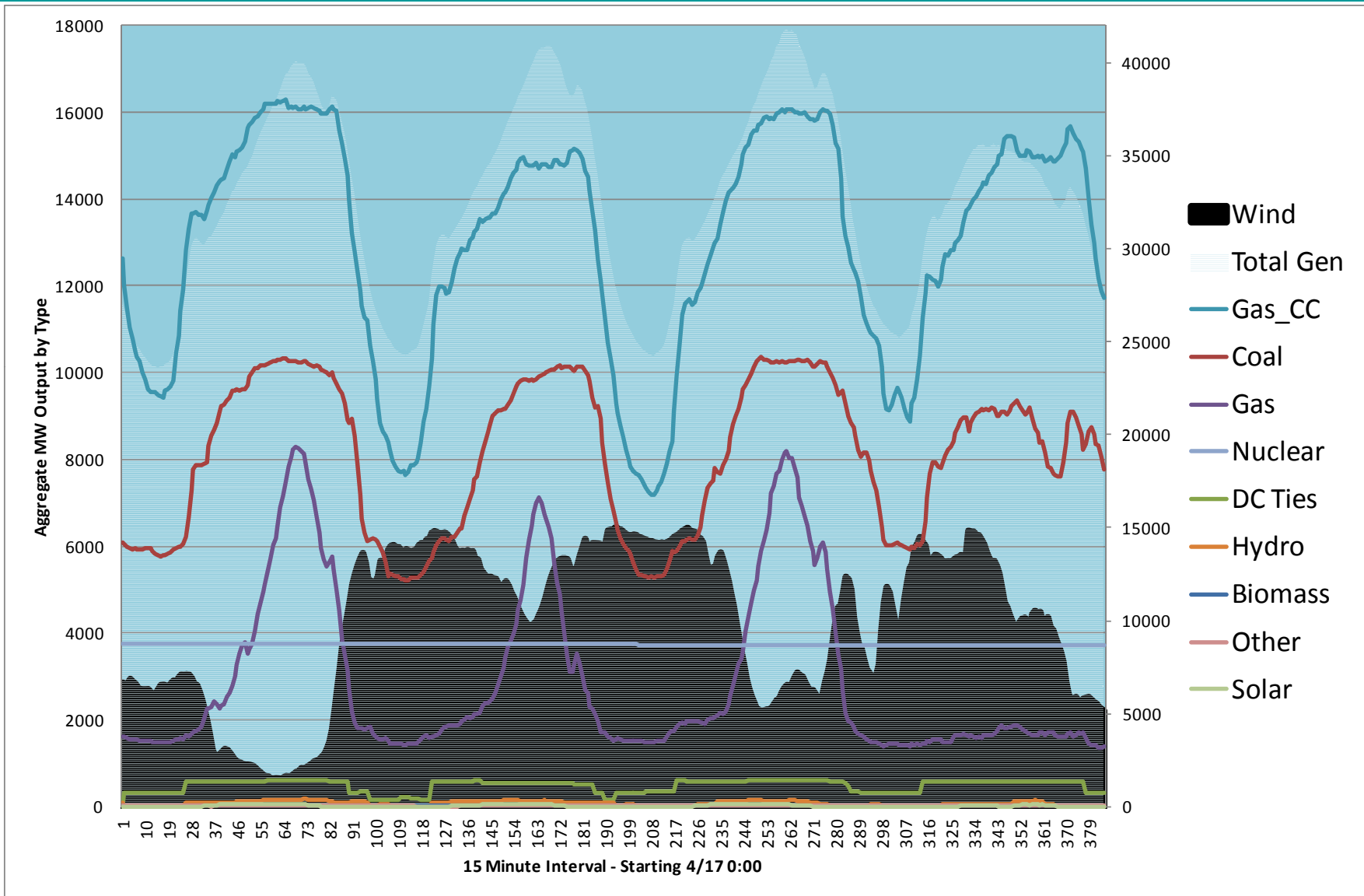Legend: ERCOT Load | PRC | Wind Generation

Primary Frequency Response

- **All generation in ERCOT is required to provide governor response with a 5% droop setting**
- **Wind farms were recently required to provide primary frequency response to frequency deviations from 60 Hz.**
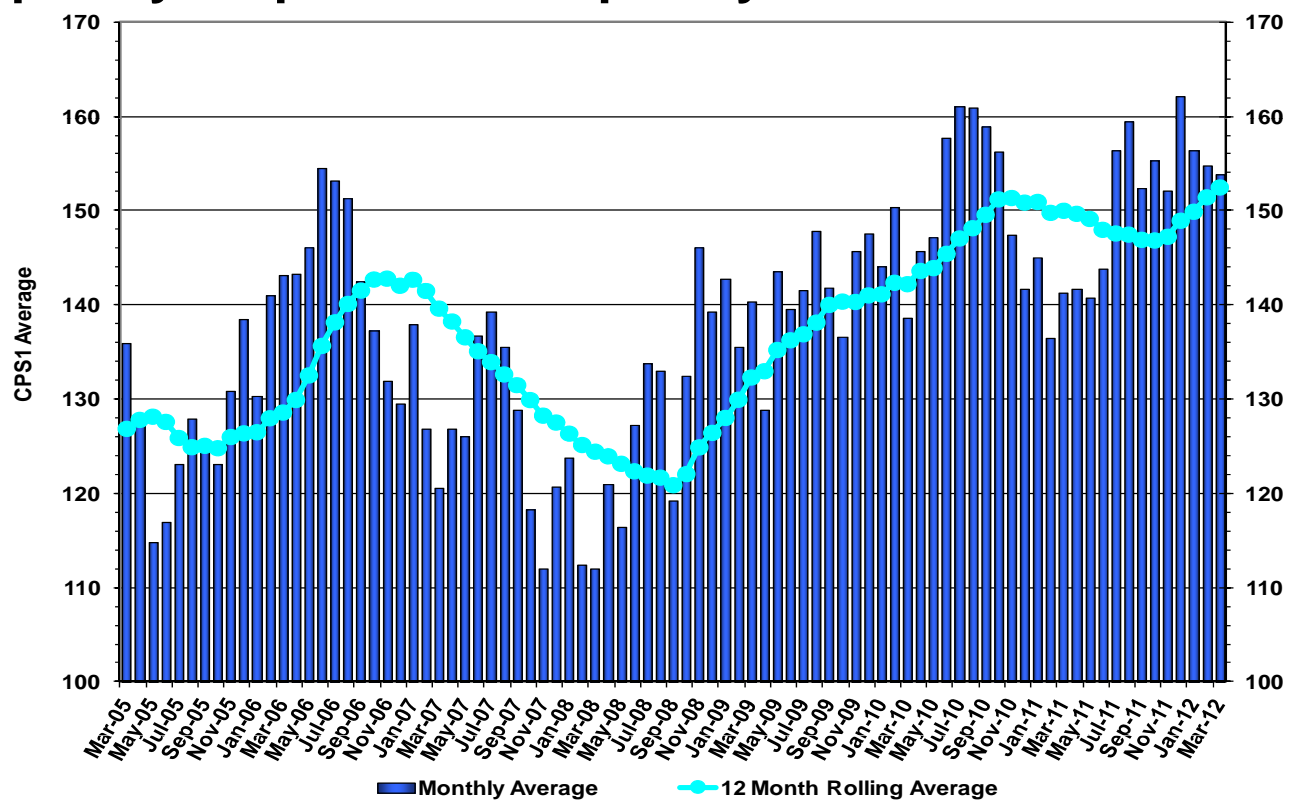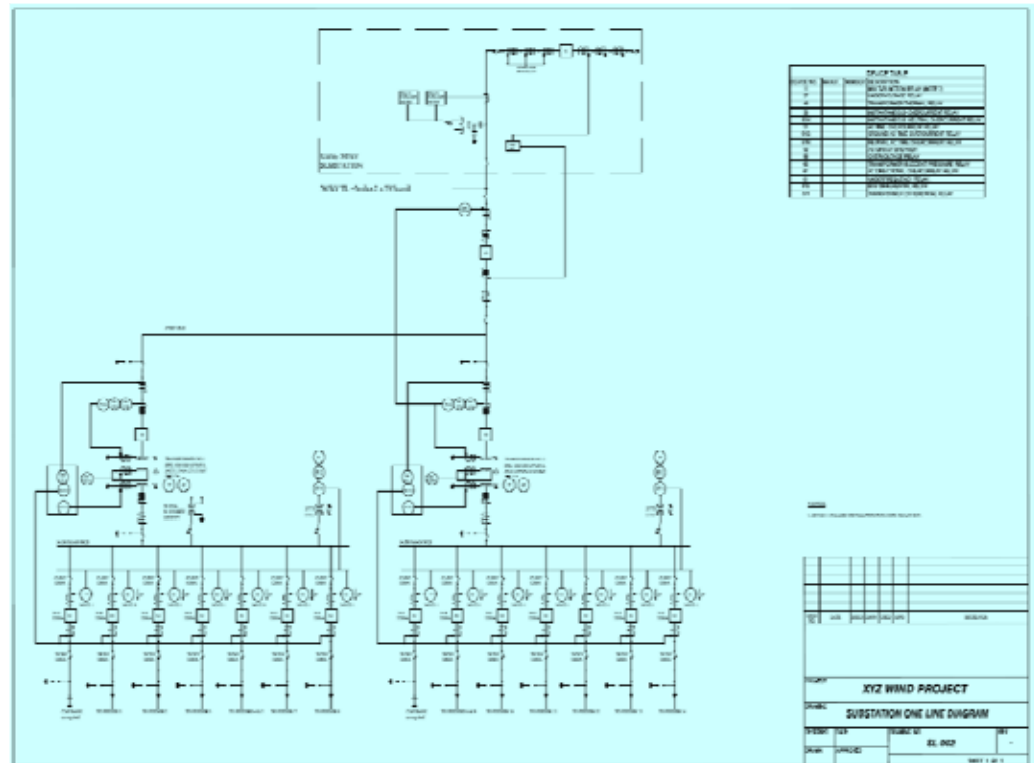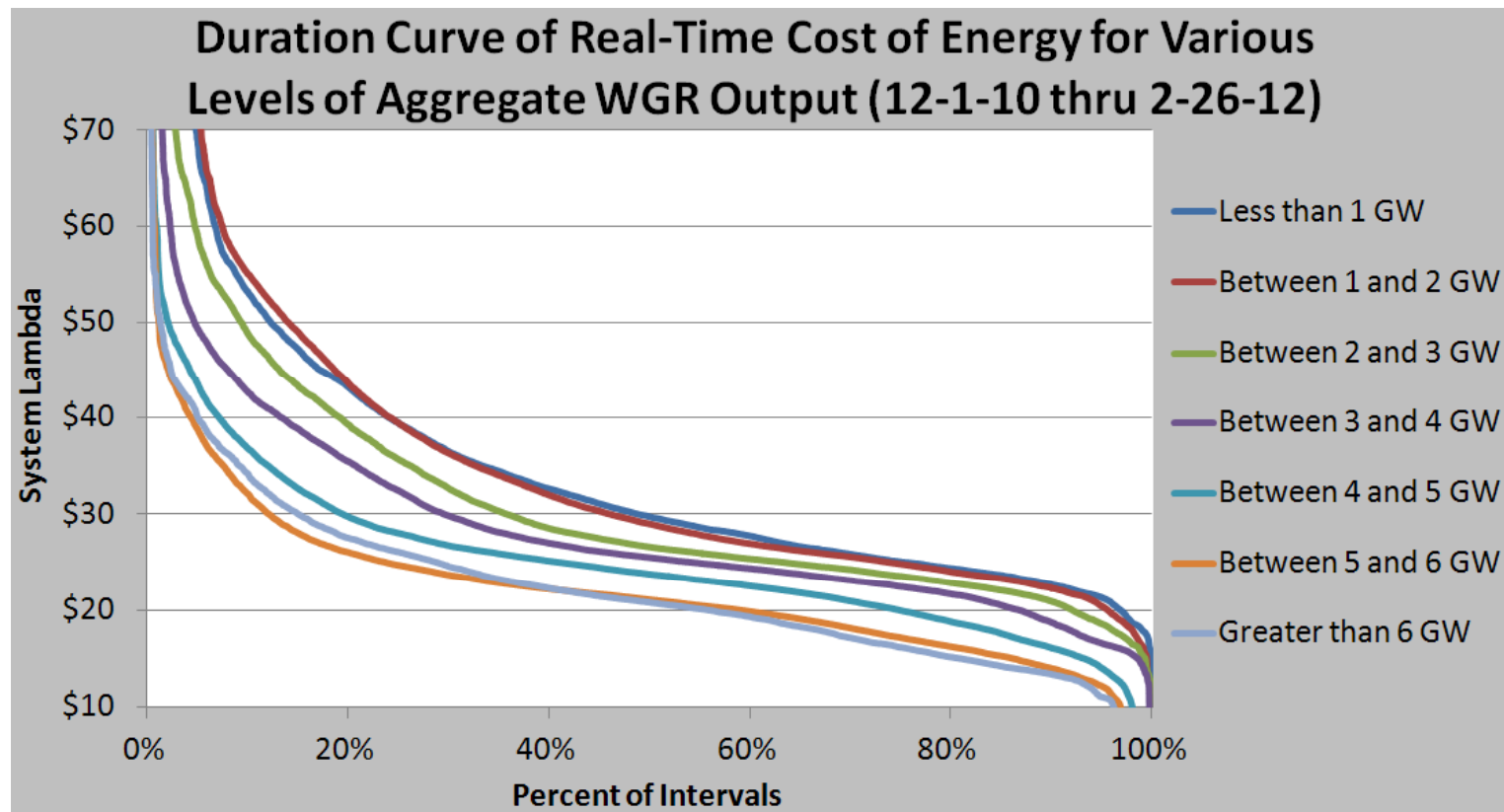
Generation Ramps

Interconnection-Related Requirements

- Inverter-connected resources may not fit with traditional technical requirements
- Need to address these issues to maintain system reliability:

- **Static and dynamic reactive capability**
- **Voltage-ride through capability**
- **Modeling**
  - Collector system and support device modeling
  - Dynamic model and parameters

- **There is a clear shift down in the duration curve of real-time prices for higher levels of wind power output**

Duration Curve of Real-Time Cost of Energy for Various Levels of Aggregate WGR Output (12-1-10 thru 2-26-12)

Questions?