Effect of market changes on the required amounts of frequency regulation ancillary services in ERCOT

Juan Andrade, Yingzhang Dong, and Ross Baldick

October 26, 2018

Abstract

- In restructured electricity markets in the US, there are multiple ancillary services, including frequency regulation and two or more types of contingency reserve.
- Frequency regulation is used to maintain supply-demand balance within each real-time market dispatch interval, which is either 15 or 5 minutes in duration, depending on region.
- As short-term load variability increases, greater quantities of frequency regulation are required to maintain electrical frequency within limits, ceteris paribus.
- With additional renewable resources such as wind, the corresponding net load variation increases.
- As wind capacity increases, we would also expect that more frequency regulation would be procured.
- The Electric Reliability Council of Texas (ERCOT) has experienced huge growth in wind over the last 20 years.
- However, the amount of frequency regulation ancillary service procured has typically decreased over time.
- We investigate why this has occurred, identifying a number of changes in the market design.
- The work highlights that market designs evolve to make better use of resources.

Outline

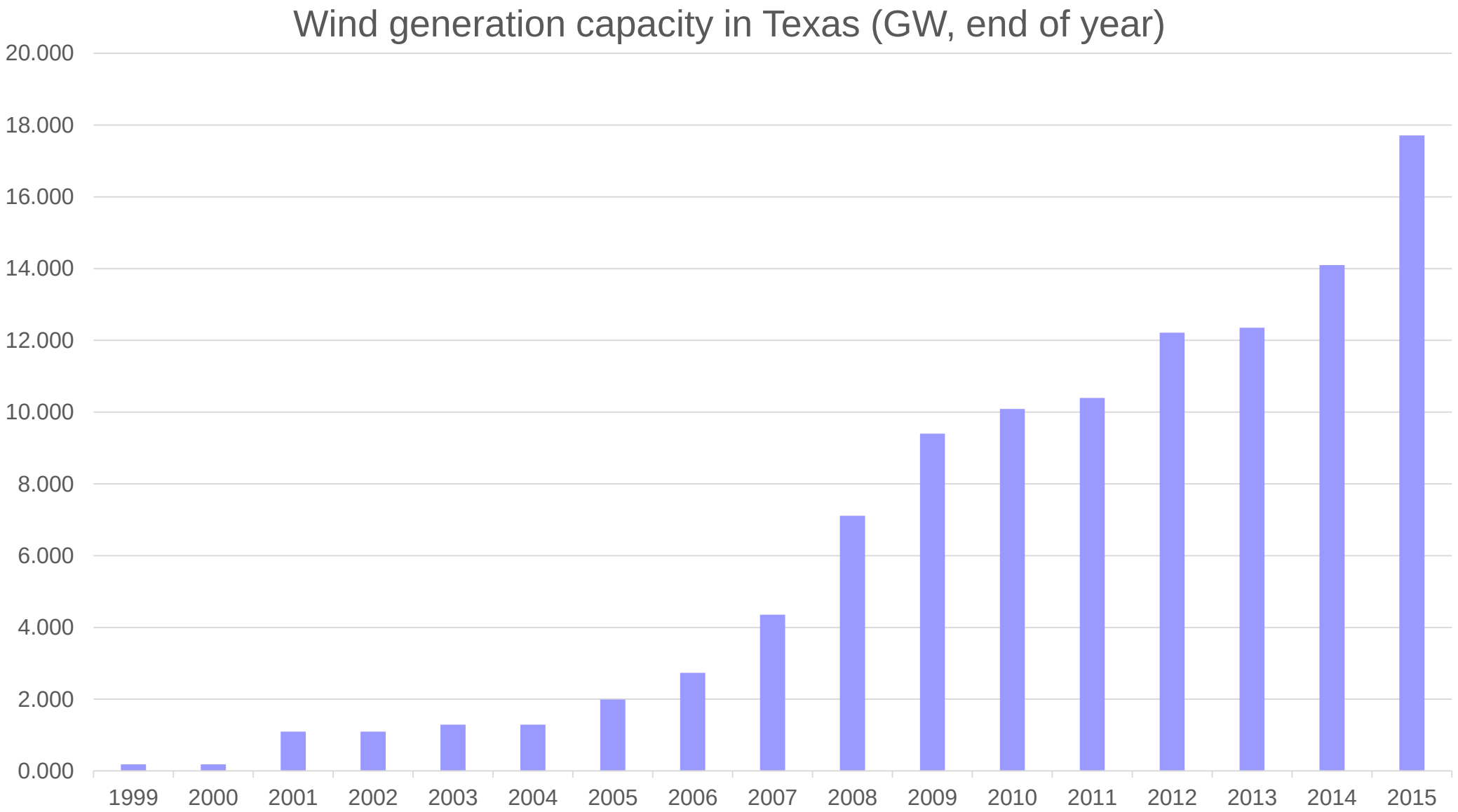
- Background: regulating reserves and frequency control,
- Description of analysis,
- Analysis limitations,
- Qualitative observations,
- Conclusion.

Background

- Significant development of utility-scale renewable generation in U.S. in the last two decades.
- Majority of these renewables are wind, but with solar now also growing rapidly.
- Texas has the largest amount of wind of any U.S. state:
  - The Electric Reliability Council of Texas (ERCOT) region has the largest penetration of wind among North American Interconnections,
  - Around 21 GW of wind power in ERCOT (about 22% of total installed capacity)(*).
  - Wind provided 17% of electrical energy in ERCOT in 2017 (*).
  - Most wind capacity installed in the last ten years.

(*) ERCOT Quick Facts 2018.

Background



Source: USDOE 2016.

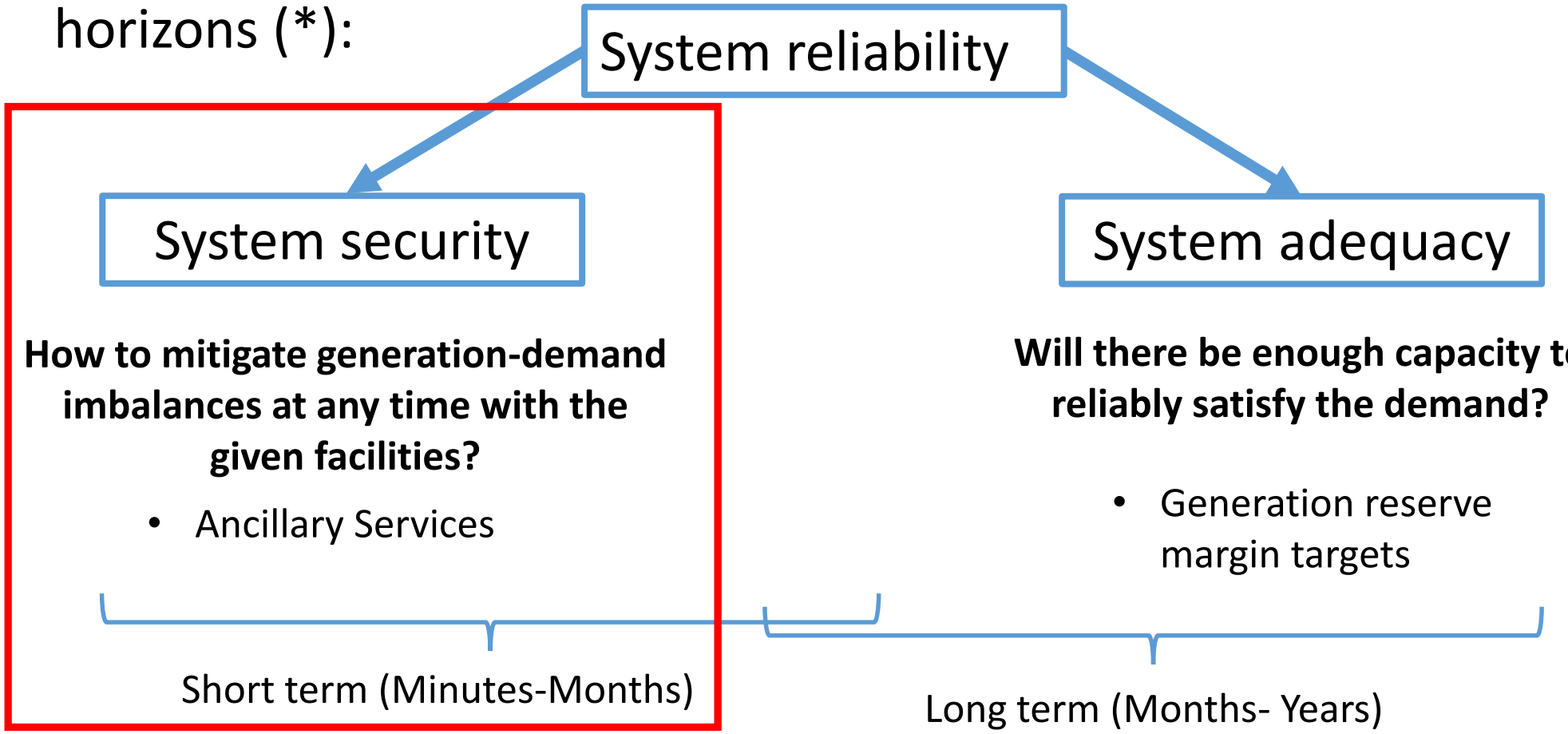
Background

- Current and future environmental policies and decreasing capital costs will likely result in further growth of renewable capacity.
- Given the intermittent/variable production of renewable generation, concerns about system reliability have arisen.
- Maintaining historical levels of reliability in the face of increasing intermittent renewables might increase costs:
  - For example, requirements for procured Ancillary Services might increase significantly.
- First discuss reliability and implications for required procured capacity of Ancillary Services.
- Then explore historical data for wind in ERCOT.

(*) ERCOT Quick Facts 2016

Background

- The concept of system reliability can be seen from two different time horizons (*):



Focus of analysis in this presentation

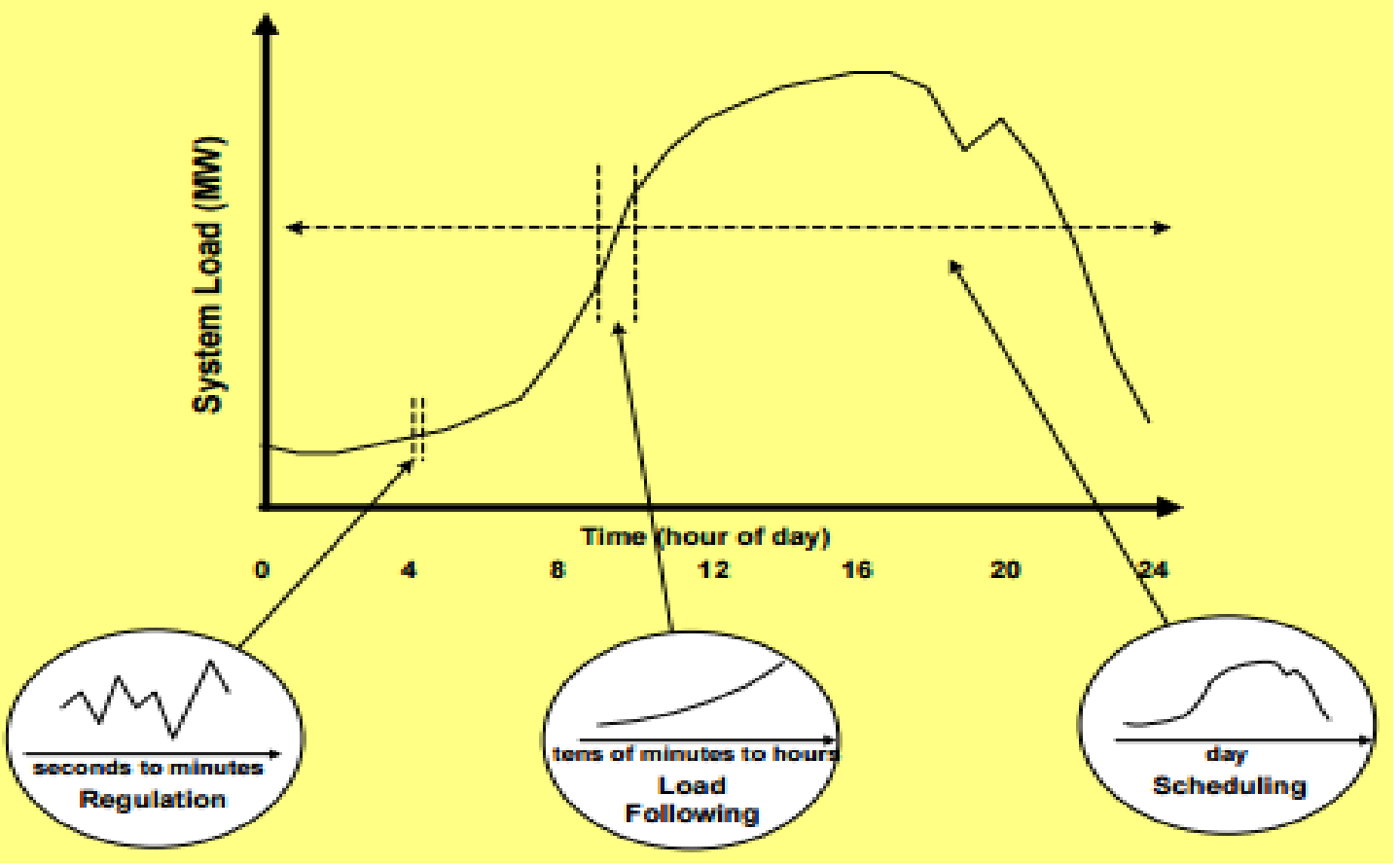
(*) R. Billington and W. Li, *Reliability Assessment of Electric Power Systems Using Monte Carlo Methods*, Plenum Press, 1994.

Background

- What are Ancillary Services (AS)?
  - Facilitate reliable delivery of energy from generation to load.
  - Examples:
    - Regulating reserve: essentially continuously control of generation (or possibly load and storage) to restore frequency towards nominal in short-term (seconds to minutes):
      - frequency deviation is due to perturbed supply-demand balance and load forecast errors,
    - Spinning or Responsive reserve: respond to sudden supply-demand imbalances typically due to outage of a generator (seconds to tens of minutes),
    - Non-spinning reserve: restore availability of other reserves if depleted by previous actions,
    - Voltage control: reactive power supply.
  - ERCOT currently recognizes 3 main types of reserves as commercial products:
    - Regulating Reserve, divided into:
      - Regulation-Up and Regulation-Down (signals to generation on typically 4 by 4 second basis, collectively “regulation AS”),
    - Responsive Reserve (full deployment within 10 minutes; known as “spinning reserves” in other US markets; up to 50% of requirements provided by interruptible loads),
    - Non-spinning reserve (committed and deployable within 30 minutes).
  - We will refer to these three types of ERCOT AS as “operational reserves.”

Background

- Time frame:
  - Operational reserves cover from seconds up through the length of the real-time economic dispatch cycle (5 minutes currently in ERCOT) and longer for full deployment of responsive reserves and for non-spinning reserve deployment.
  - (In the 5 minute and longer time domains, generation economic dispatch also helps to follow net load variation, and generation unit-commitment follows daily load periodicity.)

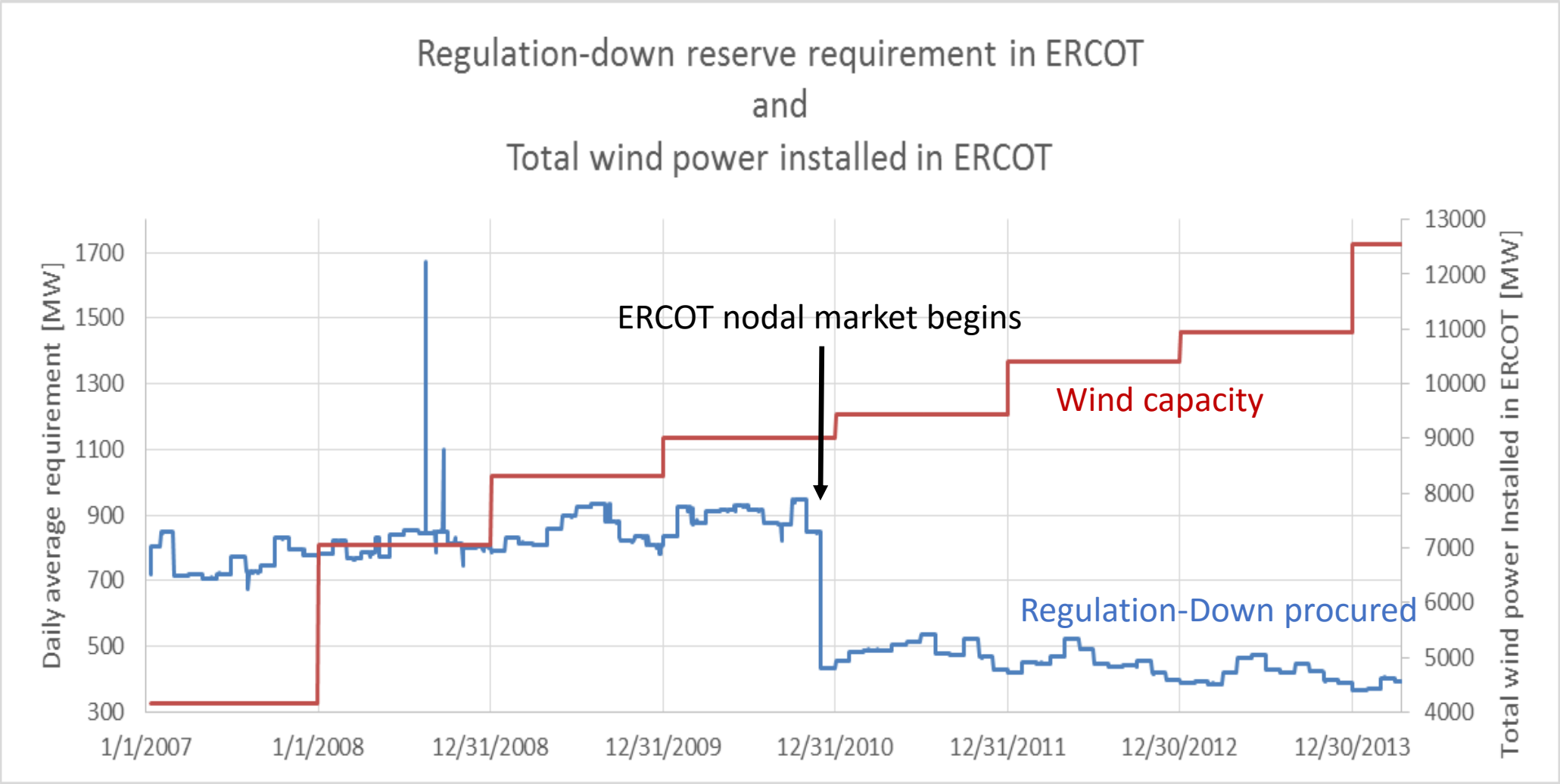


Picture from: R. E. Ela, M. Milligan and B. Kirby, "Operating Reserves and Variable Generation," 2011.

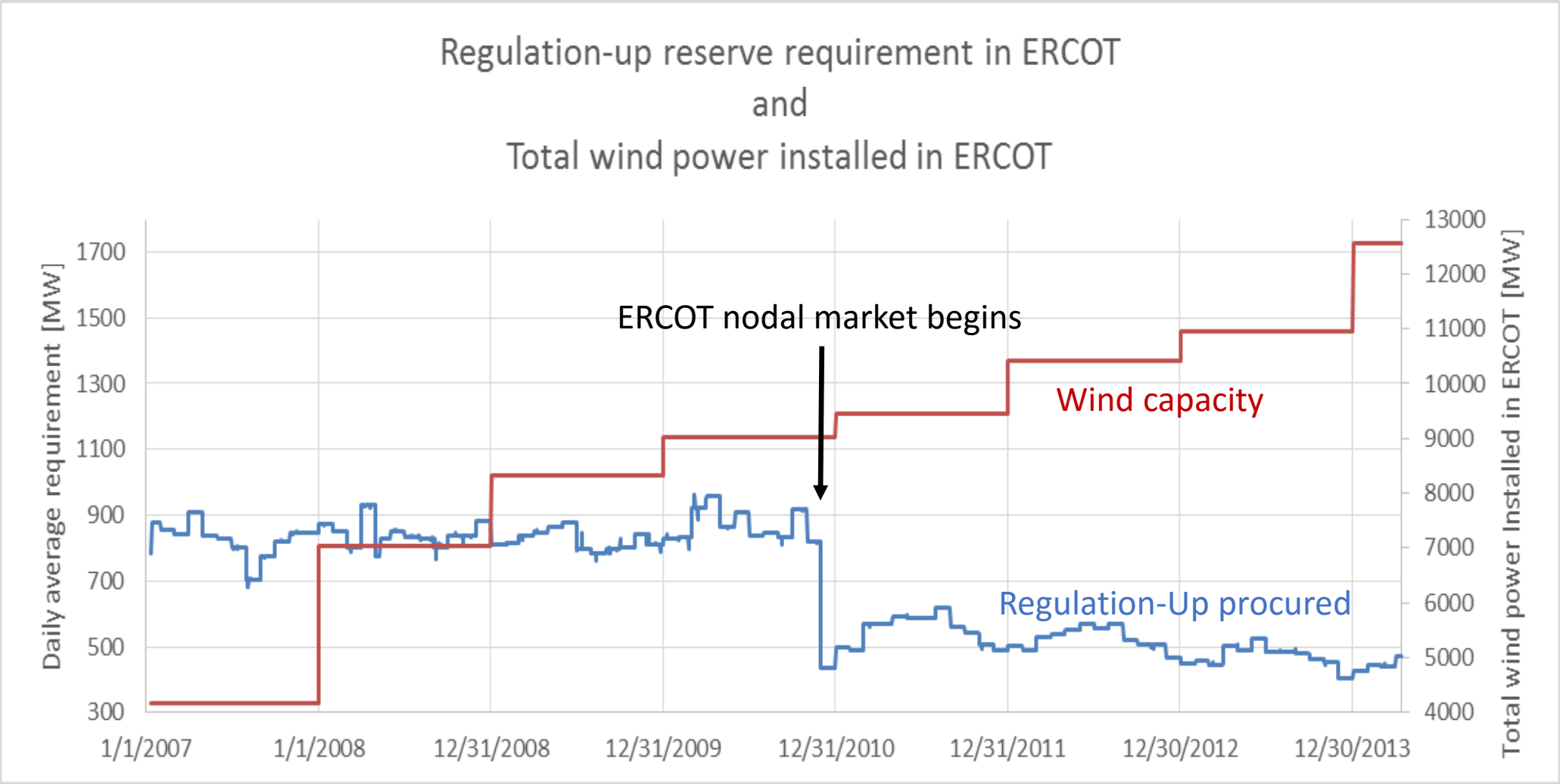
Regulating reserves

- Putting aside (the typically small) variability of dispatchable generation:
  - Regulating reserves primarily compensate for short-term variability of net load (load minus renewables) occurring between economic dispatch updates.
- Regulating reserve capacity requirements in ERCOT are specified for each of six blocks of four hours over the day and updated monthly based on:
  - Historical use ("deployment") of those reserves,
  - Anticipated changes in regulation AS needs due to changes in renewable capacity, using results of 2008 "GE study."
- All else equal, increasing wind capacity can be expected to increase needed regulating reserve capacity:
  - Results of GE study generally qualitatively consistent with this observation,
  - Increased procurement of AS would increase total costs.
- ERCOT procures AS in day-ahead market based on AS requirements.
- How does the historical record compare with this expectation?

Regulating reserves



Regulating reserves

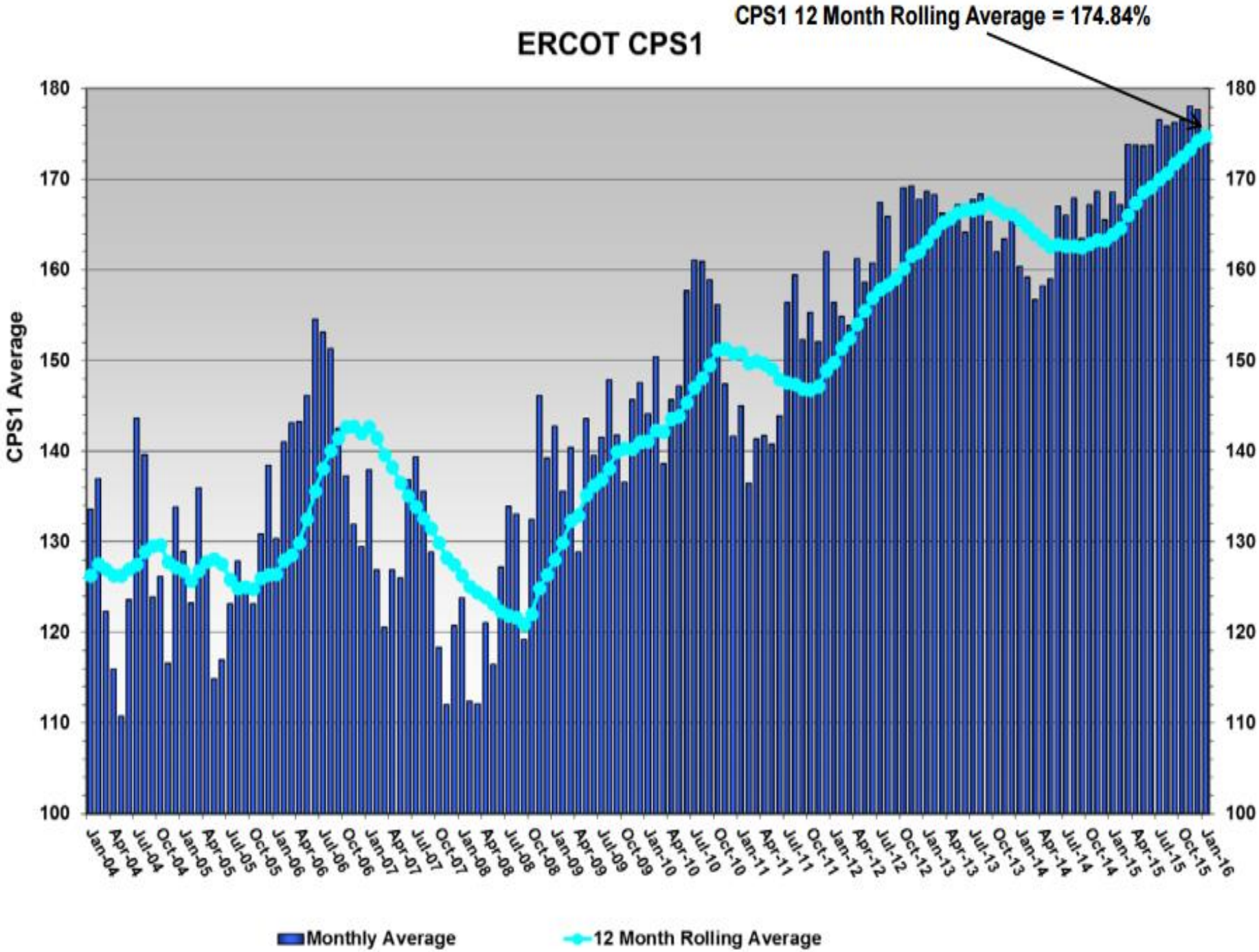


Regulating reserves

- Regulation-up and regulation-down reserve requirements have *decreased* over time despite huge increase in renewables!
- Qualitatively and quantitatively inconsistent with predictions of GE study!
- Adjustment down over time reflects the monthly updates of requirements based on historical use of the regulation resources.
- Key question is: why have requirements decreased over time despite increases in wind capacity?
- Clue: Major decrease in requirements in 2010 when market design was significantly changed:
  - Zonal representation of transmission replaced by nodal,
  - Portfolio based dispatch replaced by unit specific dispatch,
  - Day-ahead centralized unit commitment added to real-time market, and
  - Likely most significantly, dispatch interval shortened from 15 minutes to 5.

Regulating reserves

- Potential confounding issue: Have there been changes over time in the performance of ERCOT in compensating for short-term variations of supply-demand balance?
  - Perhaps the decreasing regulating reserve requirements over time corresponds to worse frequency control performance.
- Frequency control performance is assessed by the North American Electric Reliability Corporation (NERC) in terms of three standards:
  - Control Performance Standard 1 (CPS1, used for assessing control of frequency, reflecting performance of regulation AS in compensating for supply-demand balance variations),
  - Control Performance Standard 2 (CPS2, used for assessing performance of multiple balancing areas in an interconnection; not relevant to ERCOT single balancing area in ERCOT interconnection),
  - Disturbance Control Standard (DCS, used for assessing response to contingencies; not relevant for regulation AS).
- CPS1 metric assesses ability to compensate for short-term variations of supply-demand balance, and ranges up to 200%, with higher scores being better:
  - Relevant for assessing frequency control performance provided by regulation AS.


ERCOT CPS1
CPS1 12 Month Rolling Average = 174.84%
CPS1 Average
180
170
160
150
140
130
120
110
100
Jan-04
Apr-04
Jul-04
Oct-04
Jan-05
Apr-05
Jul-05
Oct-05
Jan-06
Apr-06
Jul-06
Oct-06
Jan-07
Apr-07
Jul-07
Oct-07
Jan-08
Apr-08
Jul-08
Oct-08
Jan-09
Apr-09
Jul-09
Oct-09
Jan-10
Apr-10
Jul-10
Oct-10
Jan-11
Apr-11
Jul-11
Oct-11
Jan-12
Apr-12
Jul-12
Oct-12
Jan-13
Apr-13
Jul-13
Oct-13
Jan-14
Apr-14
Jul-14
Oct-14
Jan-15
Apr-15
Jul-15
Oct-15
Jan-16
Monthly Average
12 Month Rolling Average

Regulating reserves

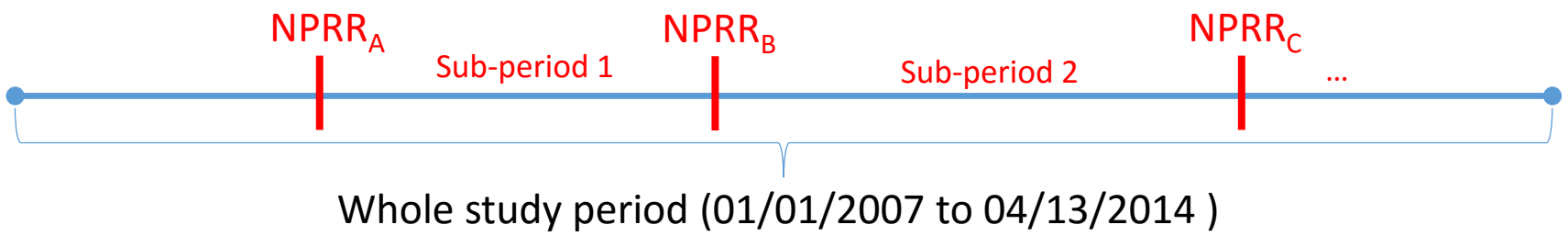
- The requirements for regulation AS have *reduced* over time:
  - *despite* increases in installed wind power capacity over time, and hence despite increases in the short-term variability of the supply-demand balance!
  - *despite* CPS1 performance improving over time!
- What explains the decrease in regulation AS requirements despite increased wind and improved CPS1 performance?
- "Big bang" change in 2010 provides clue that changes in market operations and rules have changed needs for regulating reserve capacity:
  - Also *many* other relatively smaller changes to market rules, "Nodal Protocol Revision Requests" (NPRRs).
  - Use statistical analysis to quantify effects of these changes.

Description of analysis

- Use historical record of procured regulating reserves and other data:
  - Identify the NPRRs that were statistically significant for the sudden changes in reserves requirements.
  - Identify other significant variables (e.g. installed wind power, demand)
- What data did we use?
  - Historical procured daily average Regulation-Up and Regulation-Down reserves requirements in ERCOT.
  - Daily maximum and minimum demands in ERCOT.
  - Installed generation by type (Coastal wind, non-coastal wind, thermal generation)
- An initial list of NPRRs related to wind was provided by Walter Reid (Wind Coalition), Shams Siddiqi (Crescent Power), and Dan Jones (formerly ERCOT Independent Market Monitor, now Crescent Power).
  - This list was trimmed to 23 NPRRs before applying detailed statistical analysis,
  - Some of these NPRRs were coincident with zonal to nodal change,
  - Several groups of changes were implemented within a single month and also grouped together.

Description of analysis

- Methodology:
  - We split the whole study-period into sub-periods delimited by the implementation months of the groups of NPRRs considered.



  - The transition from Zonal to Nodal market was also considered in the sub-period definition.
  - For each sub-period, a regression analysis was performed.
  - The regressors considered were: Installed power of each type, and demand.
  - The impact of the introduction of a new NPRR at the beginning of each sub-period was assessed using Regression Discontinuity Design (RDD):
    - Regressors include a dummy variable indicating pre- versus post-introduction of NPRR.

Analysis limitations

- The analysis uses data from ERCOT between 01/01/2007 to 04/13/2014:
  - Limited ability to predict outside this time-frame,
  - Requirements for regulation AS have continued to decrease subsequently, but with smaller rate of decrease, and recent evidence of increasing requirements.
- Cannot make strong statements about counter-factual scenarios such as:
  - What would be the impact if the “Competitive Renewable Energy Zone” (CREZ) transmission in West Texas had not been developed?
  - What would be the impact of a massive solar development in Far West Texas?
- Main focus is on regulation AS:
  - Related future work includes analysis of responsive and non-spinning AS.

Qualitative observations

- There are significant correlations between requirements for Regulation-Up and Regulation-Down reserves and:
  - Daily minimum demand.
  - Daily maximum demand.
  - Installed wind power.
- There are significant correlations with past reserves requirements:
  - ERCOT uses the previous 30 days deployed reserves, in part, to determine the required reserves for the next month.
  - For “big bang” transition, past deployments before December 2010 were divided by two to use in determination of December 2010 and later regulation requirements.
  - Required and deployed reserves are strongly correlated.
- Complicates the analysis of the statistics.

Qualitative observations

- RDD indicates that the following NPRRs had a significant effect on the required amounts of regulating reserves:
  - NPRR 352:

    Improvements in prediction of the maximum sustained energy production of a wind resource after a period of curtailment of the wind resource.
  - NPRR 361:

    Requires submission of 5 minute resolution wind data for real-time purposes.
  - NPRR 460:

    Relaxes the wind generation resource ramp rate limitation from 10% per minute of nameplate rating to five minute average of 20% per minute of nameplate rating and with no individual minute exceeding 25%.
- Note that there have been literally hundreds of proposed and implemented changes to the details of the market design!

Qualitative observations

- Most significant change for regulation AS requirements associated with move from zonal to nodal market:
  - in zonal market the real-time dispatches were every 15 minutes to portfolios, and in nodal market are every 5 minutes or more often to individual generation units;
  - unit specific dispatch in nodal allows for more precise control of generation;
  - co-optimization of energy and ancillary services in day-ahead market has likely improved ability to utilize flexibility of generation.
- Decreasing the dispatch interval from 15 to 5 minutes:
  - amount of procured regulation AS only needs to compensate for supply-demand variation and forecast error in a 5 minute time frame instead of a 15 minute time,
  - less operating reserves, specifically less regulation AS, is needed to cope with the smaller uncertainties between each dispatch update.
- "Big bang" in 2010 and NPRRs more than compensated for effect on regulation AS of increased net load uncertainty due to increased wind:
  - (Increase in 2012 by 500MW in responsive requirements & decrease by 500MW in non-spinning apparently associated with resource adequacy concerns and not directly associated with wind, but may be indirectly attributable to effect of wind.)
  - Further investigation necessary for responsive and non-spinning reserves.

Qualitative observations

- Various changes in ERCOT market design have reduced need for procured Regulation-Up and Regulation-Down despite increases in wind.
- Effect of changes in rules on requirements for regulation AS is apparently as large as a change of tens of GW of wind generation!
- How much more wind can be integrated without needing, for example, large-scale storage?
  - Depends on interplay of ingenuity of market participants and fundamental physical requirements to match supply-demand balance with the decreasing inertia contributed by thermal generation,
  - “It’s hard to make predictions, particularly about the future.”

Conclusion

- Requirements for regulating reserves have tended to decrease over time in ERCOT despite increasing amounts of renewables and improved CPS1 scores.
- “Big bang” in 2010 together with several NPRRs have resulted in better utilization of regulation AS capacity:
  - Reducing the total required regulation AS capacity, despite the greatly increasing amount of variable generation in system.
- Future predictions of AS requirements are uncertain:
  - Increased renewables would tend to increase needs, but
  - Changes in rules and operational methods can utilize underlying AS capacity more effectively, and
  - Introduction of battery and other fast responding resources could further change needs for procured capacity.