



Wind Integration in ERCOT

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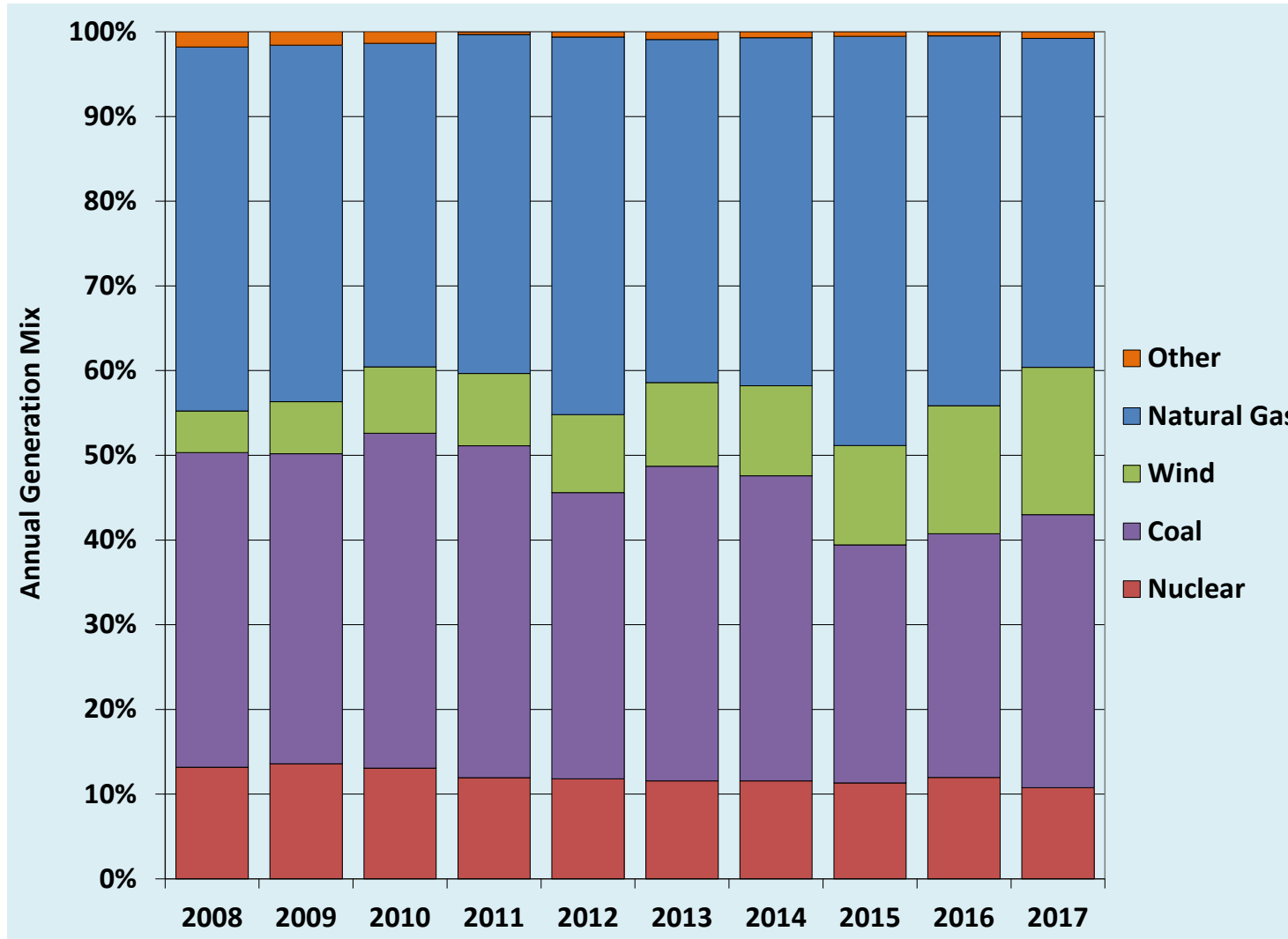
Thoughts on ERCOT's Wind Generation Experience

- More wind, more wind, more wind
- Better reliability metrics
- Reduced ancillary services requirements

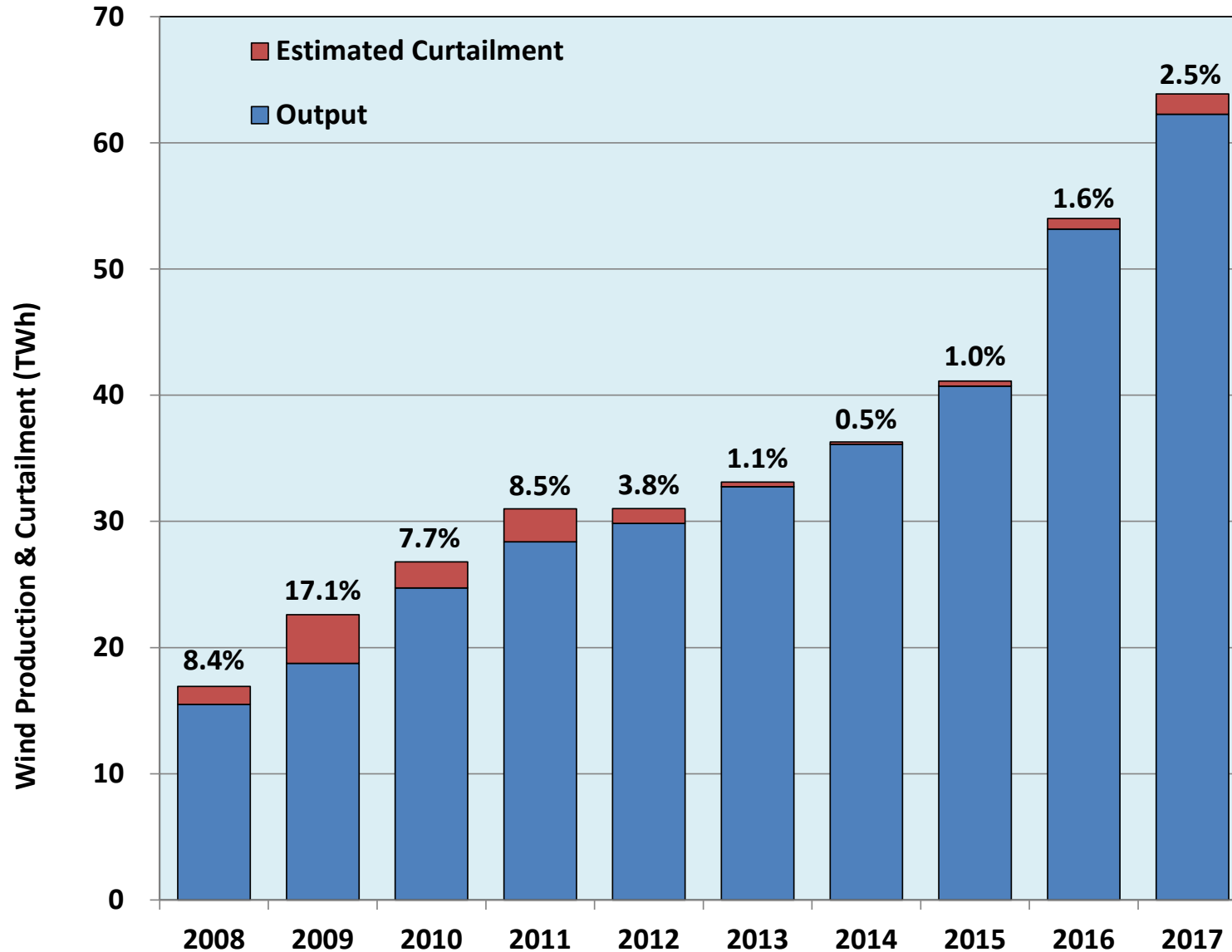
Geography



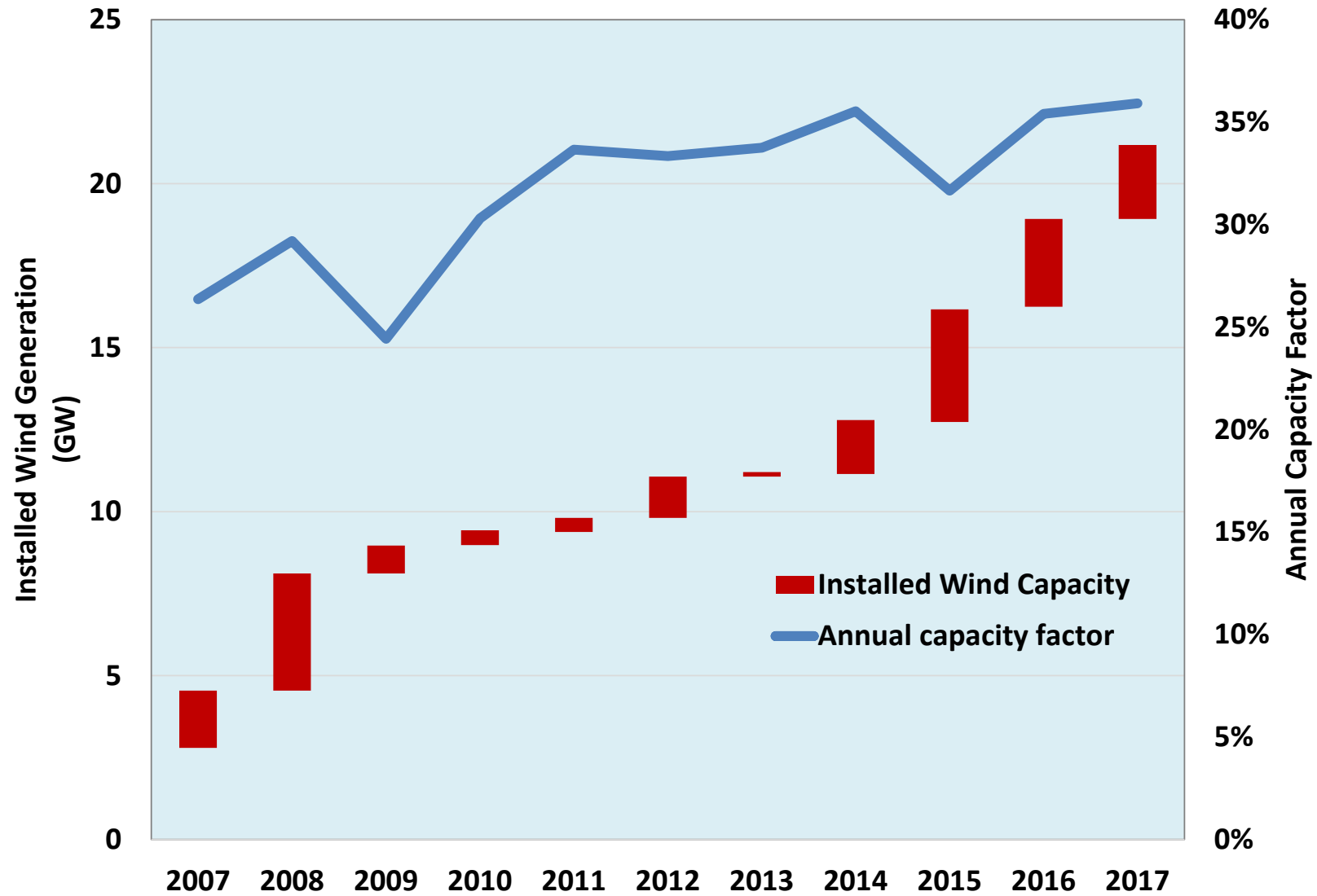
ERCOT Annual Energy by Fuel Type



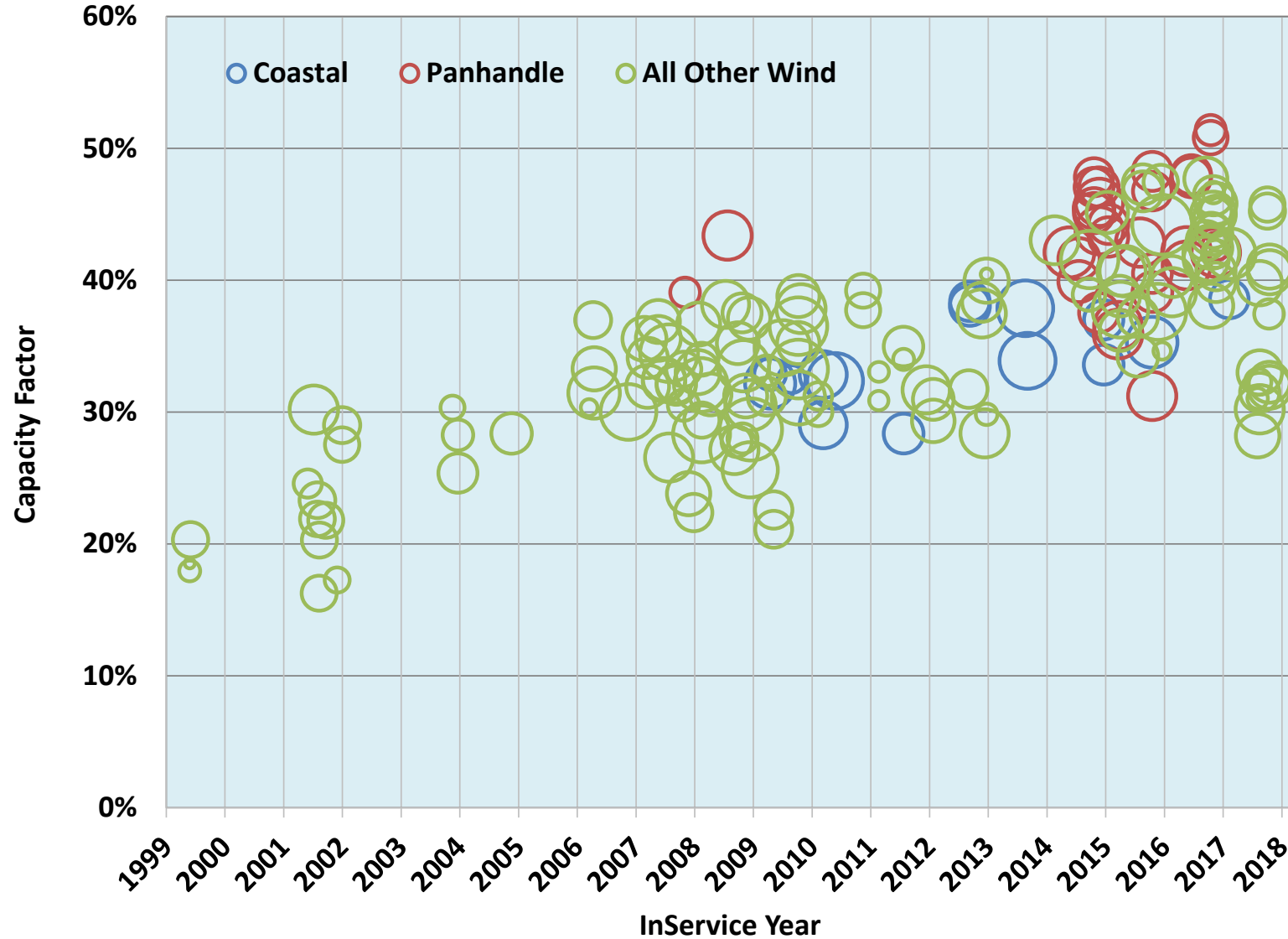
Wind Output and Estimated Curtailment



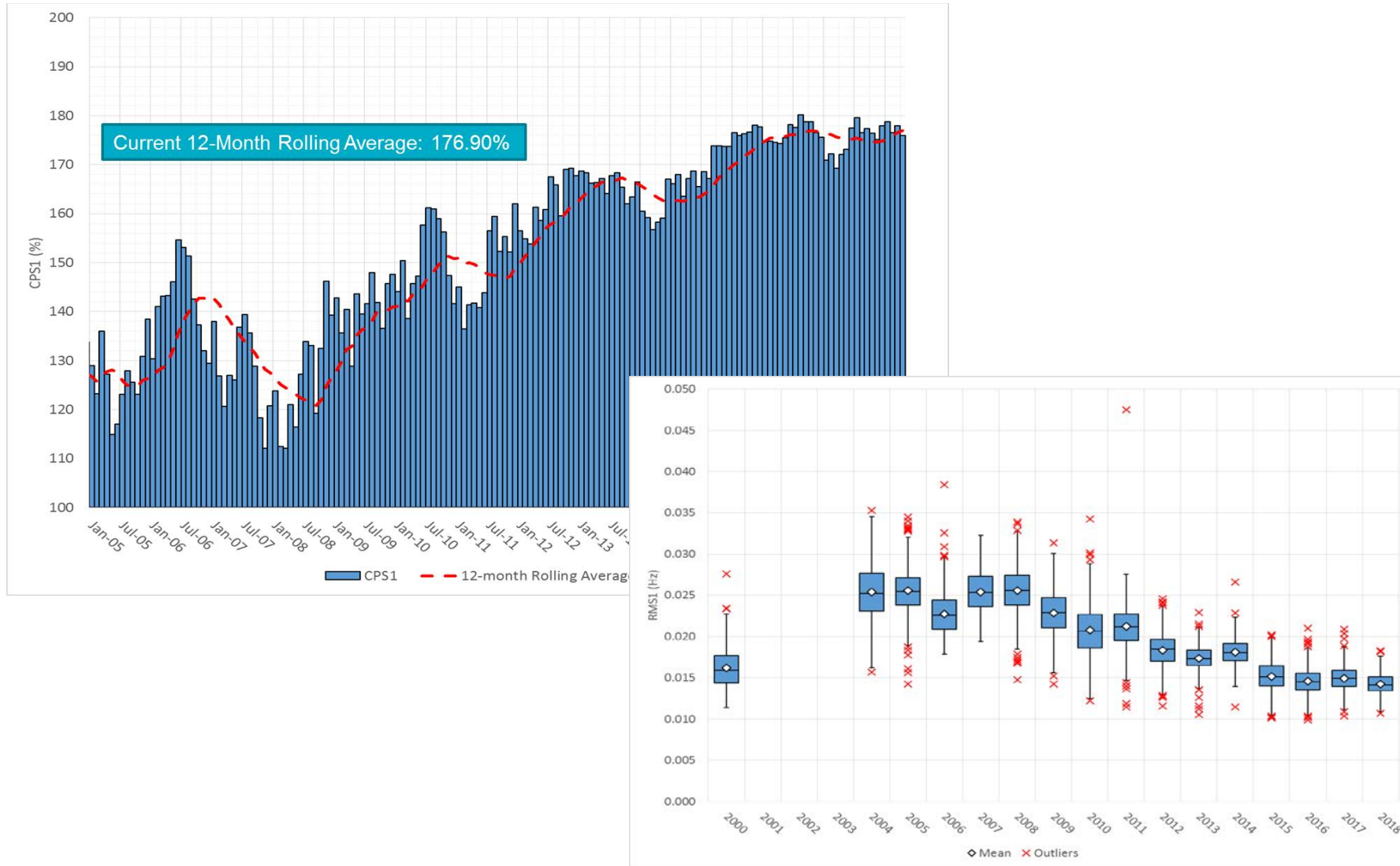
More wind producing more



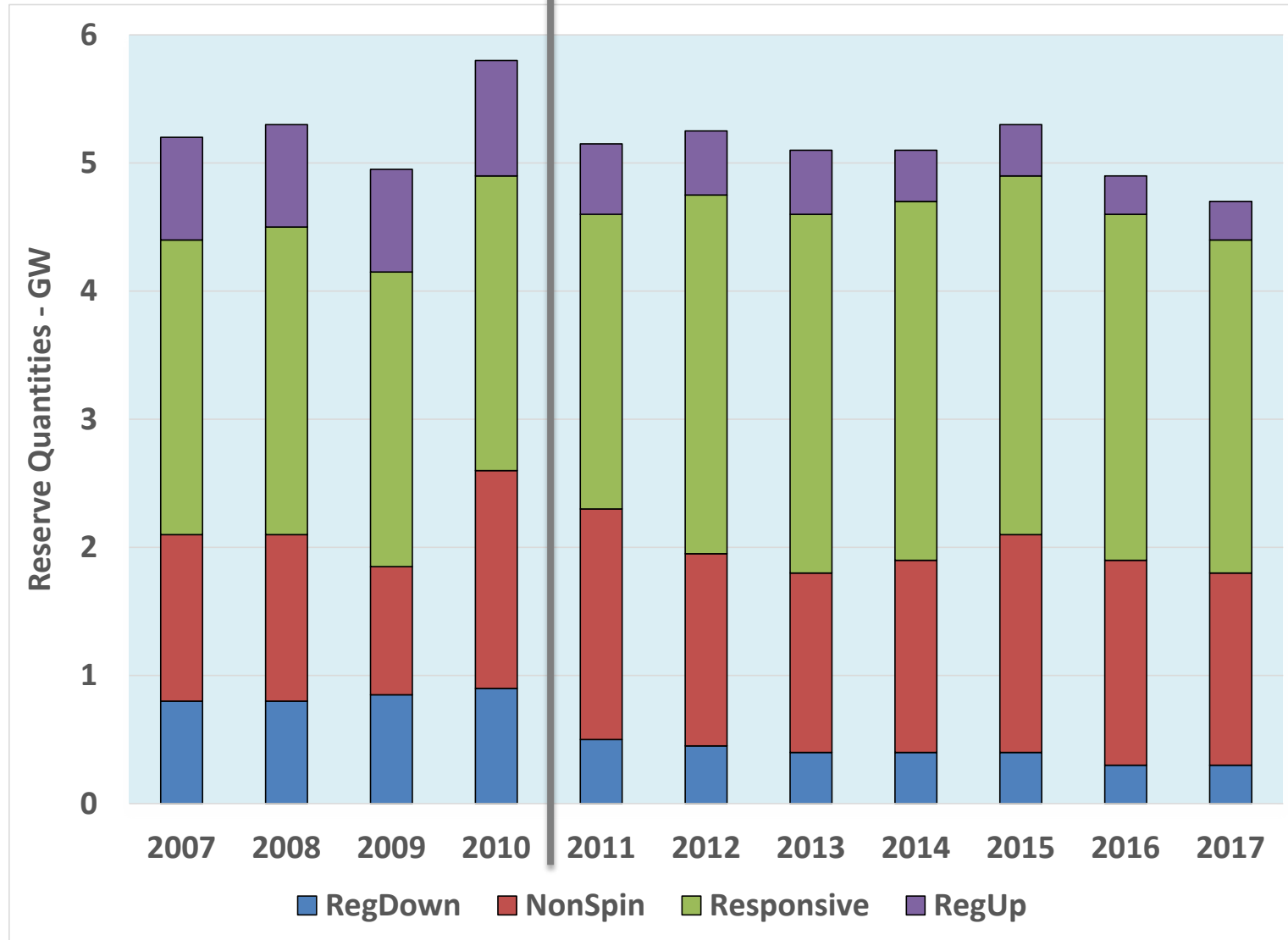
2017 Unit Specific Wind Generation Capacity Factor



Improved Reliability Metrics



Declining Requirements for Ancillary Services



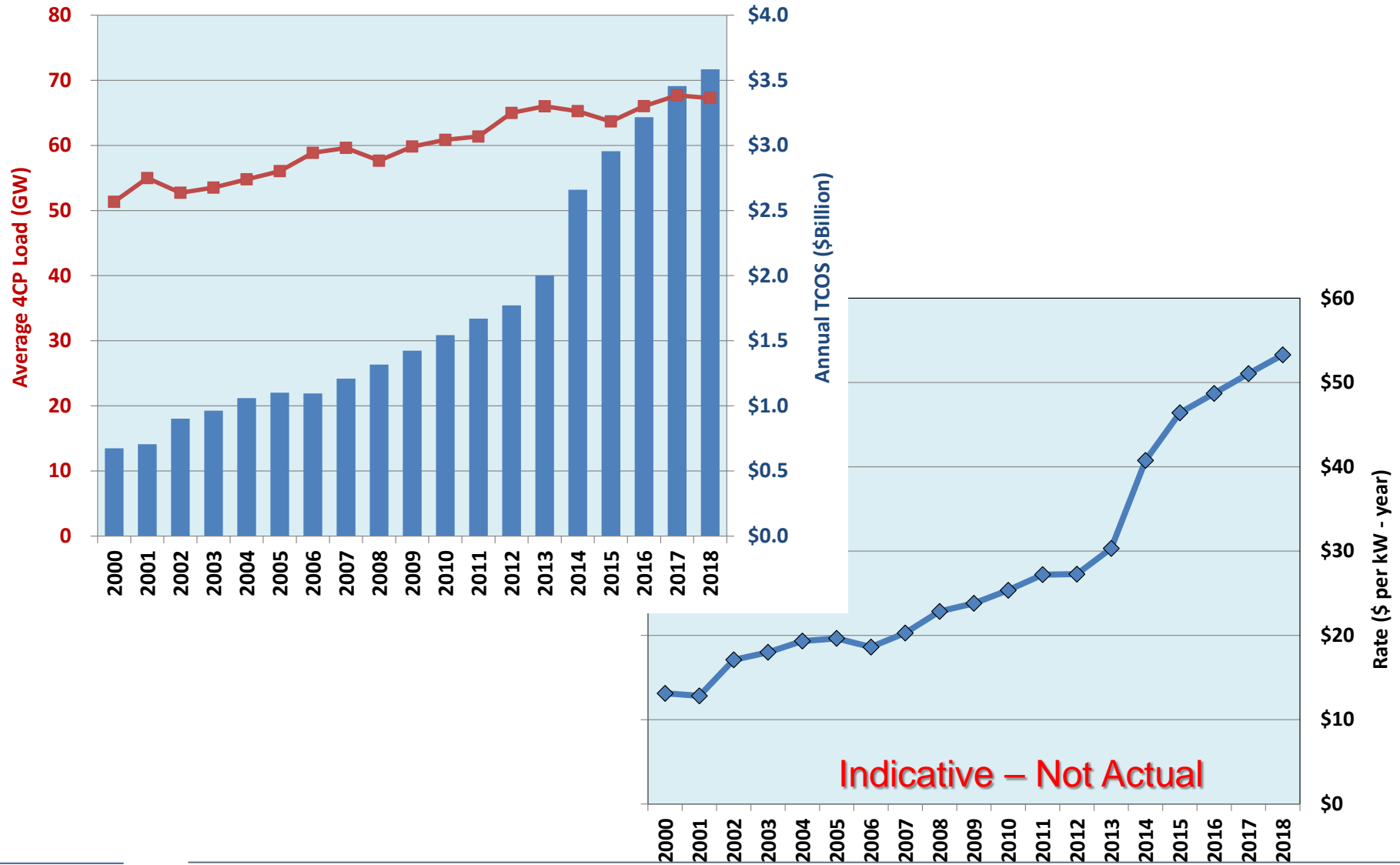
Key Enablers

- Common carrier model for Transmission
- Centralized forecasting of wind output
 - for every wind generator
 - ramp events
- Real-time output variations accommodated

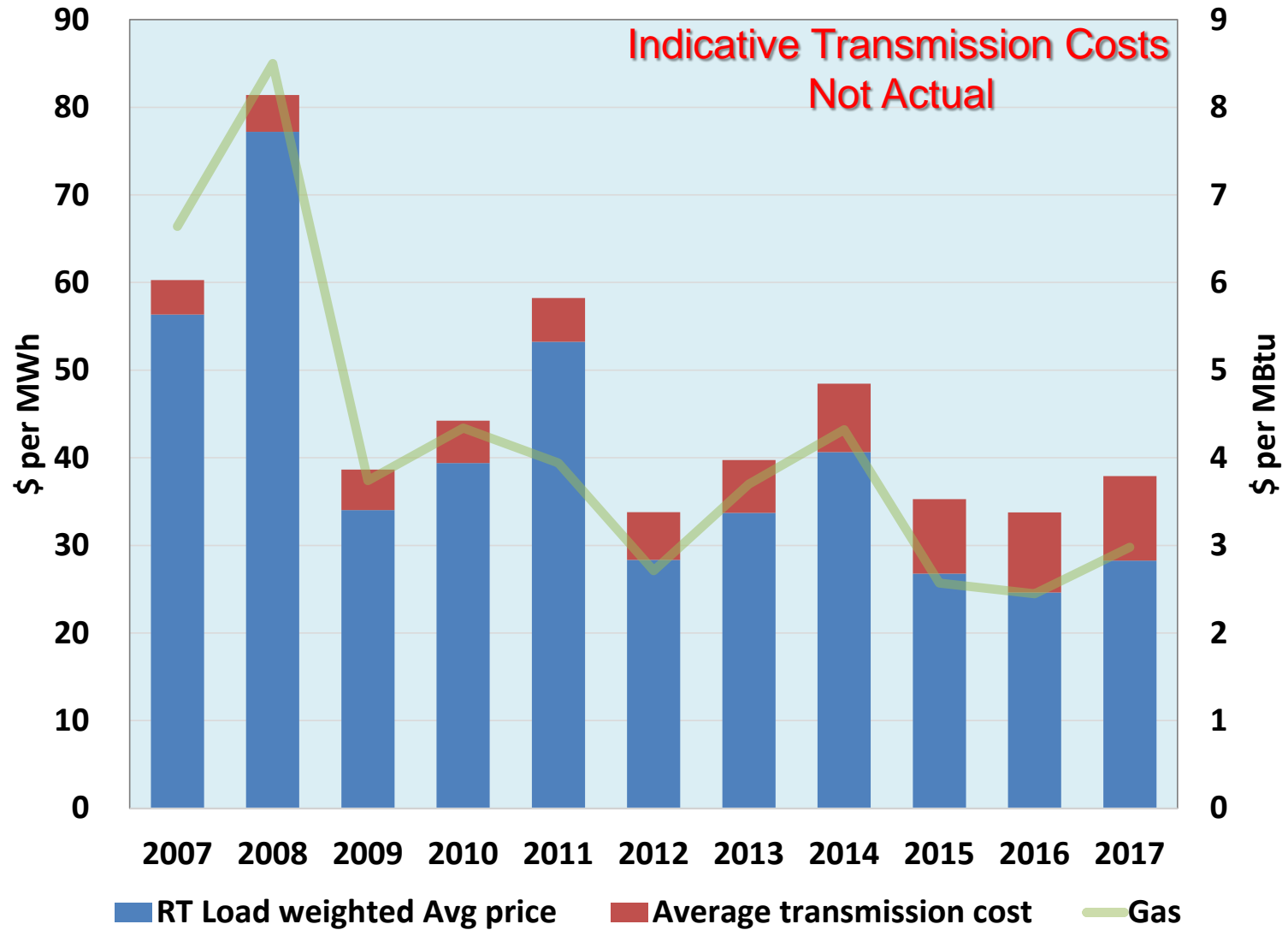
ERCOT Transmission

- All loads pay for all transmission
- Generators are not required to make any transmission investment past their step-up transformer
- Public policy choice to build out transmission system in advance of need
 - CREZ investment - \$7B

Transmission Costs



Transmission and Energy costs



ERCOT Wind Forecasts

- Hourly forecast of wind production potential for each Wind-powered Generation Resource (WGR) updated hourly, for next 168 hours. (STWPF)
- Determine probability distribution of the hourly production potential from all wind-power in ERCOT for each of the next 168 hours. (TEWPF)
- WGR provide turbine availability via outage scheduler

ERCOT Wind Forecasts - WGR requirements

- Install and telemeter to ERCOT site-specific meteorological information necessary to produce the STWPF and TEWPF forecasts.
- ERCOT requires the following data be provided from each WGR every five minutes:

MW Average

Wind Speed

Wind Direction

Temperature

Barometric Pressure

HSL Average

Num of Turbines On

Num of Turbines Off

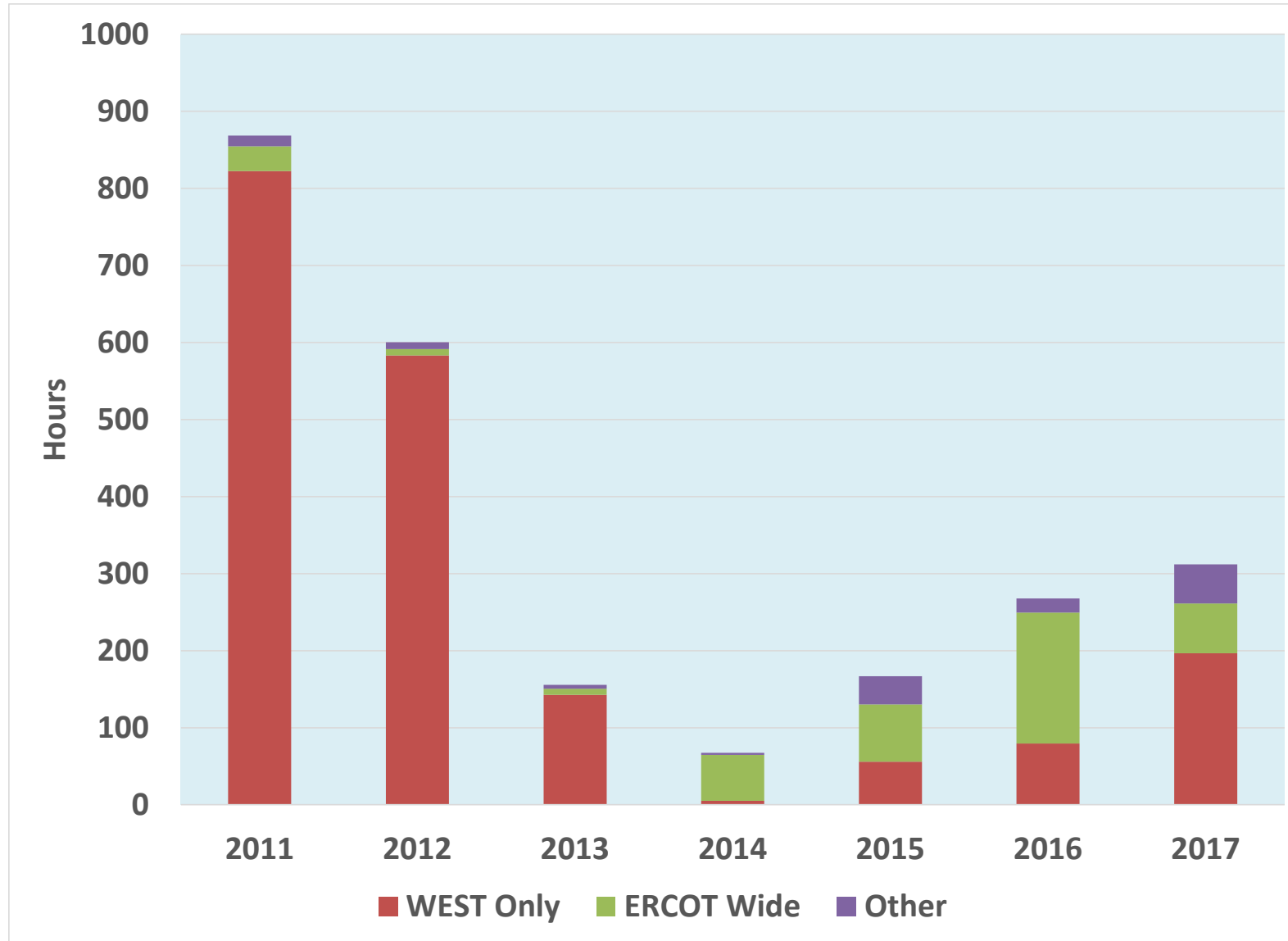
Num of Turbines Unknown

Curtailement Flag

Accommodating variable output

- ERCOT dispatch executes every 5 minutes
- WGR High Sustained Limit (HSL), when not curtailed, to be telemetered as equal to the WGR's current meter reading
- When curtailed, WGR's receive a curtailment flag from ERCOT along with their Base Point (dispatch level)
- When WGR is curtailed, the HSL to be telemetered is the expected output, but for the curtailment
- WGR ramping when curtailed limited to 20% per minute, unless installed before 2009 and have a good excuse

Negative prices



In Summary

- ERCOT's experience
 - More wind, more wind, more wind
 - Better reliability metrics
 - Reduced ancillary services requirements
- Enablers
 - Common carrier model for Transmission
 - Centralized forecasting of wind output
 - Real-time output variations accommodated