Integrating Wind Energy in ERCOT

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Wind Turbine Guidelines Advisory Committee

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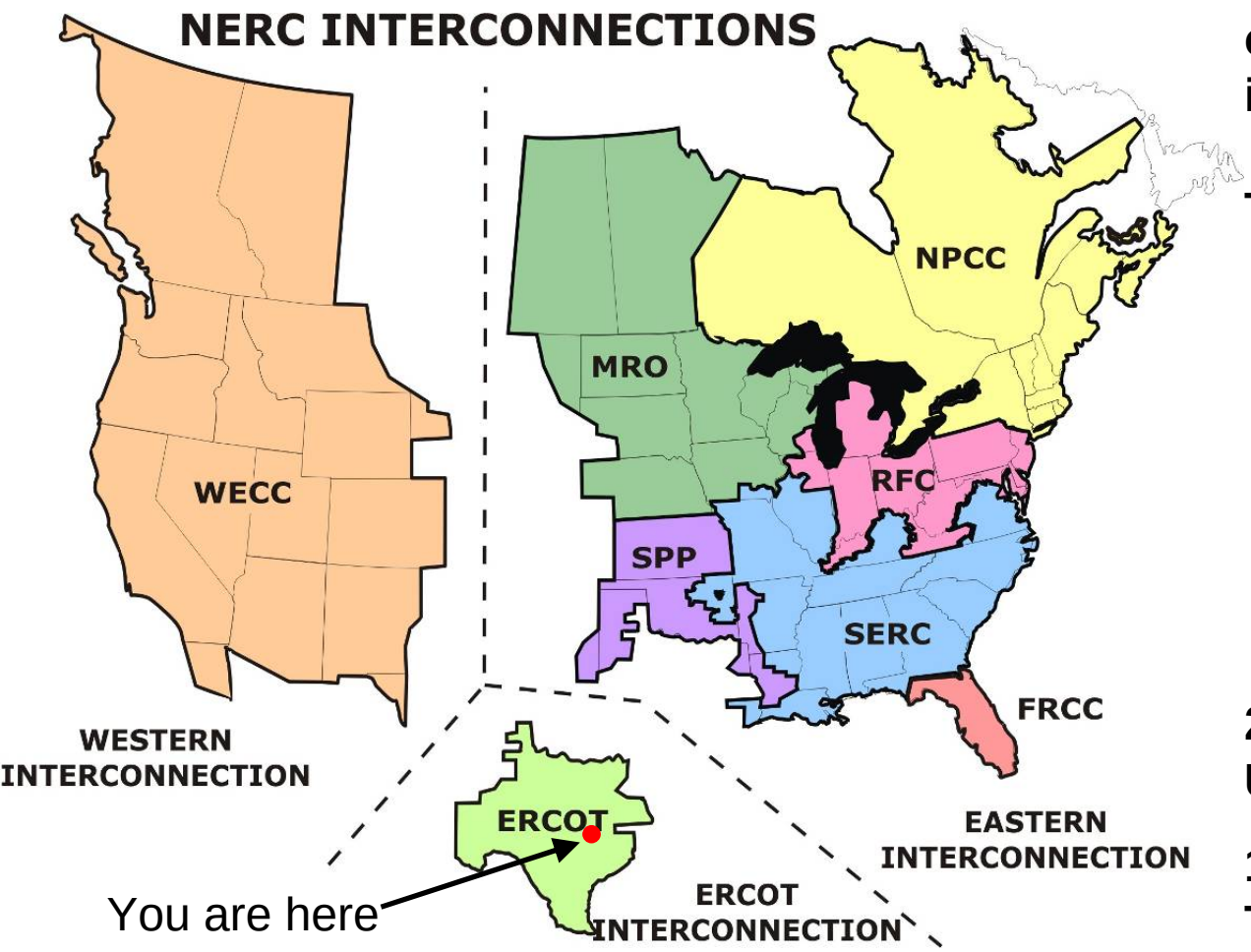
North American Electric Grids



The ERCOT Region is one of 3 NERC grid interconnections.

The ERCOT grid:

-75% of Texas land
-85% of Texas load
-38,000 miles of transmission lines
-550+ generation units
-62,339 MW peak demand (set 8/17/06)

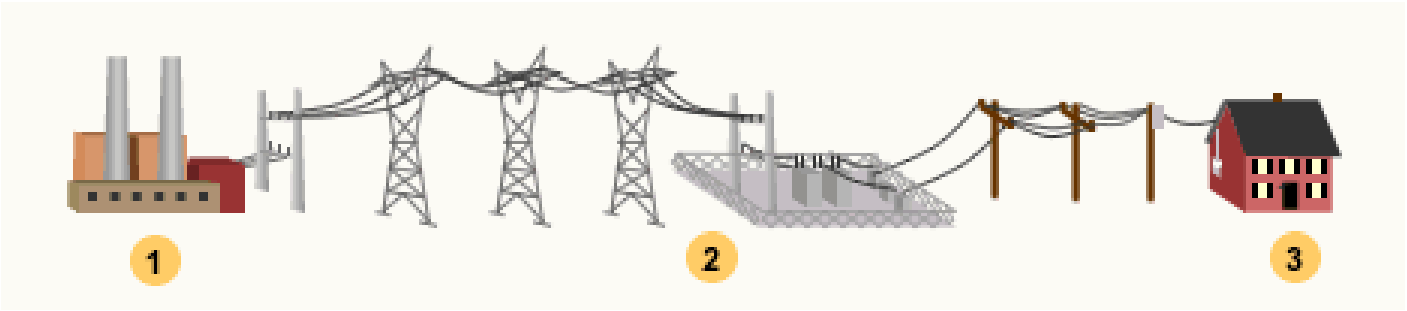
2,877 MW of Switchable Units

1,106 MW of Asynchronous Tie Capacity (820 MW with Eastern Interconnection)

So What is a Deregulated Electricity Market?

In ERCOT:

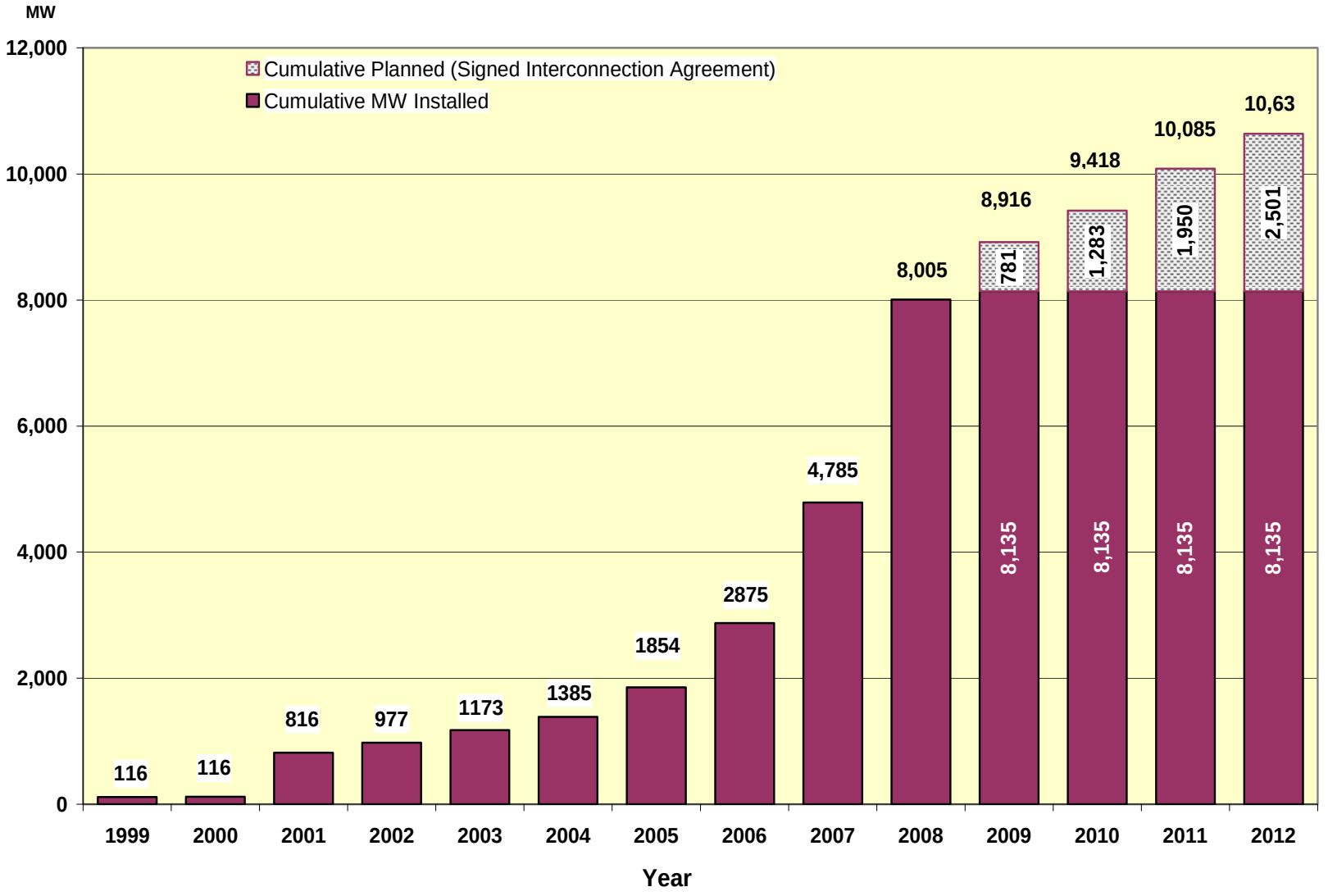
- **Any party can connect their generation to the transmission system**
- **Retail customers can choose their electricity service provider**
- **Transmission and distribution (T&D) are still regulated**
- **ERCOT, Inc., operates the transmission system to facilitate the deregulated wholesale and retail markets**



Why Is There So Much Wind in ERCOT

- **Marginal cost of electricity is set by gas generation in most hours (high variable cost)**
- **Generators do not pay for transmission system upgrades (ERCOT has a postage-stamp transmission rate, paid by load)**
- **Wind resources in Texas are world-class: over 30 GW of wind generation potential with greater than 40% net capacity factor and over 100 GW of wind generation potential with greater than 35% net capacity factor**
- **ERCOT contains three of the ten largest cities in the United States (Houston [4], San Antonio [7] and Dallas [9]; Austin and Fort Worth are in the top 20)**

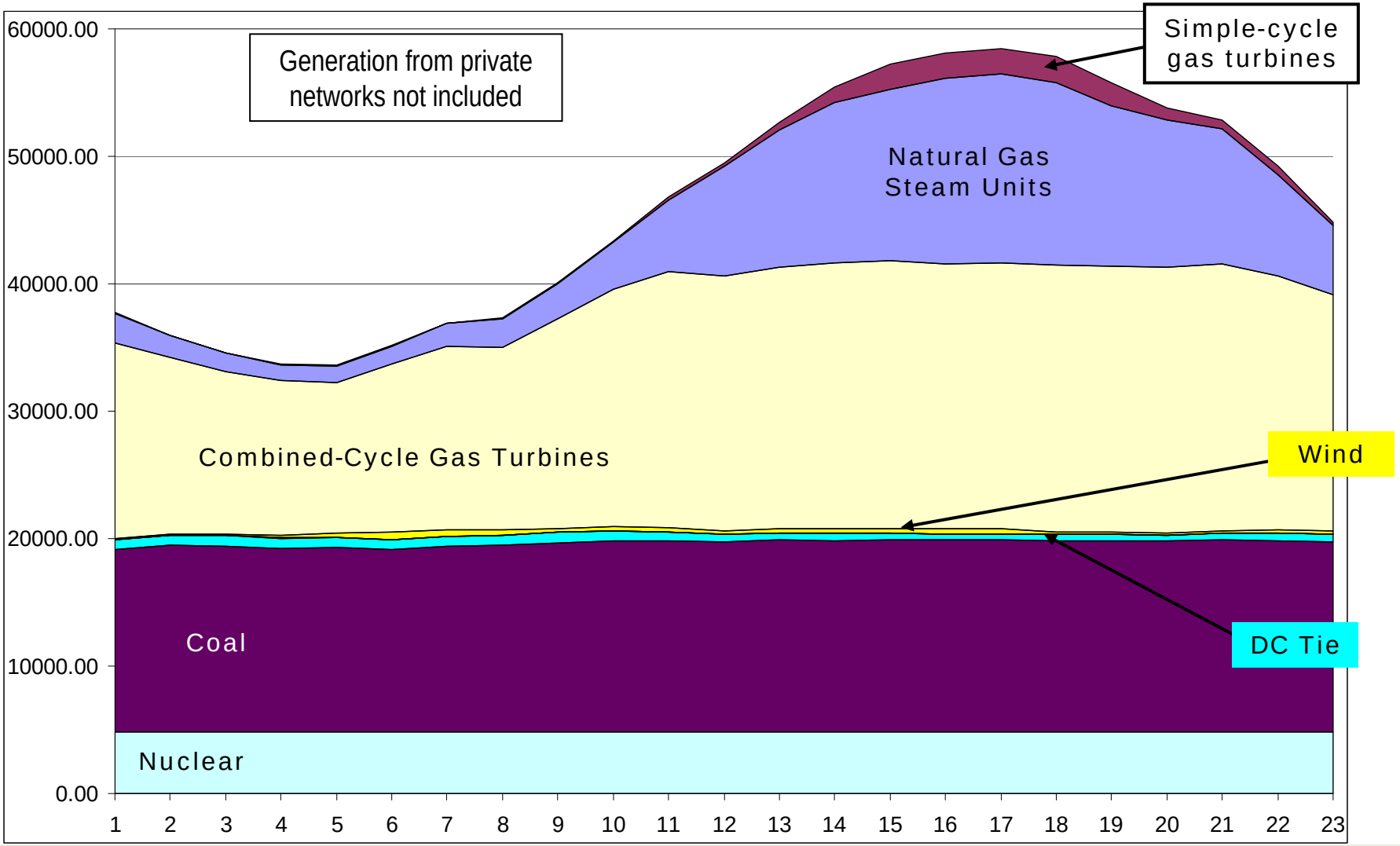
So How Much Wind Generation is in ERCOT?



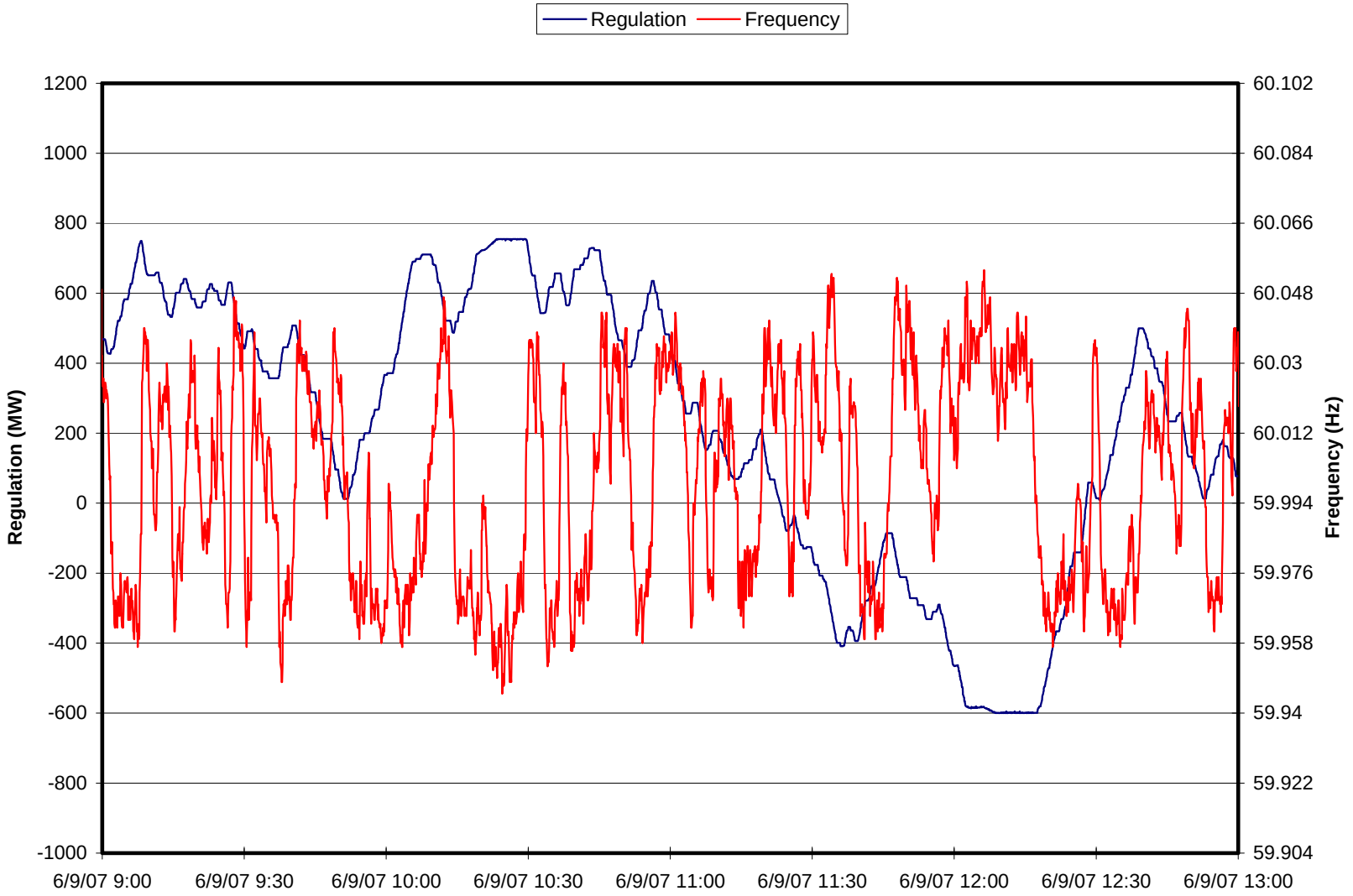
(as of May 31, 2009)

The Primary Challenge – Wind Integration

ERCOT's Peak Day (8/17/06) by Fuel Type



Operations Must Maintain System Frequency



Example Operations Report

REAL-TIME DATA

Posted Date	28-JUN-2009	
Posted Hour	1422	
Actual System Demand (Frequency Control)	56845	MW
Scheduled Frequency	60.000	Hz
Actual Frequency	59.990	Hz
Time Error	-0.137	sec
Total Generation	56298	MW
Current Aggregated Regulation Deployment*	86	MW
Adjusted Responsive Reserve	3788	MW
Total On-Line Capacity	61645	MW
Total Spinning Reserve	5347	MW
Total Wind Output	1120	MW

DC Tie Flows

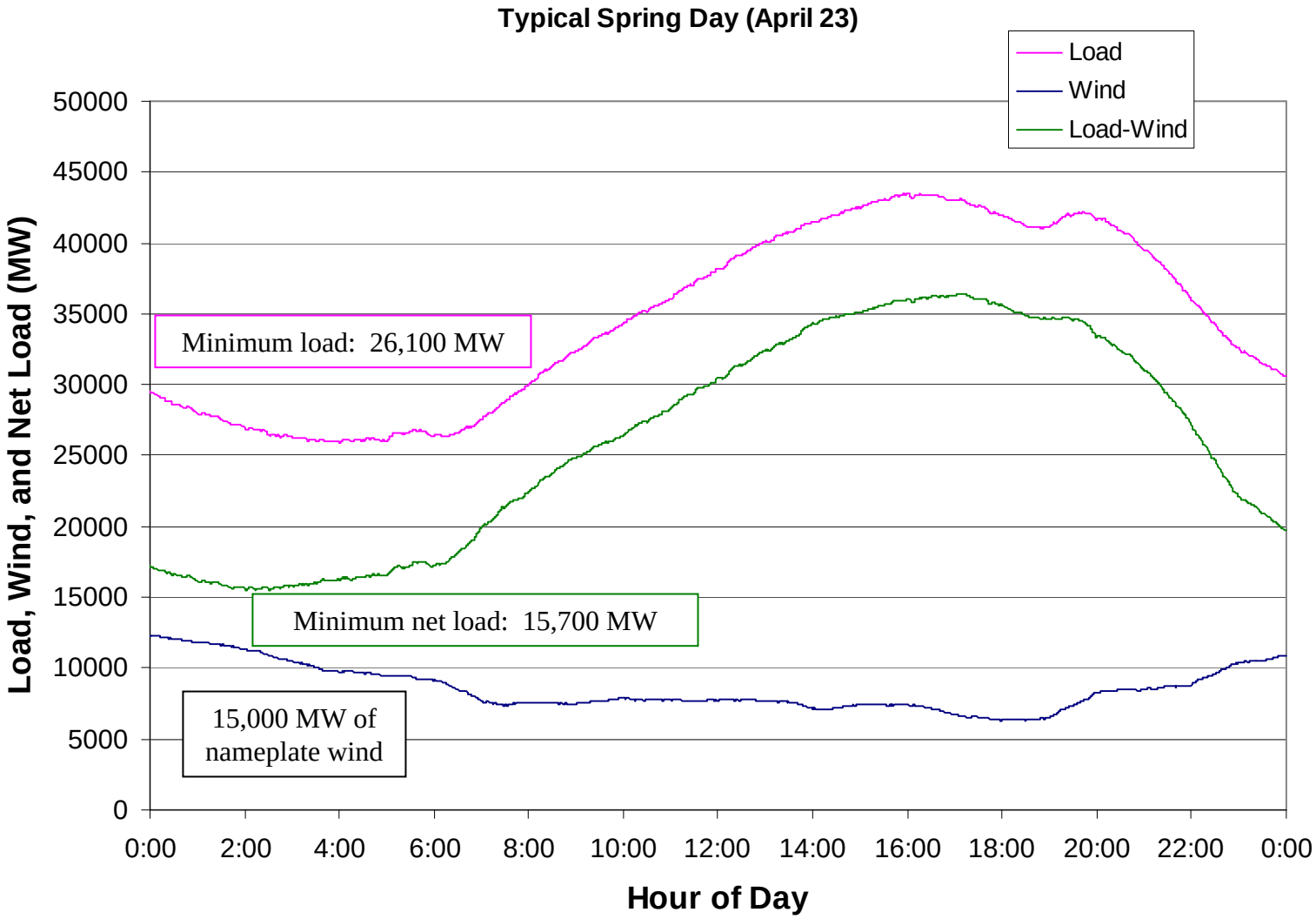
Line	Scheduled	Actual	Imp. Lim.	Exp. Lim.
DC_E	-341	-341	550	550
DC_L	-80	-80	80	40
DC_N	-96	-96	210	210
DC_R	0	0	0	150
DC_S	-30	-30	30	30
Total	**-547**	**-547**	**870**	**980**

Monitored CSC/CRE Flow	MW	MVAR	LIMIT
NORTH-HOUSTON	1597	-97	3147
NORTH-SOUTH	687	28	986
NORTH-WEST	-191	76	735
SOUTH-NORTH	-687	-28	386
WEST-NORTH	191	-76	987

*** Negative(-) = UP REG Deployed**
Positive = DOWN REG Deployed

Help

“Net-Load” Calculation – An Operator’s Viewpoint

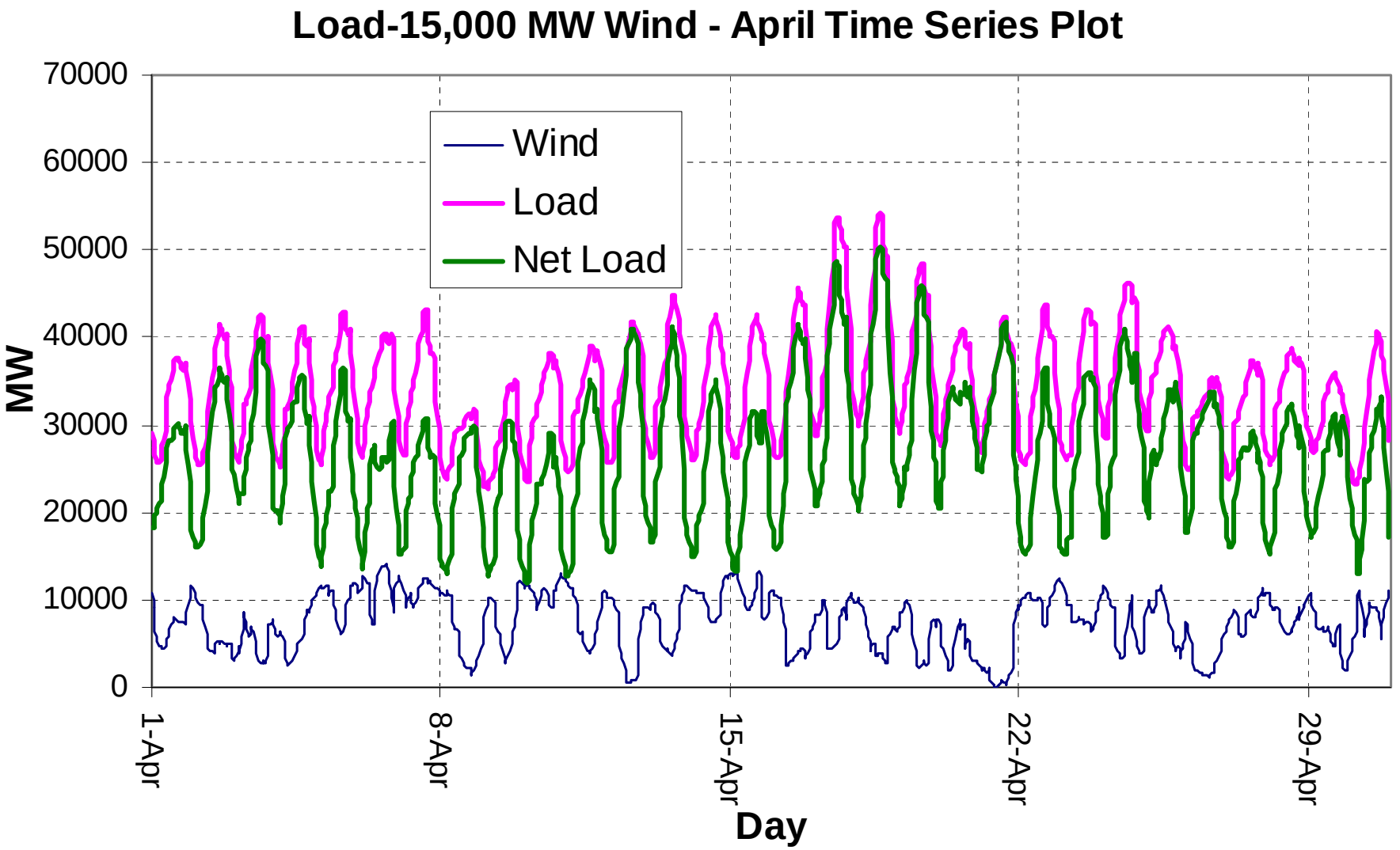


Similar to load, operator can’t control wind generation output

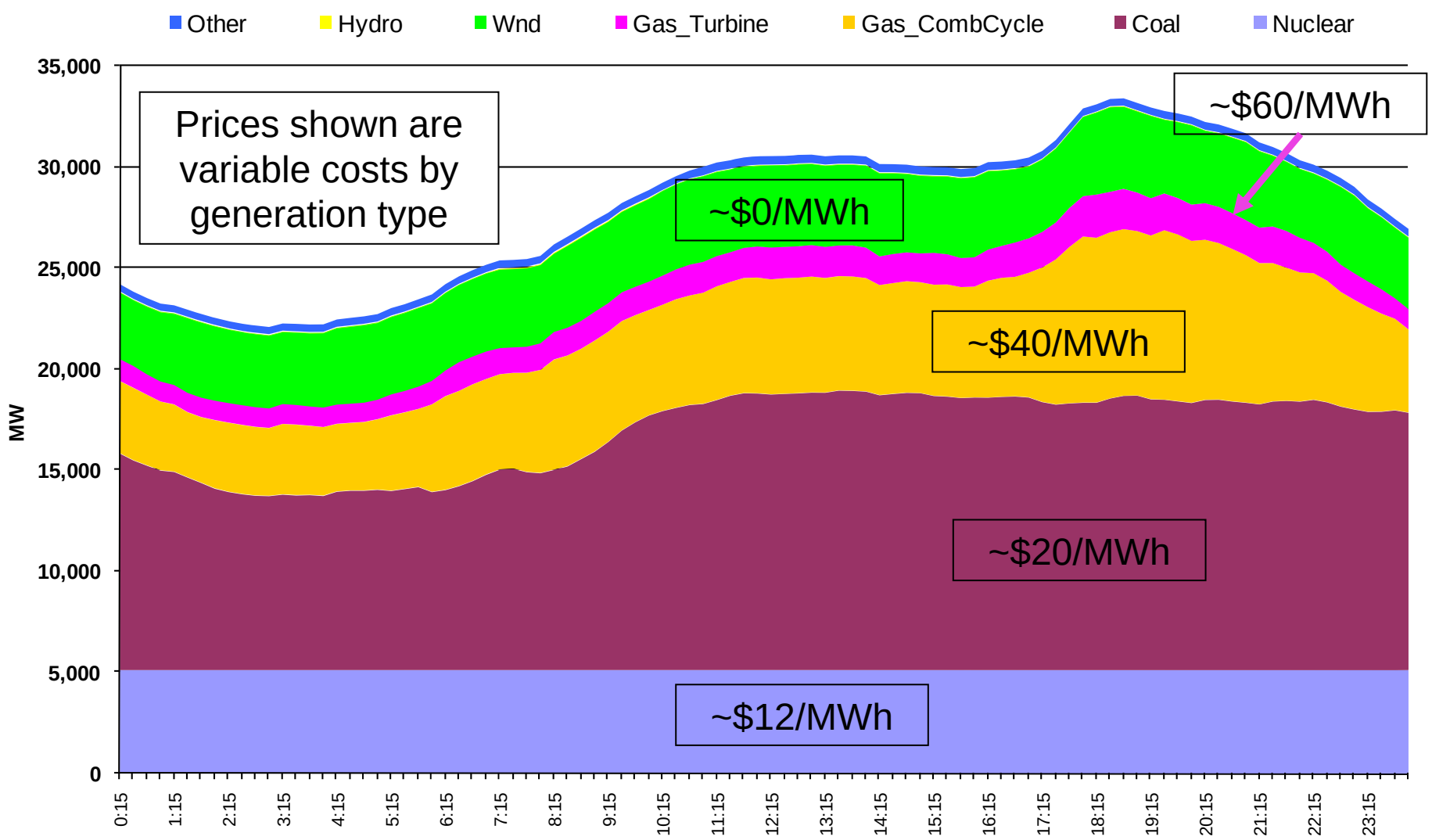
Net load predictability is key to reliable operations

Additional large increases in wind generation will change the typical load shape

Wind Generation Alters Net Load Shape



ERCOT Generation – December 26, 2008

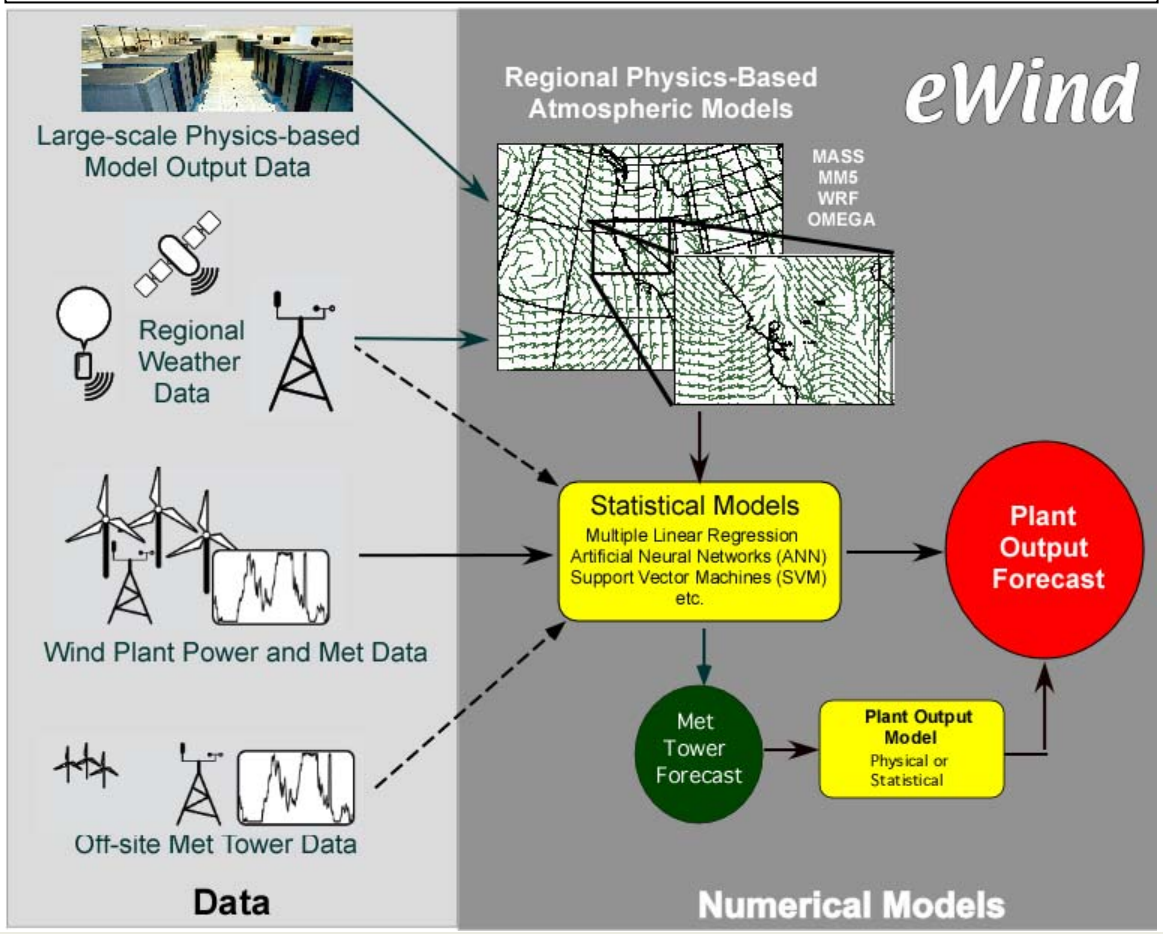


Over 92,000 MWh of wind generation

Components of State-of-the-Art Wind Forecast Systems

- Combination of physics-based (NWP) and statistical models
- Diverse set of input data with widely varying characteristics
- Importance of specific models and data types vary with look-ahead period
- Forecast providers vary significantly in how they use forecast models and input data

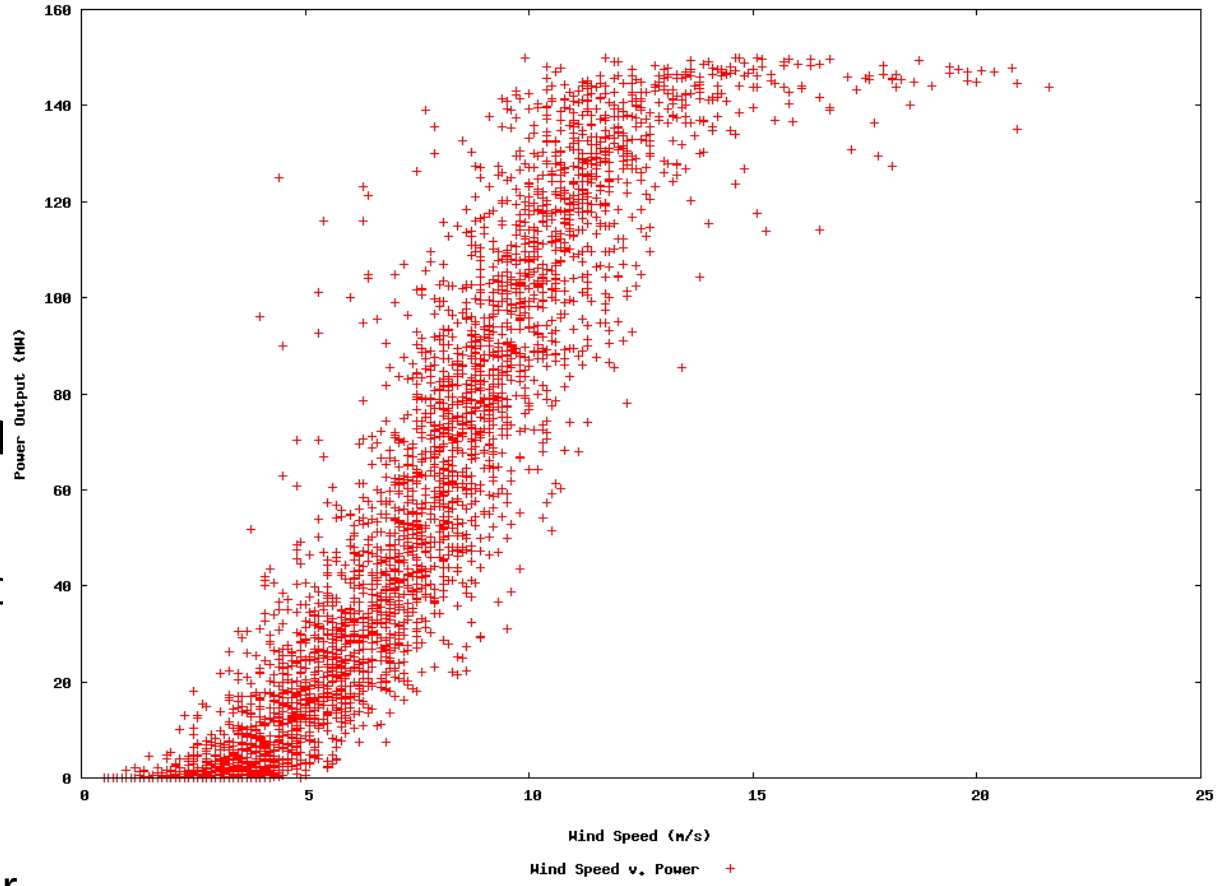
Input Data, Forecast Model Components and Data Flow for a State-of-the-Art Forecast System



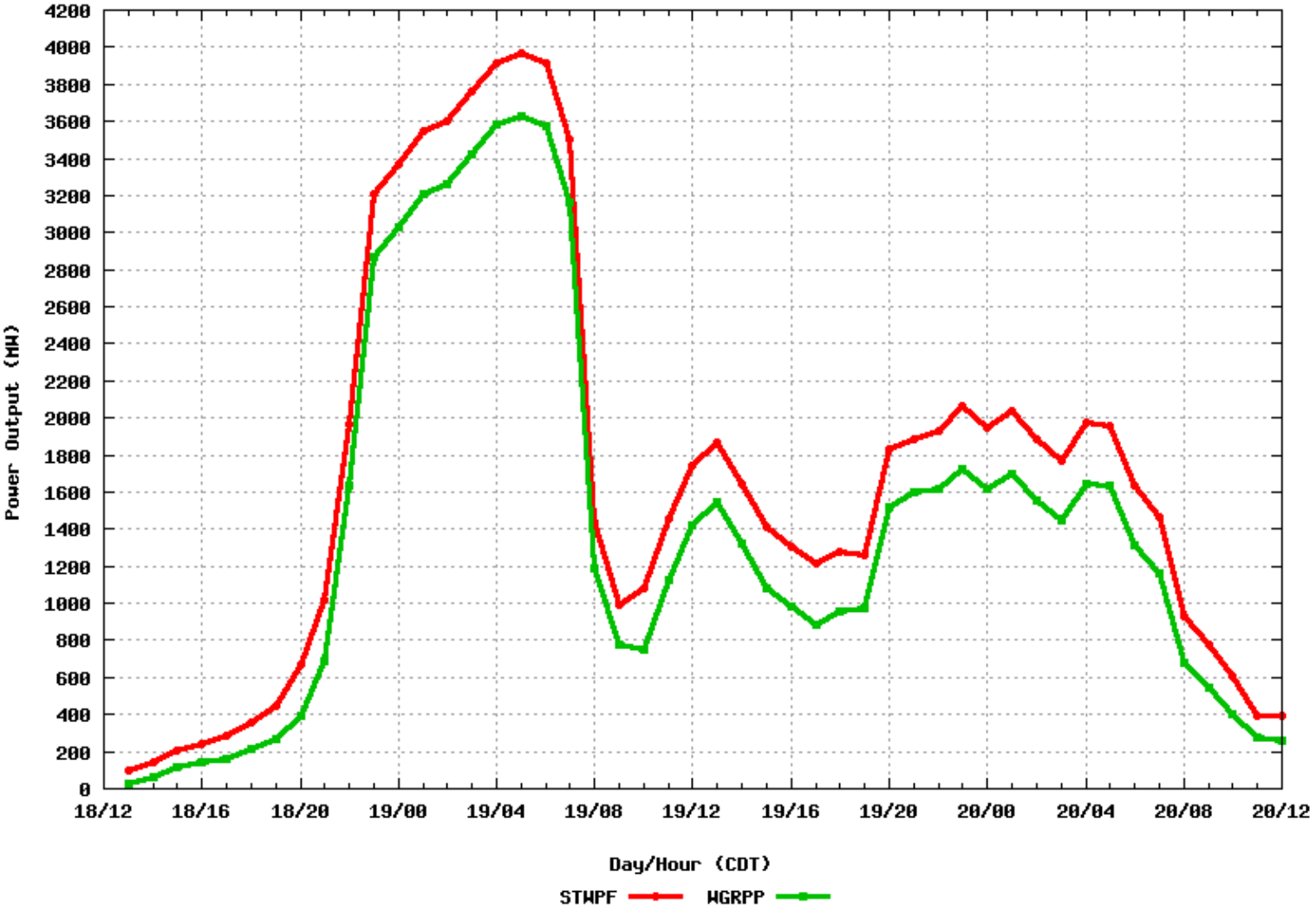
Wind Generation Forecasting is Complex

- **Two primary sources of uncertainty**
  - Position on power curve
  - Predictability of weather regime
- **Useful to distinguish between sources**
  - Estimate weather-related uncertainty from spread of forecast ensemble
  - Estimate power curve position uncertainty by developing statistics over all weather regimes

A real facility-scale power curve



Example 48-Hour ERCOT Wind Generation Forecast



Red line represents expected wind generation

Green line represents 80% confidence forecast

Wind Persistence

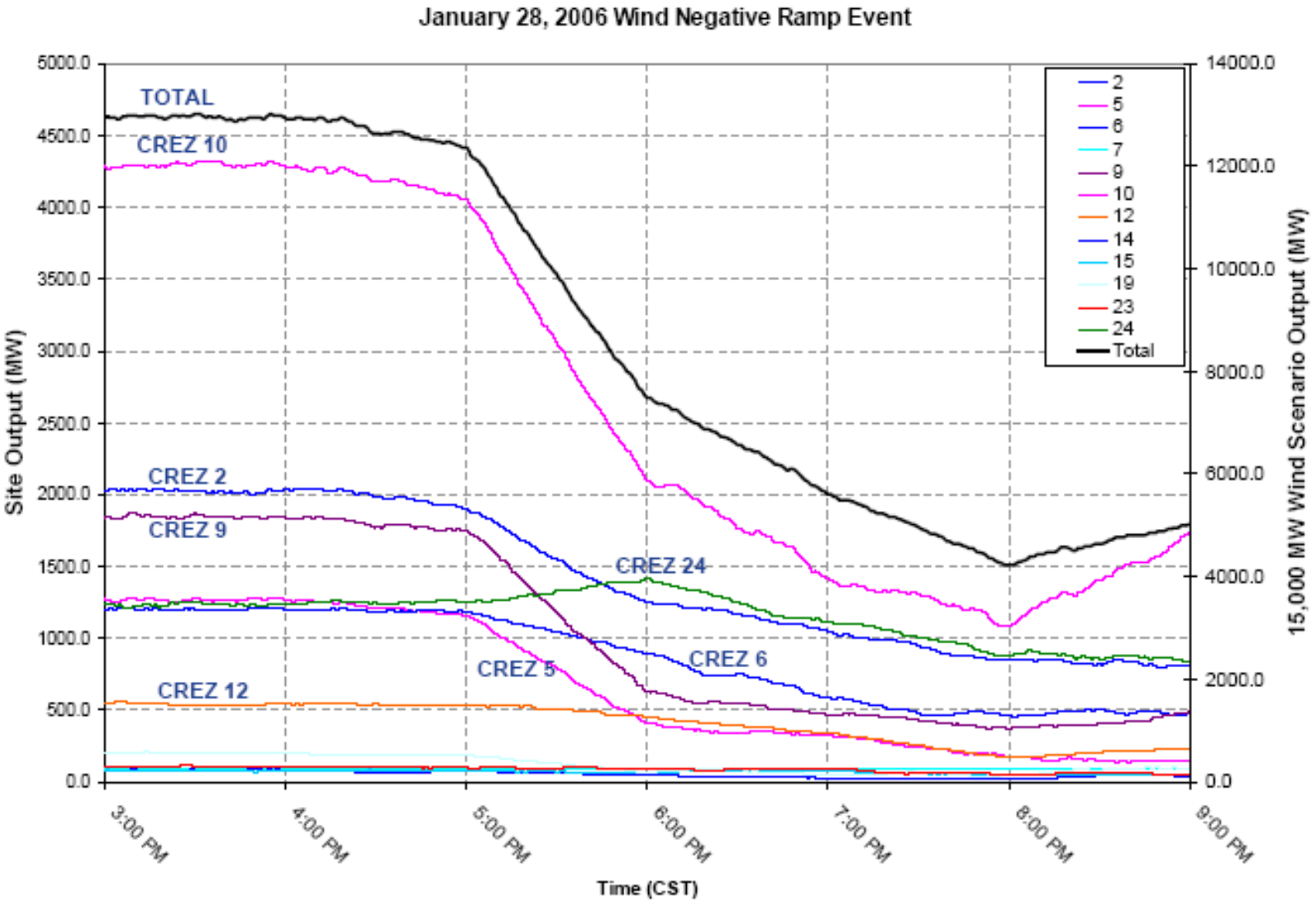
15-Minute Wind State Transition Probabilities (15,000 MW*)

Probability that wind output will change from one level to another within 15 minutes

Current State (Output) \ Next State (Output, % rated capacity)	0-10%	11-20%	21-30%	31-40%	41-50%	51-60%	61-70%	71-80%	81-90%	91-100%
0-10%	0.8386	0.1614	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11-20%	0.0225	0.8602	0.1173	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
21-30%	0.0000	0.0486	0.8445	0.1069	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
31-40%	0.0000	0.0000	0.0598	0.8232	0.1170	0.0000	0.0000	0.0000	0.0000	0.0000
41-50%	0.0000	0.0000	0.0000	0.0655	0.8176	0.1169	0.0000	0.0000	0.0000	0.0000
51-60%	0.0000	0.0000	0.0000	0.0000	0.0667	0.8079	0.1253	0.0000	0.0000	0.0000
61-70%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0641	0.8495	0.0864	0.0000	0.0000
71-80%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0514	0.8701	0.0785	0.0000
81-90%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0516	0.9134	0.0350
91-100%	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0791	0.9209

- Diagonal probabilities show that *on average* there is a **85%** chance that wind output will persist – change by no more that 10% of rated capacity in fifteen minutes
  - Average probability of <7% that wind output will drop by more than 10% of rated in 15 minutes
- Negligible chance that wind will change by more than 20% of rated in 15 minutes

Wind Generation is Intermittent



Ancillary Services Requirements

As wind capacity increases, ancillary service requirements increase in order to maintain reliability

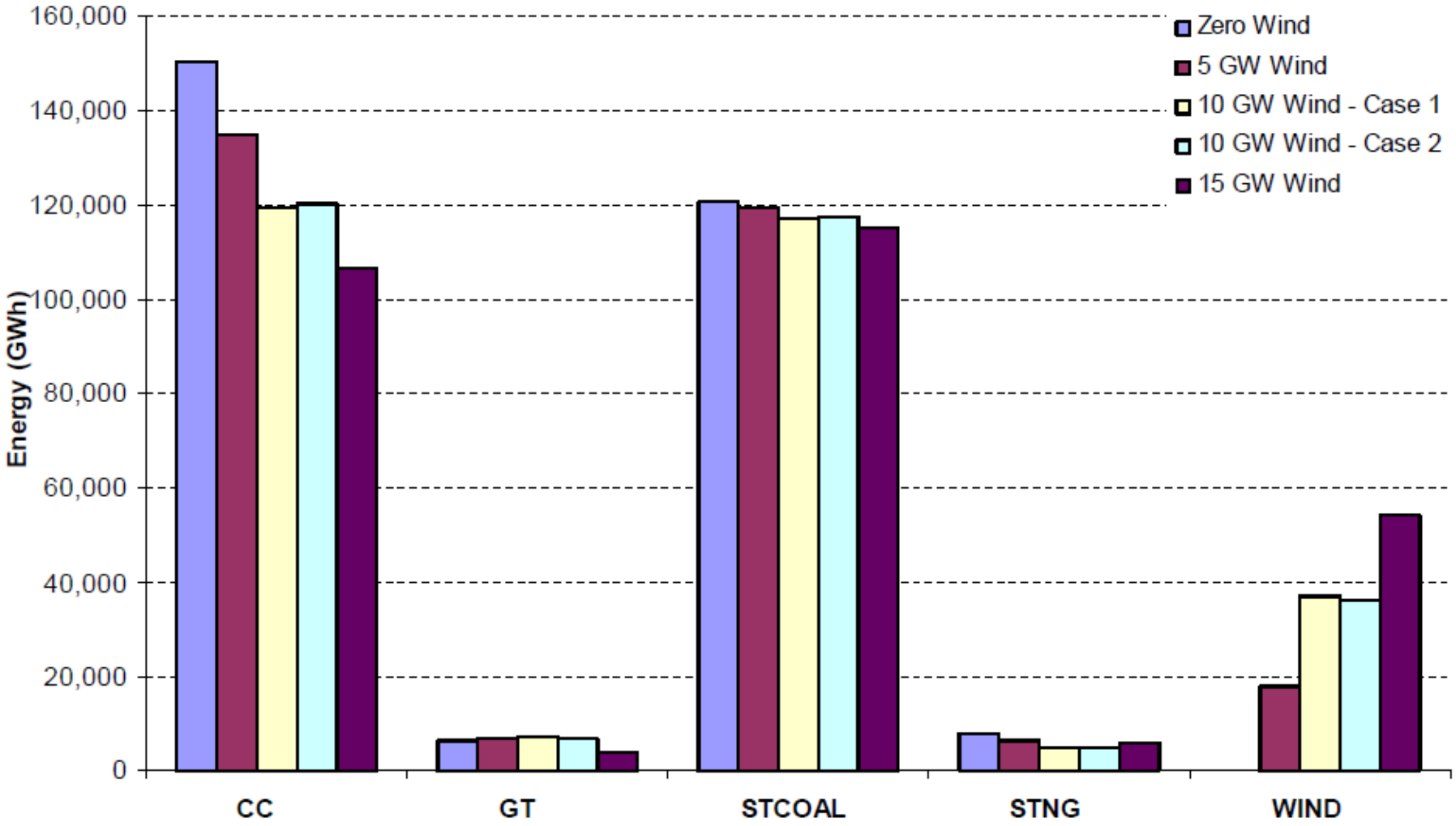
Ancillary Services include:

- **Regulation Service (Frequency Control)**
- **Non-Spin Service (Off-line Quick Start Units)**
- **Replacement Reserve Service (Off-line)**
- **Responsive Reserve Service (On-line resources for emergency replacement of energy)**

Annual Thermal Generation Impacts

Energy Output

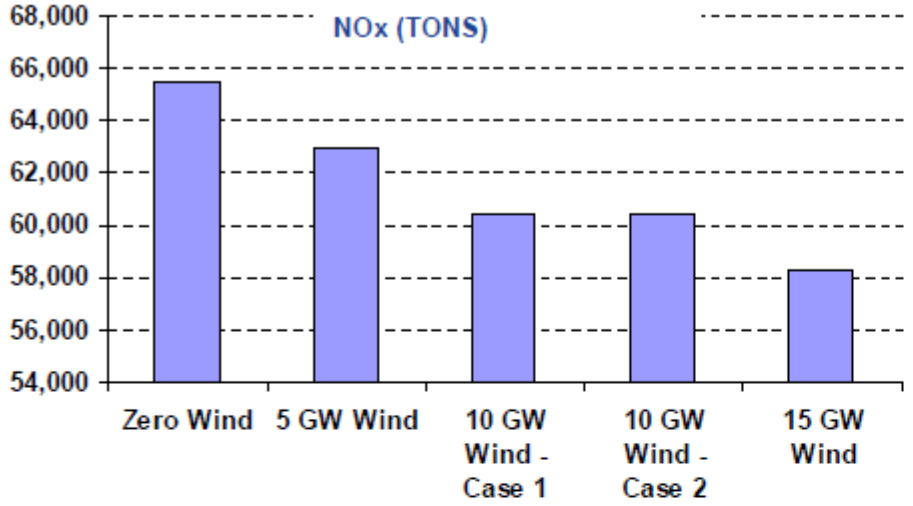
Commitment Based on State-of-Art Forecast

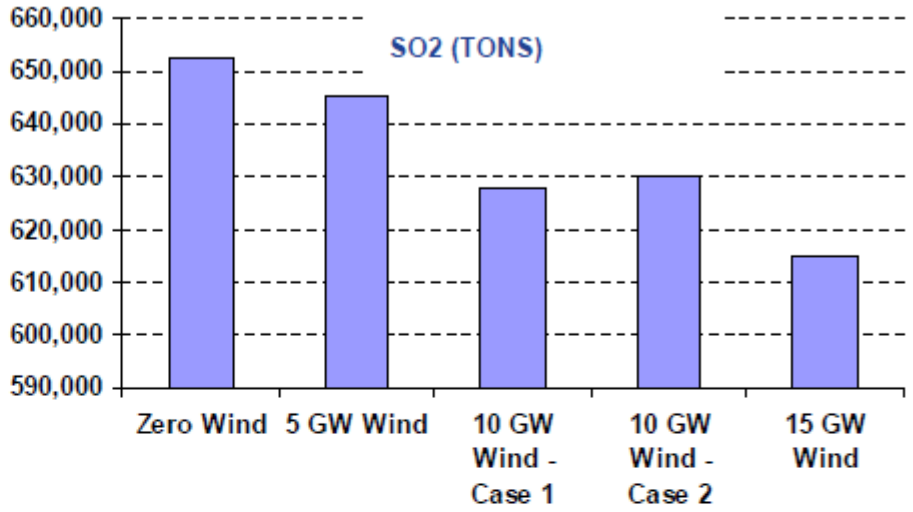


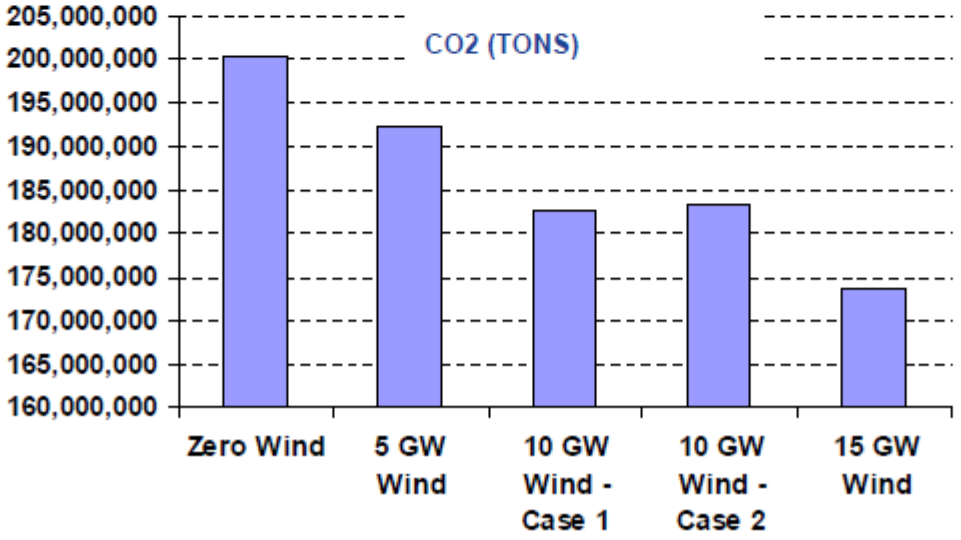
Major impact is on combined cycle unit operation, consistent with results observed in other studies

imagination at work

Annual Emissions Impacts







The Future of Market Adaptation

- **Other Renewable Sources**
- **Nodal Market**
- **Smart Meters – Load Response**
- **Distributed Generation**
- **Plug-In Hybrid Vehicles**

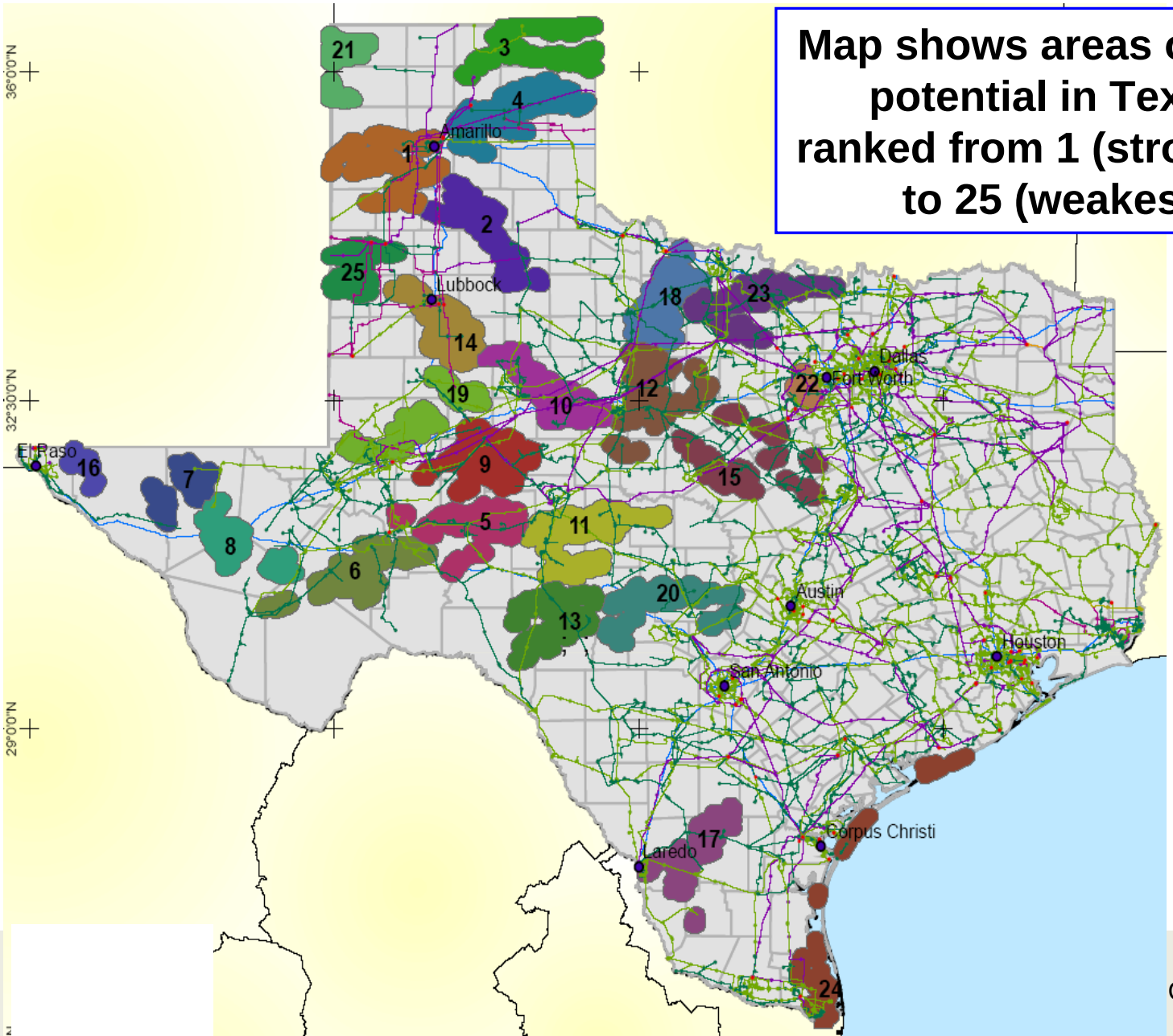
Additional Resources

- **Utility Wind Integration Group maintains a library of integration studies**
- **http://www.uwig.org/opimpactsdocs.html**
- **Over 20 different studies conducted by operating regions throughout the United States, Canada, and Europe. Also contains several summary documents and the recently completed "NERC Integration of Variable Generation Task Force Report."**

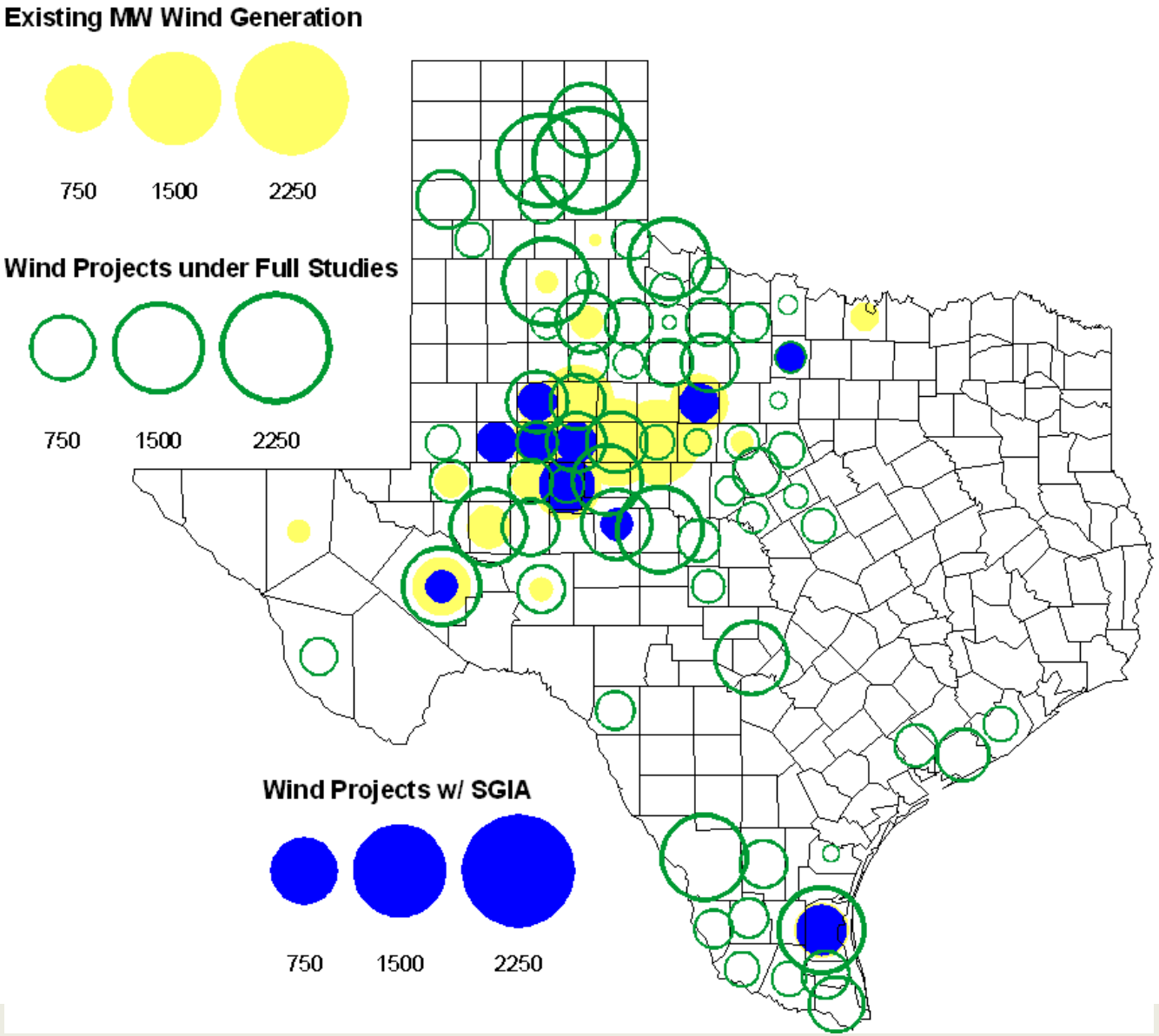
Questions?

Additional Background Materials

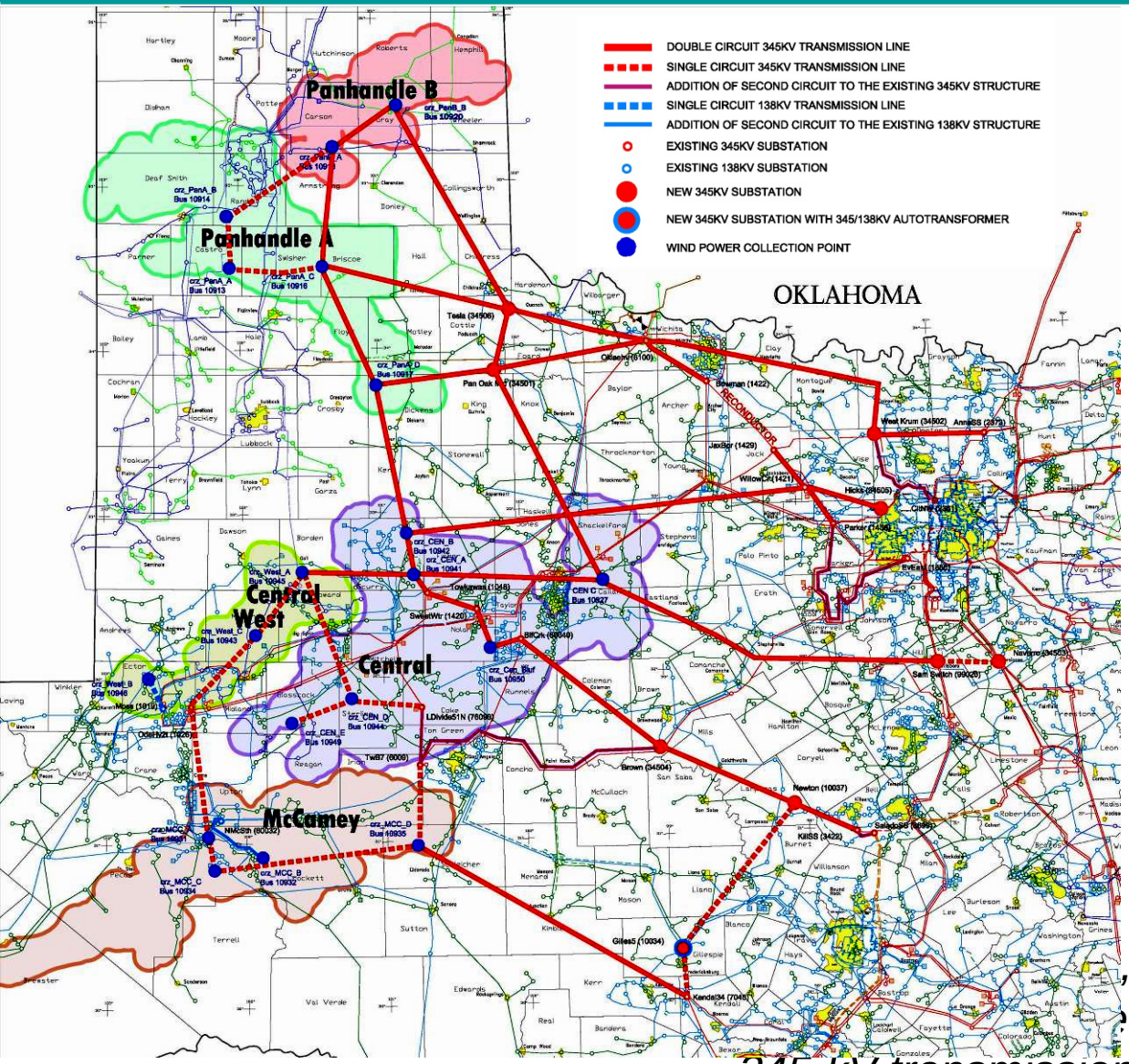
Wind Resources in Texas



Where is the Wind Generation in ERCOT?



Competitive Renewable Energy Zones



Zone	New Wind Capacity (MW)
Panhandle A	3,200
Panhandle B	2,400
Central	3,000
Central West	1,100
McCamey	1,900

, PUCT has designated CREZs
d 2,376 circuit miles of new
345-kV transmission

Cost of New Generation