Experience in Texas with Declining Inertia

Julia Matevosyan
Resource Adequacy
ERCOT

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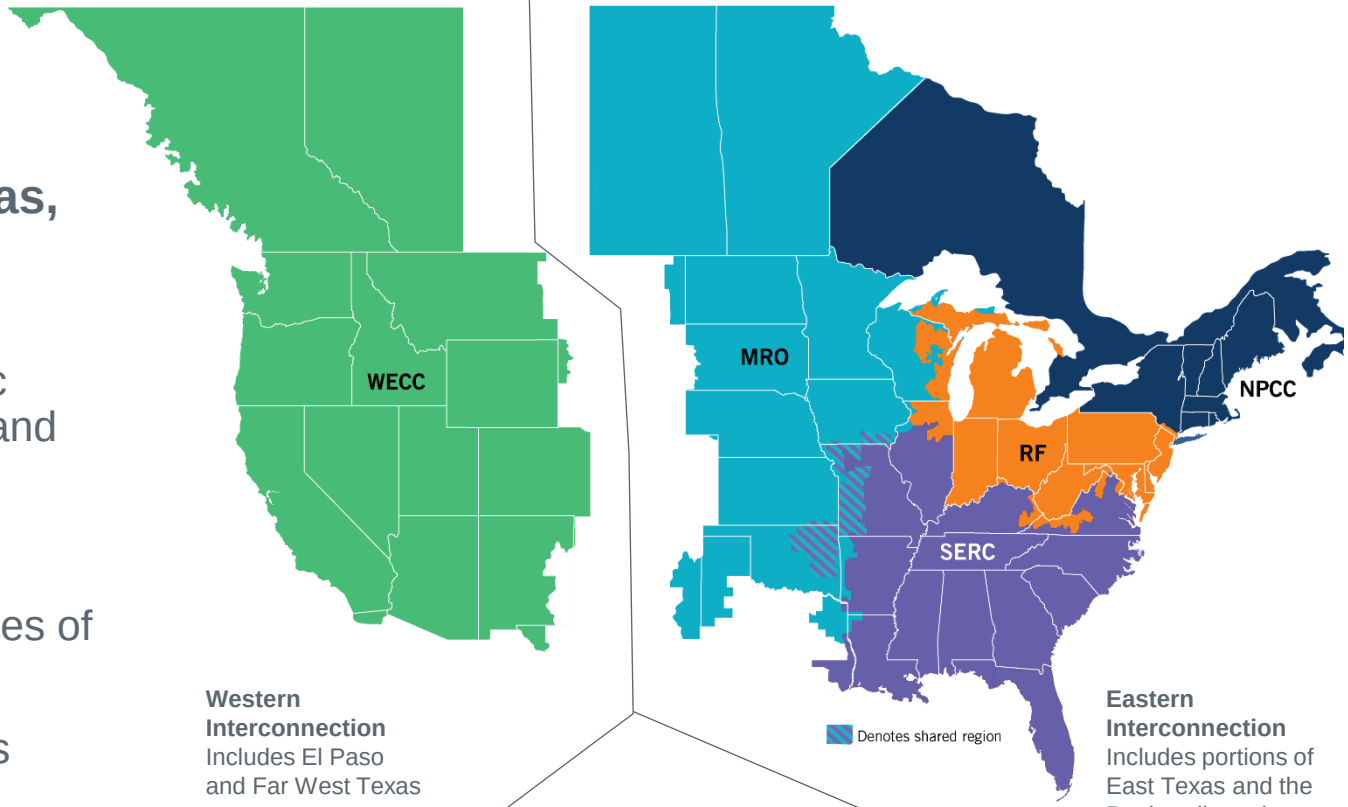
The ERCOT Region

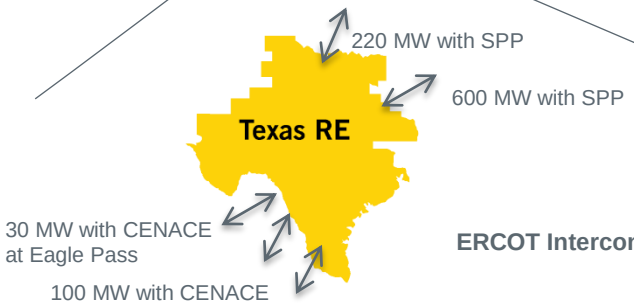
The interconnected electrical system serving most of Texas, with limited external connections

- 90% of Texas electric load; 75% of Texas land
- 74,820 MW peak, August 12, 2019
- More than 46,500 miles of transmission lines
- 680+ generation units (excluding PUNs)



Western Interconnection
Includes El Paso and Far West Texas

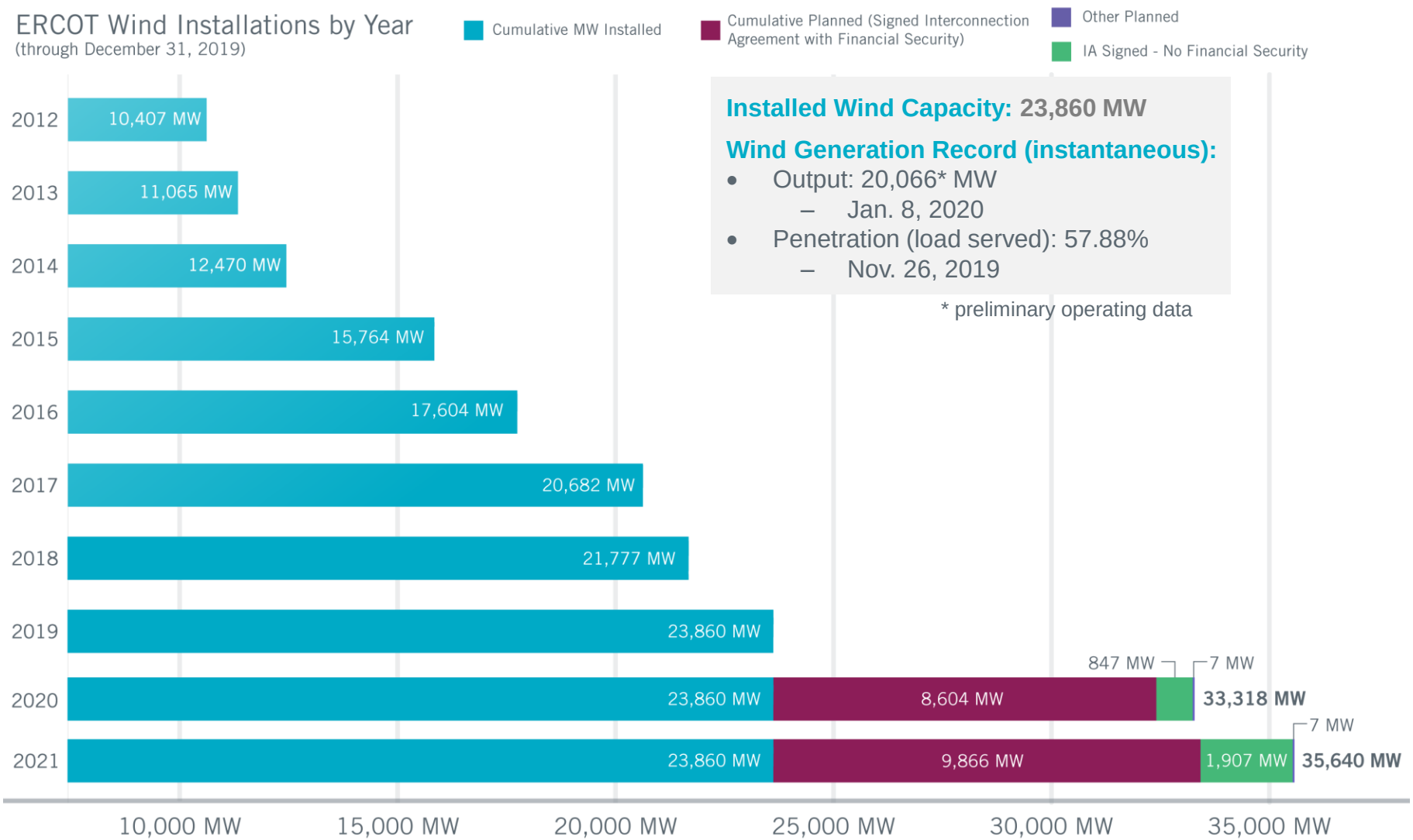
Eastern Interconnection
Includes portions of East Texas and the Panhandle region



ERCOT Interconnection

ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity

Wind Generation Capacity – December 2019



Installed Wind Capacity: 23,860 MW

Wind Generation Record (instantaneous):

- Output: 20,066* MW
  - Jan. 8, 2020
- Penetration (load served): 57.88%
  - Nov. 26, 2019

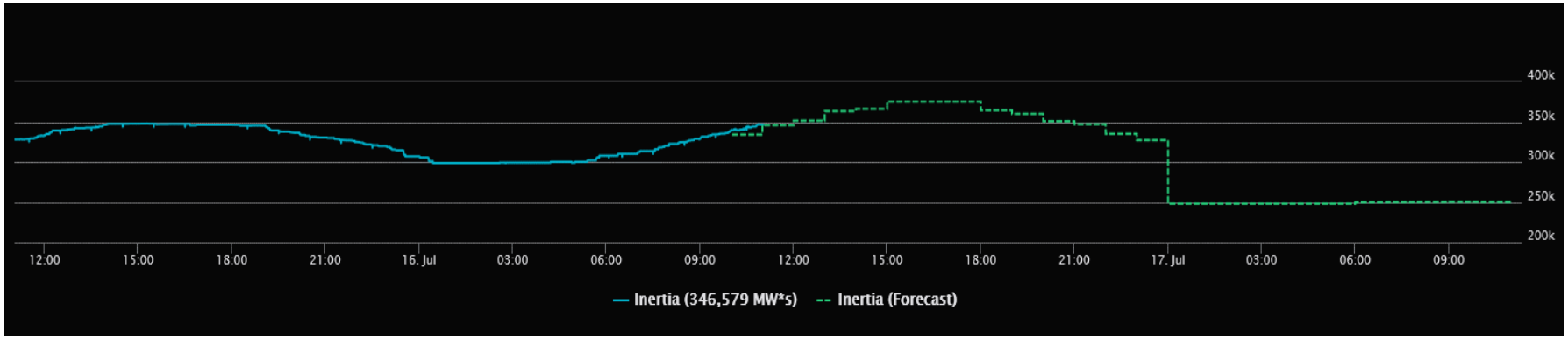
* preliminary operating data

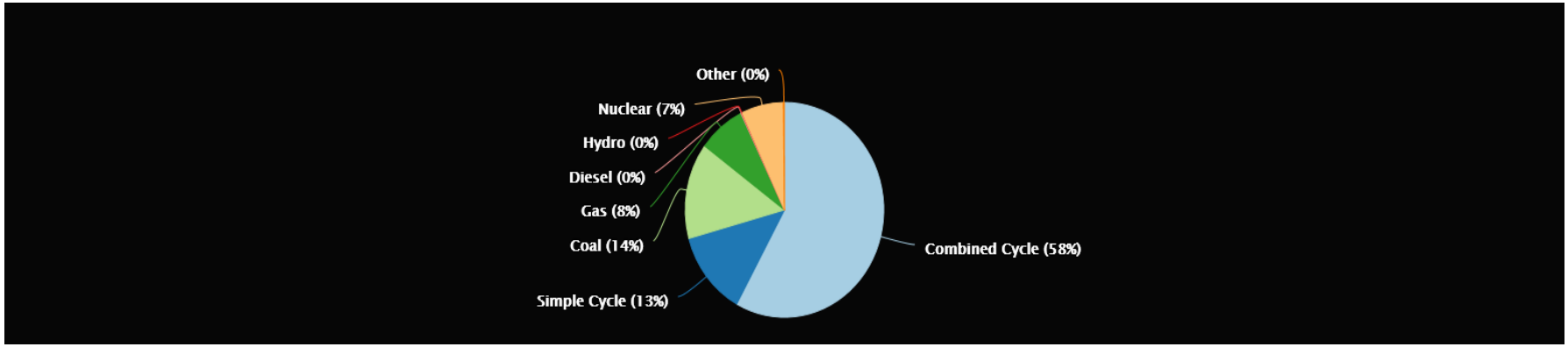
*Other Planned capacity reflects projects under 10 MW in size that are not included in the Resource Integration and Ongoing Operations Interconnection Services (RIOO-IS) System.

Inertia Monitoring and Solutions

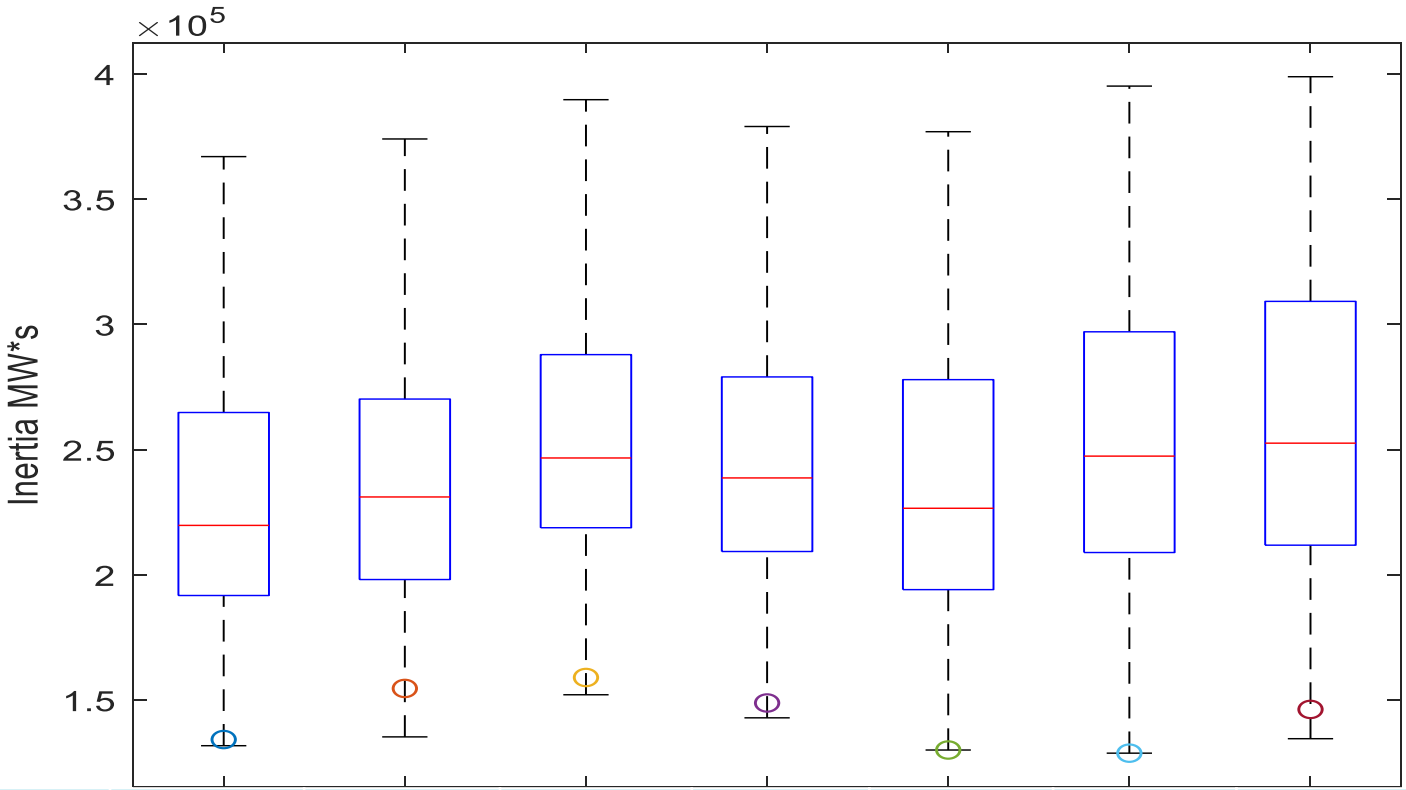
- Synchronous Inertia monitoring and forecasting set up in the control room since 2015 (summing inertia of each online synch. generator);
- Minimum inertia to date 129 GWs;
- ERCOT also determined “critical inertia” as inertia level below which, following a trip of two largest generating units, existing frequency control is not fast enough to arrest the frequency before it triggers underfrequency load shedding.
- Critical inertia determined as 100 GWs based on stability analysis;

Inertia Monitoring in Real-Time and Forecasting





ERCOT Inertia 2013-2019



Date and Time	2013 3/10/13 3:00 AM	2014 3/30/14 3:00 AM	2015 11/25/15 2:00 AM	2016 4/10/16 2:00 AM	2017 10/27/17 4:00 AM	2018 11/03/18 3:30 AM	2019(Jan-Nov) 3/27/2019 1:00 AM
Min synch. Inertia (GW*s)	132	135	152	143	130	128.8	134.5
System load at minimum synch. Inertia (MW)	24,726	24,540	27,190	27,831	28,425	28,397	29,883
Non-synch. Gen. in % of System Load	31	34	42	47	54	53	50

Inertia Trend, Key Points

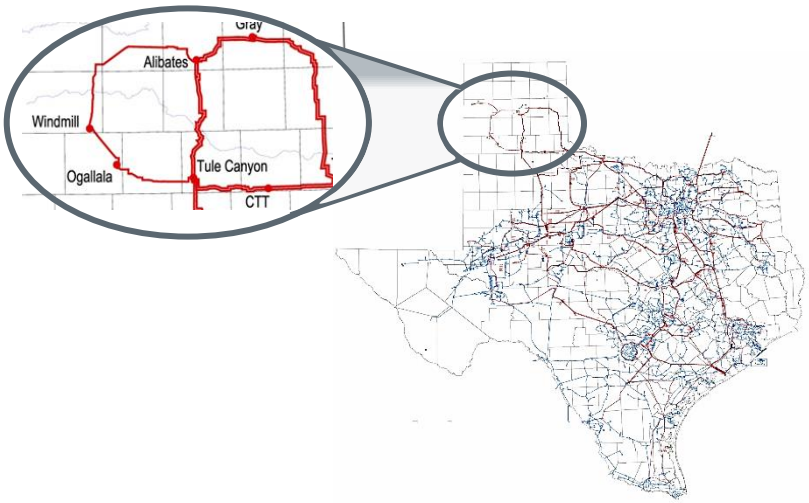
- Since then ERCOT more than doubled wind generation capacity (2013-2019)
- Intuitively it was expected for inertia to decline as a result, however it did not follow the expected declining trend
- Inertia trend is effected by a combination of factors:
  - Higher minimum loads offset higher off-peak wind output resulting in higher minimum net-loads, which also lead to more synchronous units staying committed
  - Wind power production from some areas is curtailed due to weak grid/voltage stability considerations
  - Lower natural gas prices led to more Combined Cycle (CC) plants staying committed
  - Coal retirements led to more Combine Cycle (CCs) staying committed; CCs have higher inertia per committed MW capacity
  - Steady inertia contribution from Private Use Networks

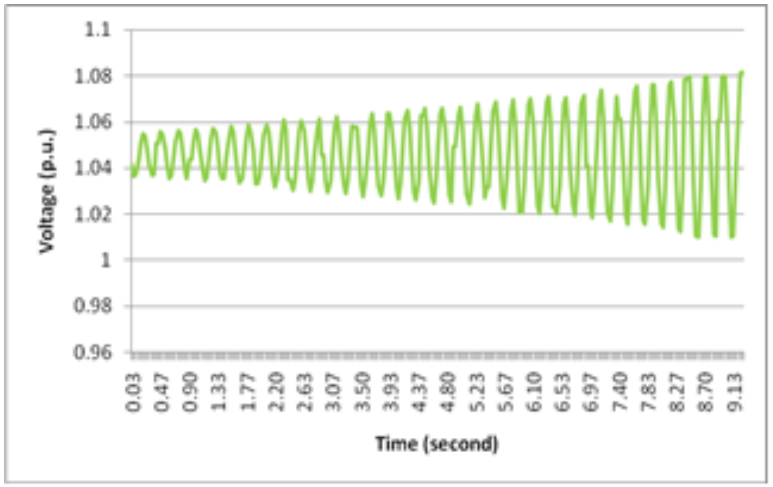
Inertia and Ancillary Services

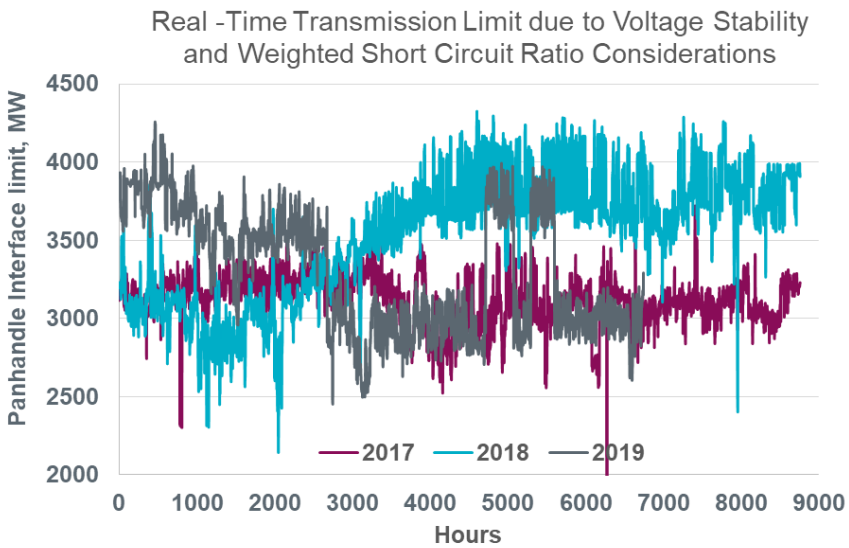
- Frequency containment reserve (called Responsive Reserve Service) is based on expected inertia conditions and sufficiency monitored in real time;
- Fast Frequency Response (a new Ancillary Service) is implemented in March 2020 (full response in 0.25 s, at 59.85 Hz)
- With implementation of FFR and once the participation starts, critical inertia will reduce from 100 GWs to 90 GWs
- Currently, sufficient inertia is expected online to serve growing energy demand and Ancillary Services
- As more inverter-based resources seek qualification to serve the demand and provide AS this may change in the future

Weak Grid Issues in Panhandle

- ~ 4 GW in service, ~1.2 GW planned (most projects are wind generation)
- ~2.3 GW in service, 2.5 GW planned in the nearby area
- No local load or synchronous generators
- Voltage support and system strength issues
- Two SynCons were installed system strength and dynamic voltage support

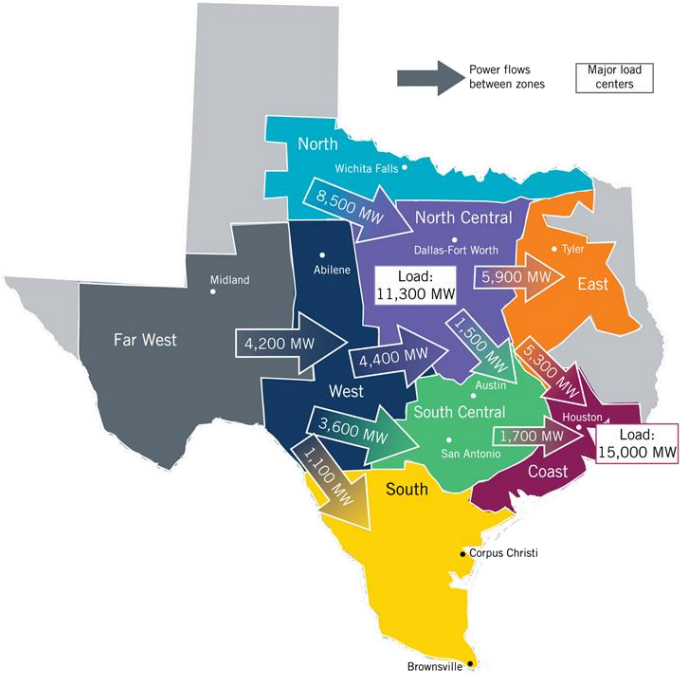






ERCOT High Penetration Study

- ~70% Penetration of Inverter-Based Wind and Solar Resources
- Less Synchronous Generators
- Reduced System Strength
- Significant active and reactive power losses
- IBR controls require sufficient system strength for reliable operation or more robust inverter control capability is required, grid forming (?)
- Synchronous condensers are subject to synchronous machine instabilities (inter & intra area oscillations & angular instability)



Load:	42.2 GW (includes PUNs)
Solar output:	17 GW (90% dispatch)
Wind output:	11 GW (48% dispatch)
West Texas Exports:	15.5 GW (major 345 kV circuits)
Losses (MW):	6%

http://www.ercot.com/content/wcm/lists/144927/Dynamic_Stability_Assessment_of_High_Penertration_of_Renewable_Generatio....pdf

Summary

- All other factors being constant, inertia is expected decline in proportion to installed capacity of inverter-based generation;
- ERCOT monitors and analyses system inertia, determined critical inertia, procures reserves based on expected inertia conditions and implemented faster frequency response product that allows to reduce critical inertia
- On the other hand, ERCOT's load is growing, lower gas prices and coal retirement result in more CCs committed and higher overall inertia.
- Private Use Networks generation provide significant portion of system inertia and currently does not respond to energy price as other generation
- Finally, more pressing weak grid/voltage stability issues are resulting in wind generation curtailments in some areas; more synchronous generation is being brought online than if wind power production was unrestricted:
  - Synchronous condensers can be installed to provide necessary grid support, but may also be not a viable long term option.
  - Grid forming inverter?

Ongoing and Future Work

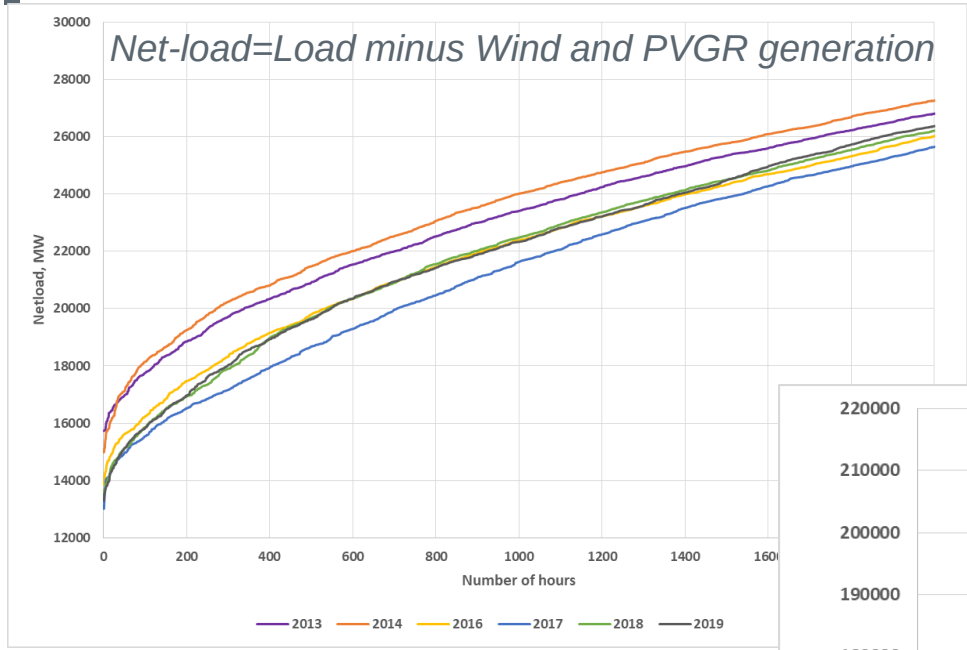
- ERCOT will keep monitoring and analyzing historical inertia data
- Currently developing methods to forecast inertia trends longer term based on historic results
- As the system will start reaching critical inertia there are procedures in place for the operators to maintain sufficient inertia online.
- If critical inertia constraint starts binding very often inertia or other “grid support” product may be introduced
- ERCOT is also looking for ways to address weak grid issues (e.g. installing synchronous condensers while, possibly, requiring POD from inverter-based resources)
- A lot of work going on with inverter-based resource model accuracy improvement, EMT studies, making real time transient stability analysis possible
- ERCOT is following progress of relevant initiatives worldwide (particularly GB, ENSTO-E, Australia)

Thank you! Questions?

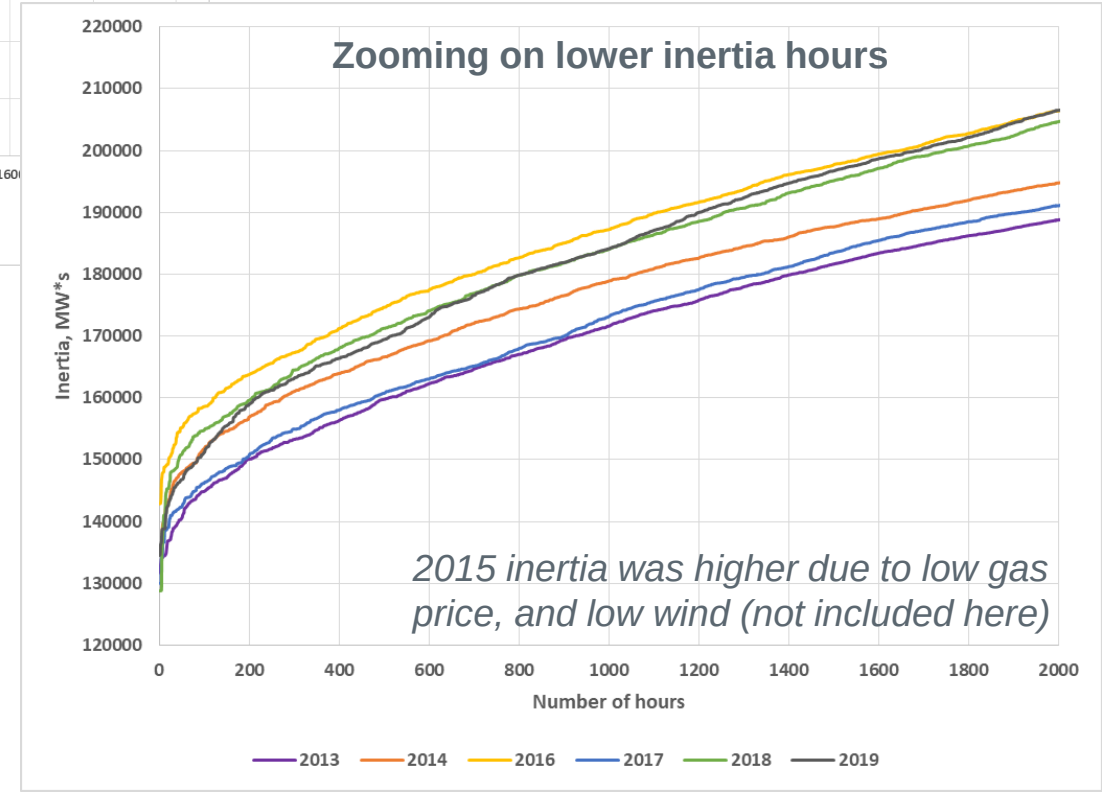
Julia Matevosyan

jmatevosjana@ercot.com

Net-load and Inertia Duration Curves 2013-2019

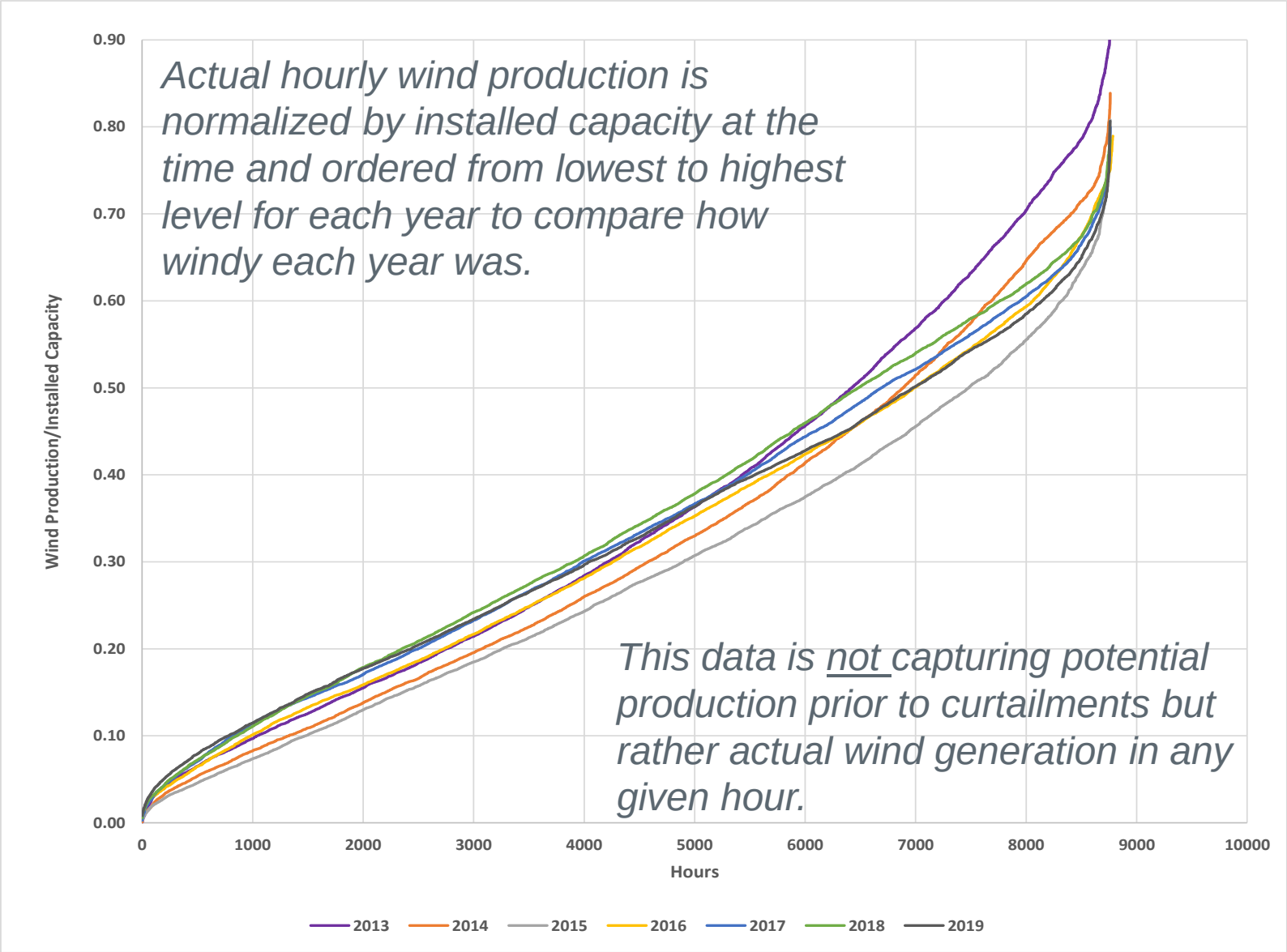


- 2016-2019 Net-load lower than 2013-2014 due to more installed wind capacity;
- 2017 Load is lower than 2018-2019 while windiness similar to 2018;

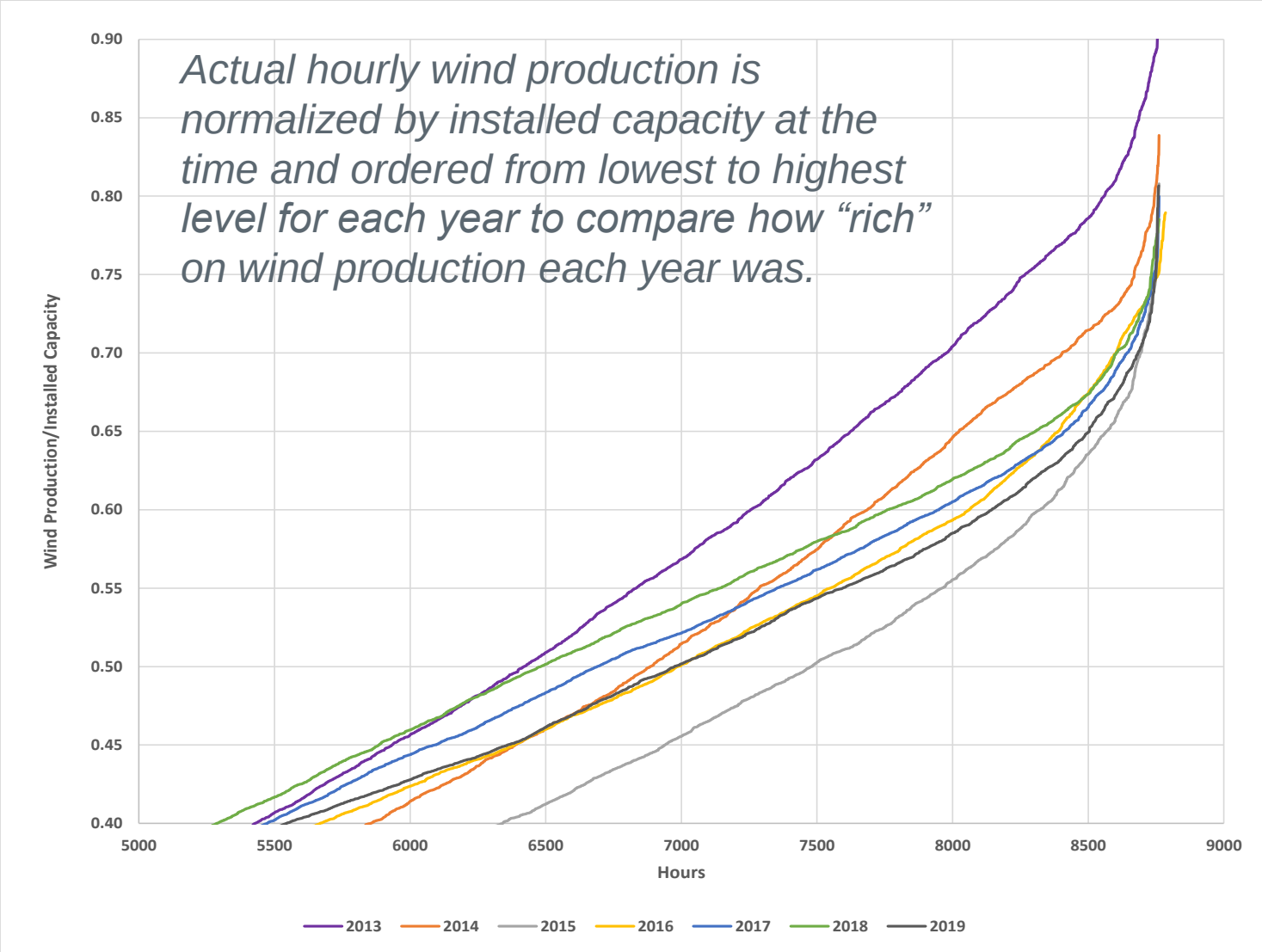


- Similar inertia in 2013 & 2017, the former is due to higher natural gas price/more Coal commitment, the latter due to lower net-load also combined with significant Coal commitment
- 2014-2016 inertia is higher, due to low gas prices/more Combined Cycle committed instead of Coal
- This trend continues in 2018-2019, influenced also by Coal retirements

Relative Wind Production Duration Curve 2013-2019

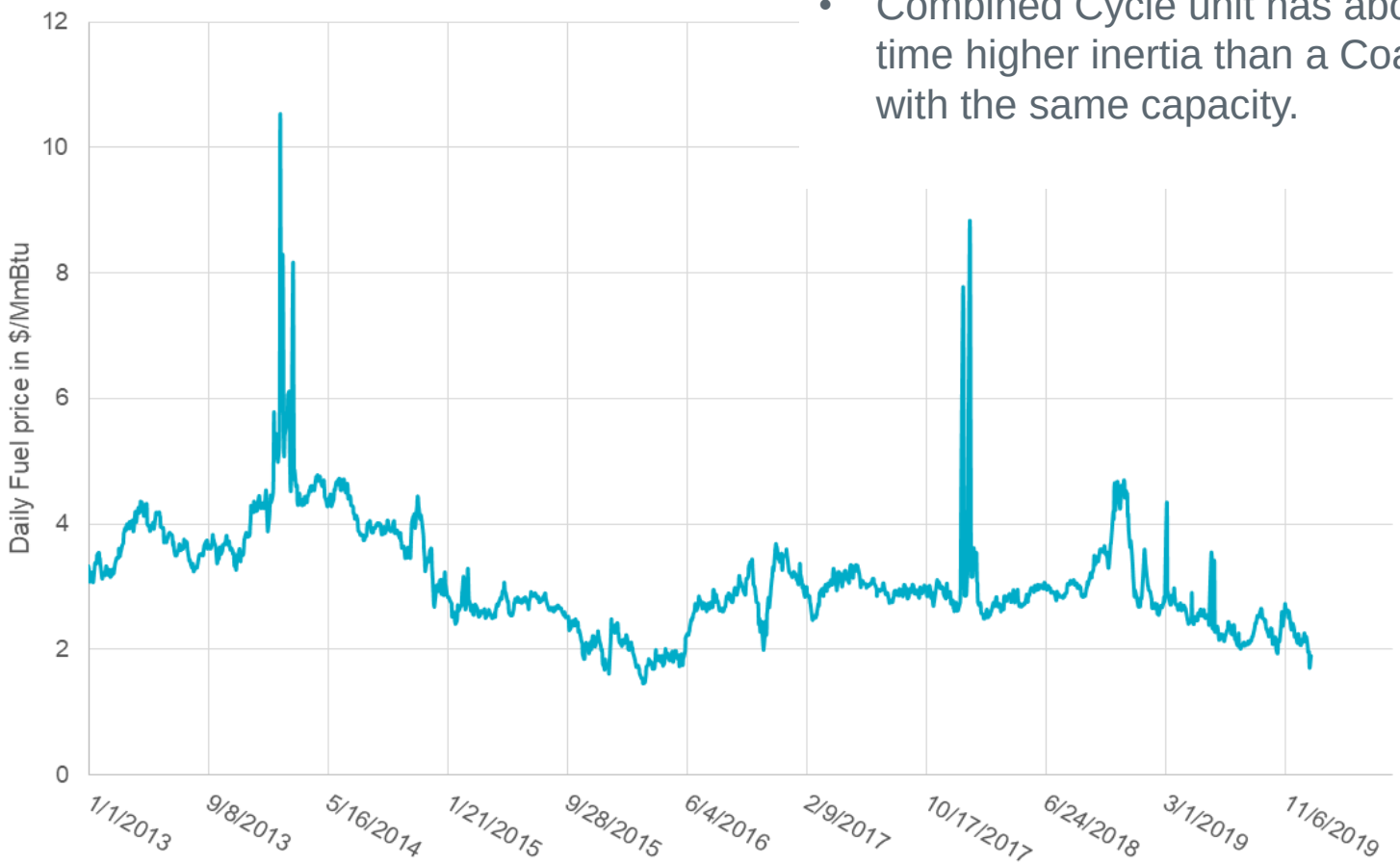


Relative Wind Production Duration Curve 2013-2015 (zoomed)

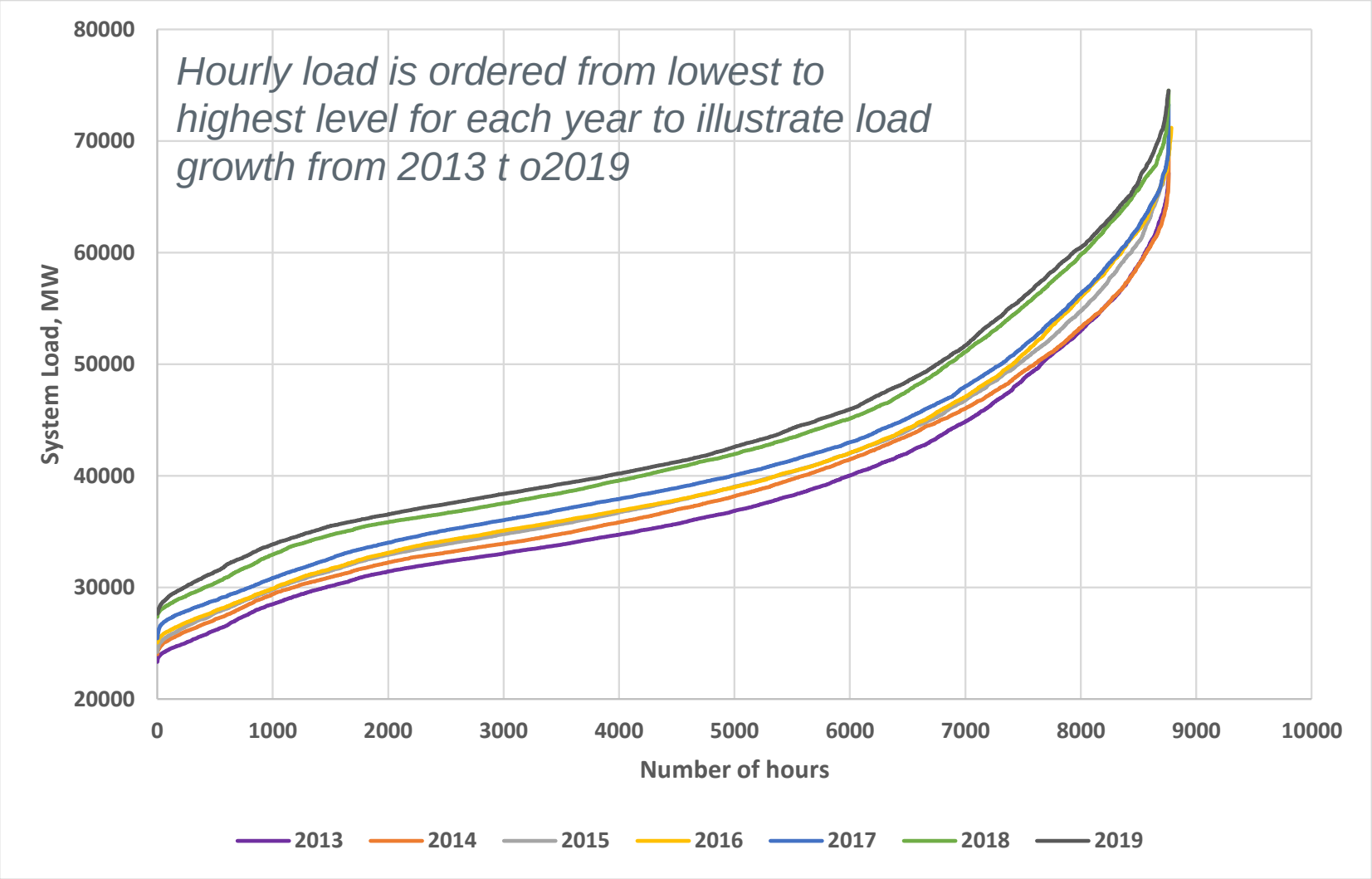


Gas Prices 2013-2019

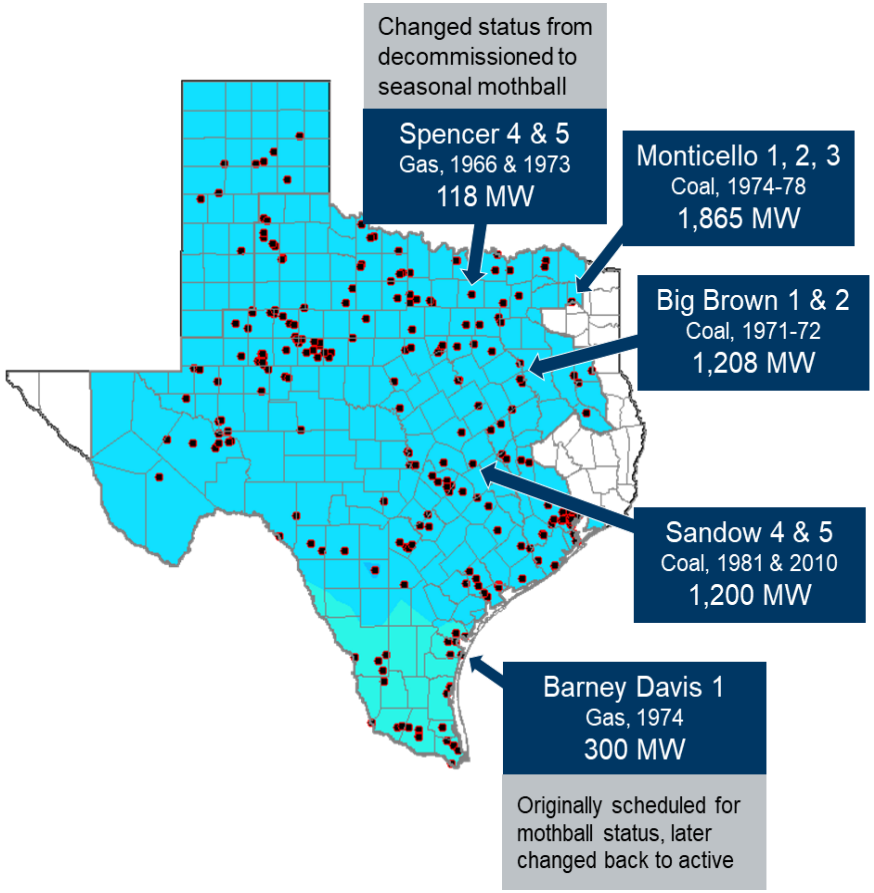
- Gas prices affect unit commitment and therefore inertia
- Combined Cycle unit has about 1.5 time higher inertia than a Coal unit with the same capacity.



Load Duration Curves (2013-2019)

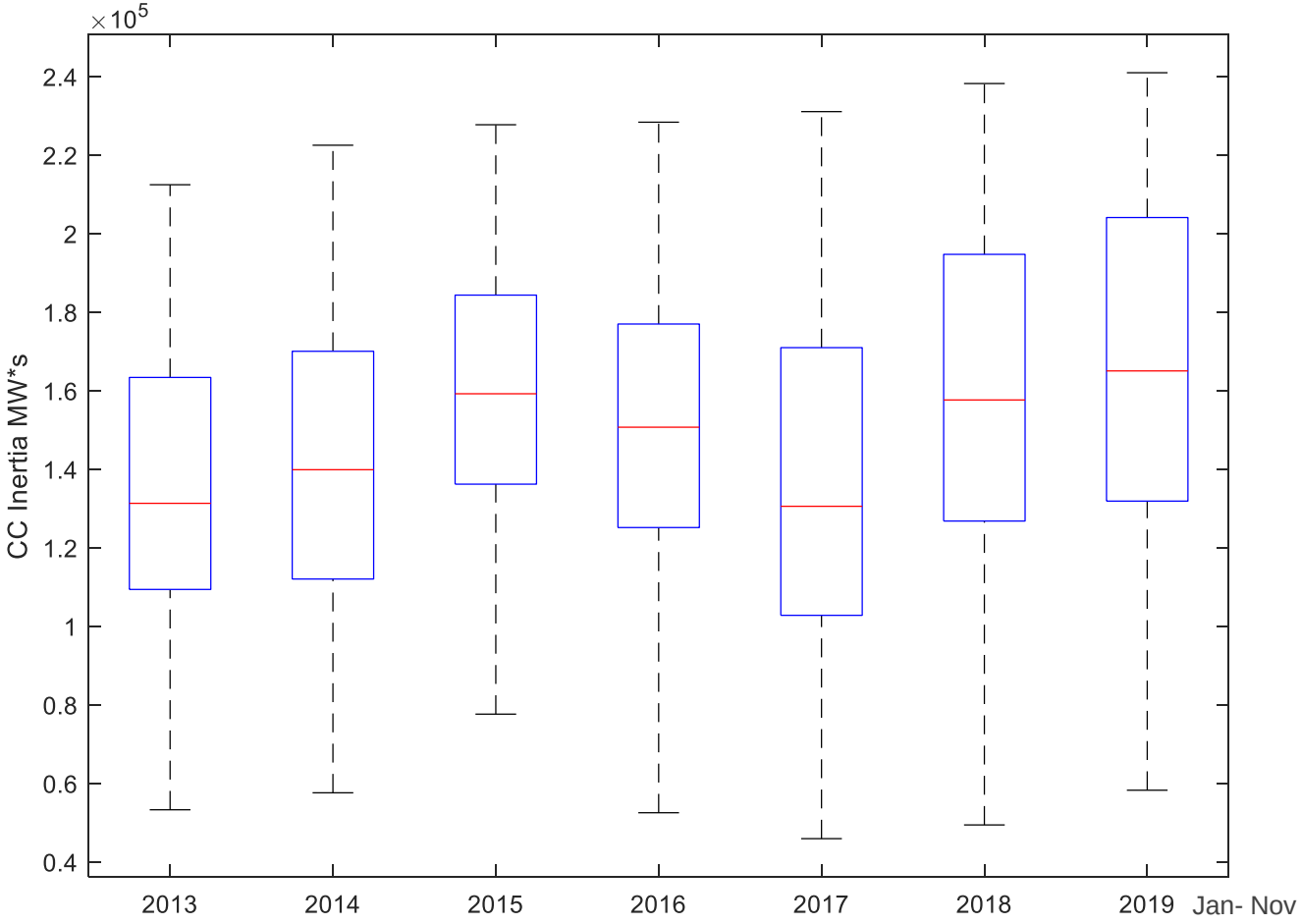


Coal Retirements

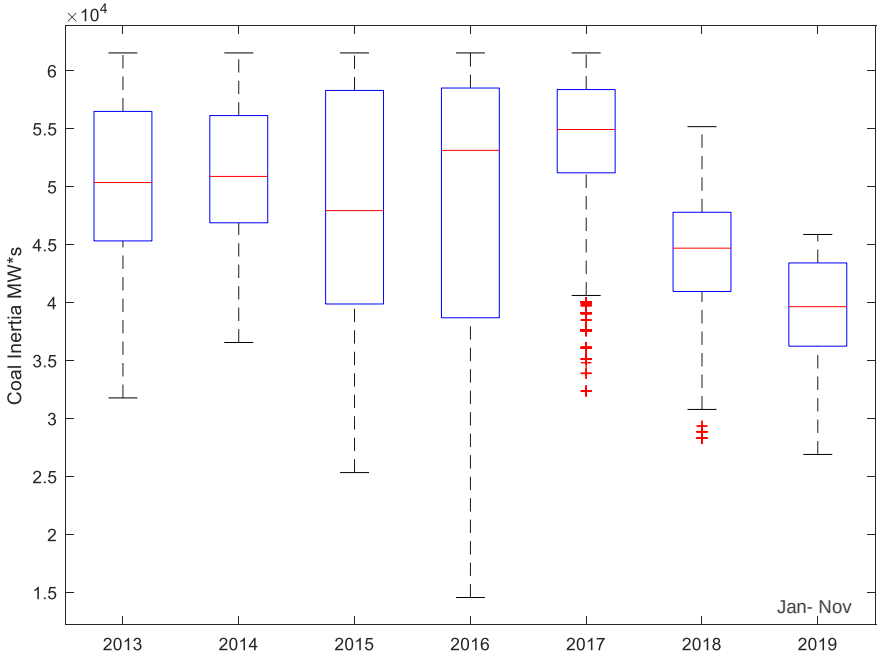


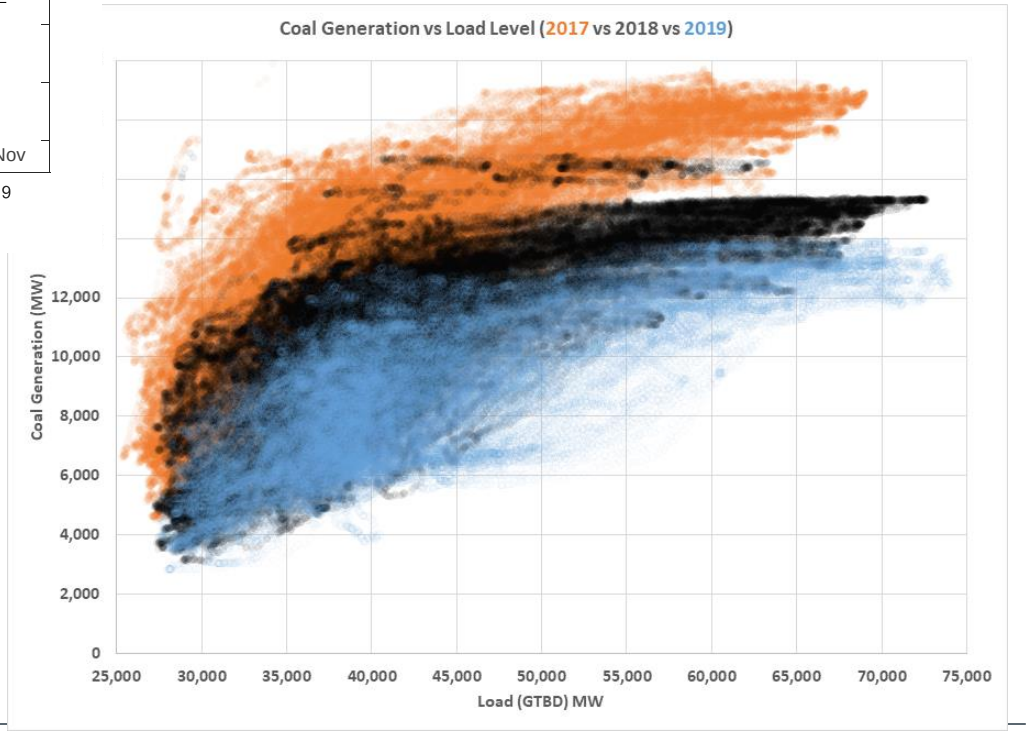
- In late 2017, ERCOT received Notices of Suspension of Operations for 10 units, totaling about 4,700 MW of capacity.
- Total inertia of retired coal units > 12 GW*s
- Additionally, JT Deely 1 & 2 (850 MW) mothballed at the end of 2018
- Gibbons Creek 1 (470 MW) mothballed since October 2018 and retired in October 2019
- These two unit's total inertia was >4 GW*s

Combined Cycle Inertia

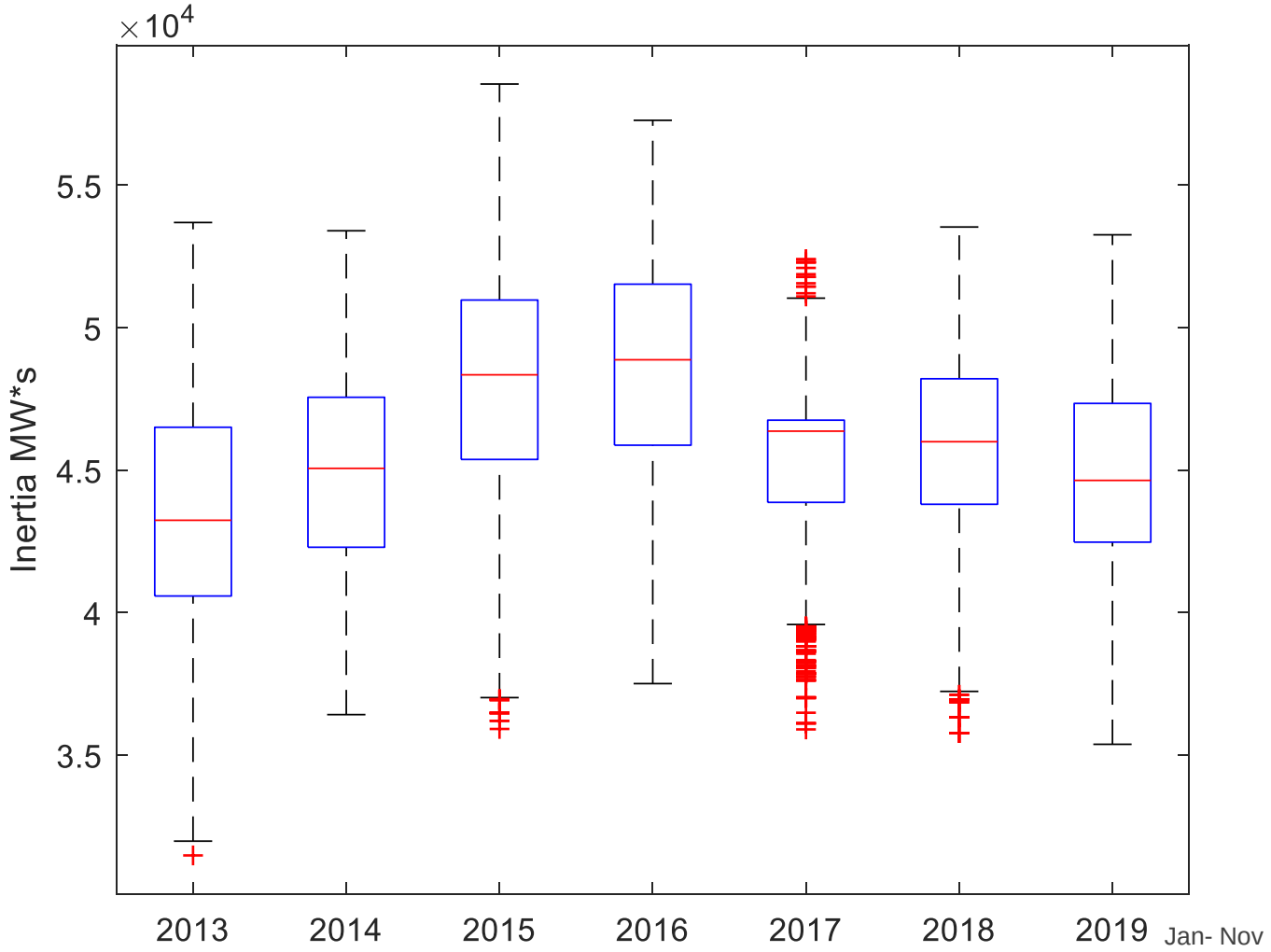
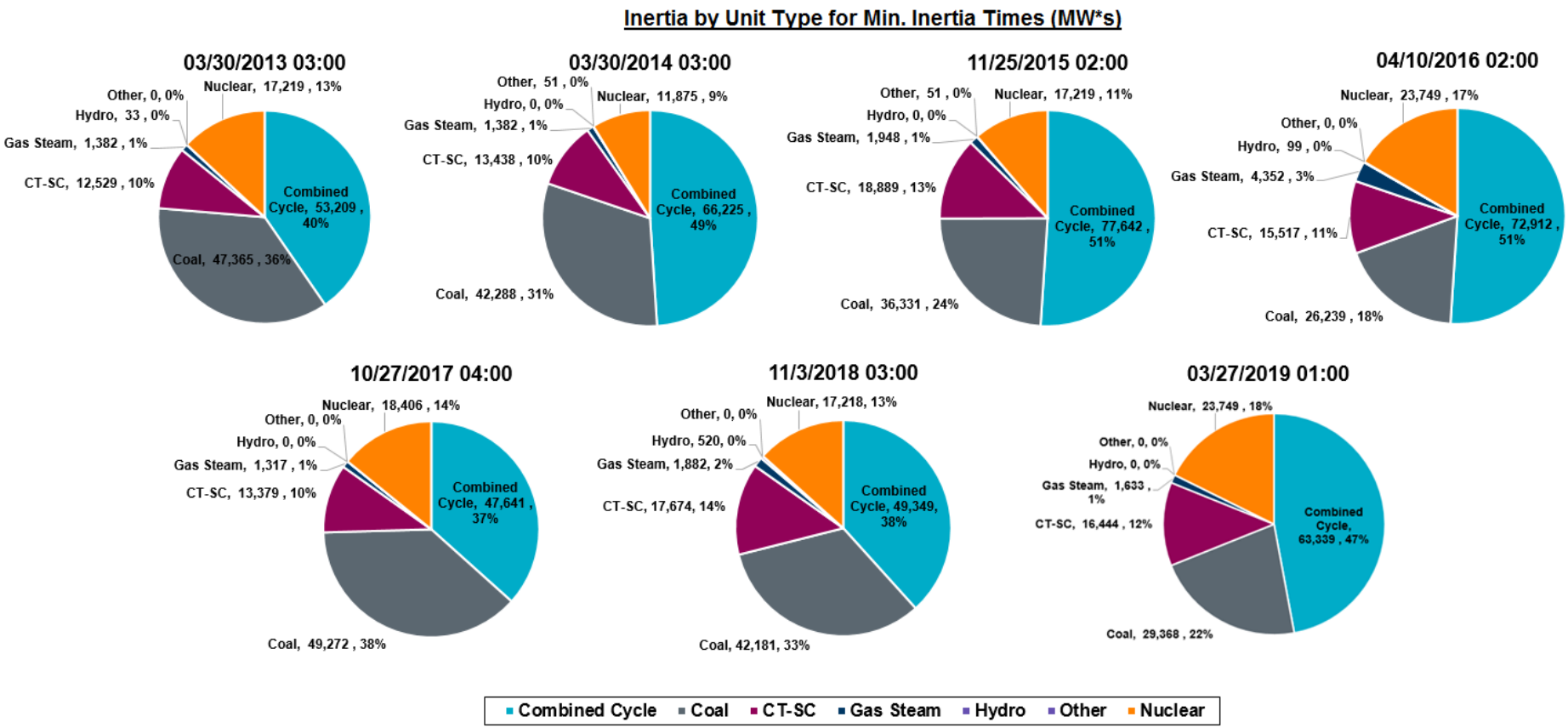


Coal Inertia





PUN Inertia


×10^4
5.5
5
4.5
4
3.5
Inertia MW*s
2013
2014
2015
2016
2017
2018
2019
Jan- Nov

Inertia by Unit Type during Minimum Inertia Hour in Each Year