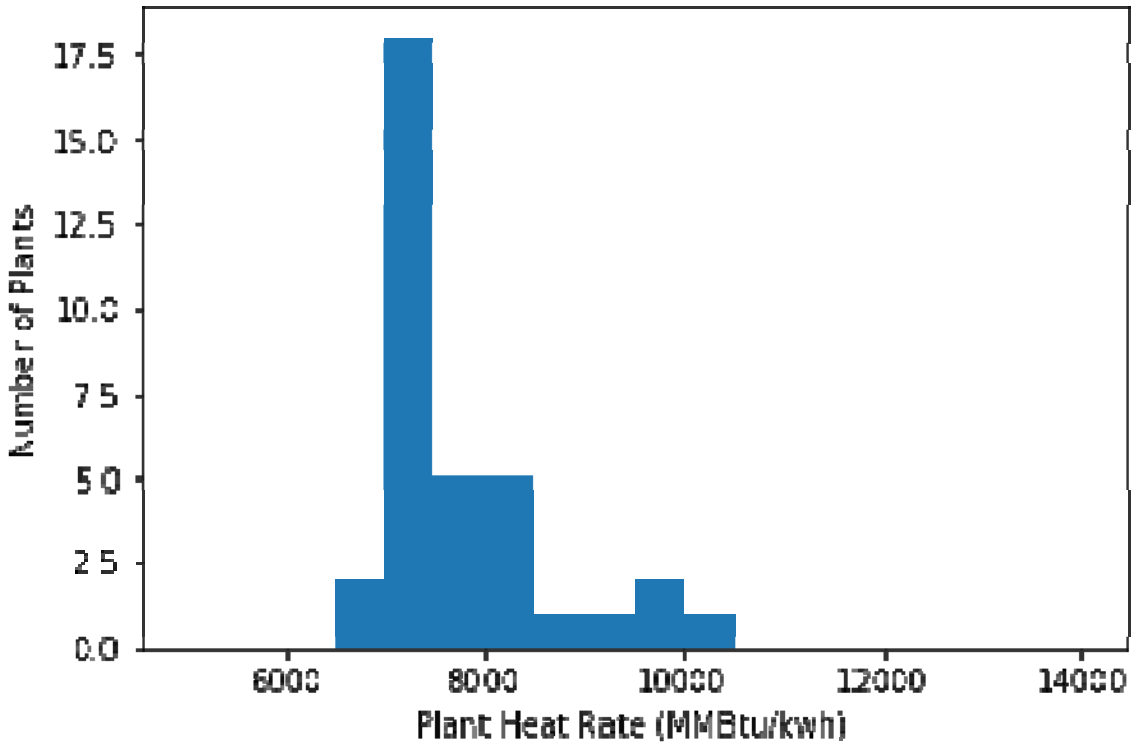
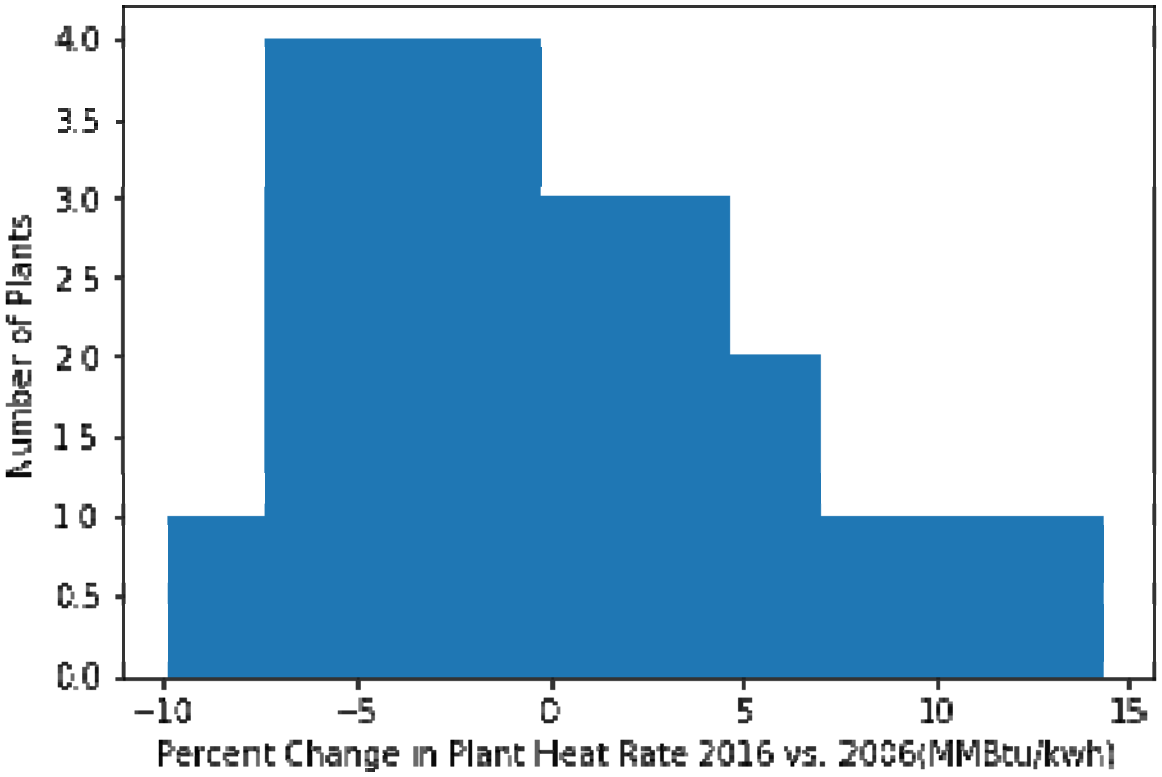
Impact of the Growth of Wind Energy on CCGT Heat Rates for ERCOT Plants

I. Initial Exploratory Analysis

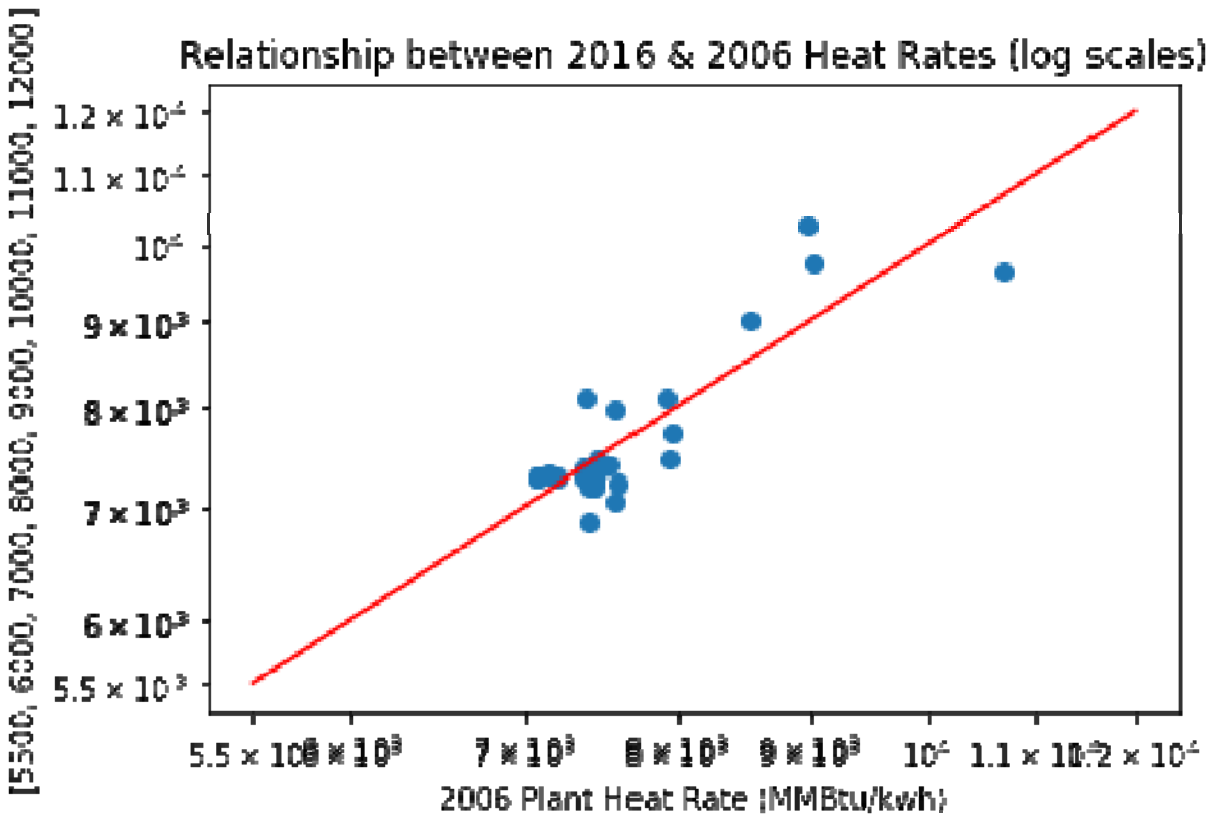
Histogram of ERCOT Heat Rates in 2016



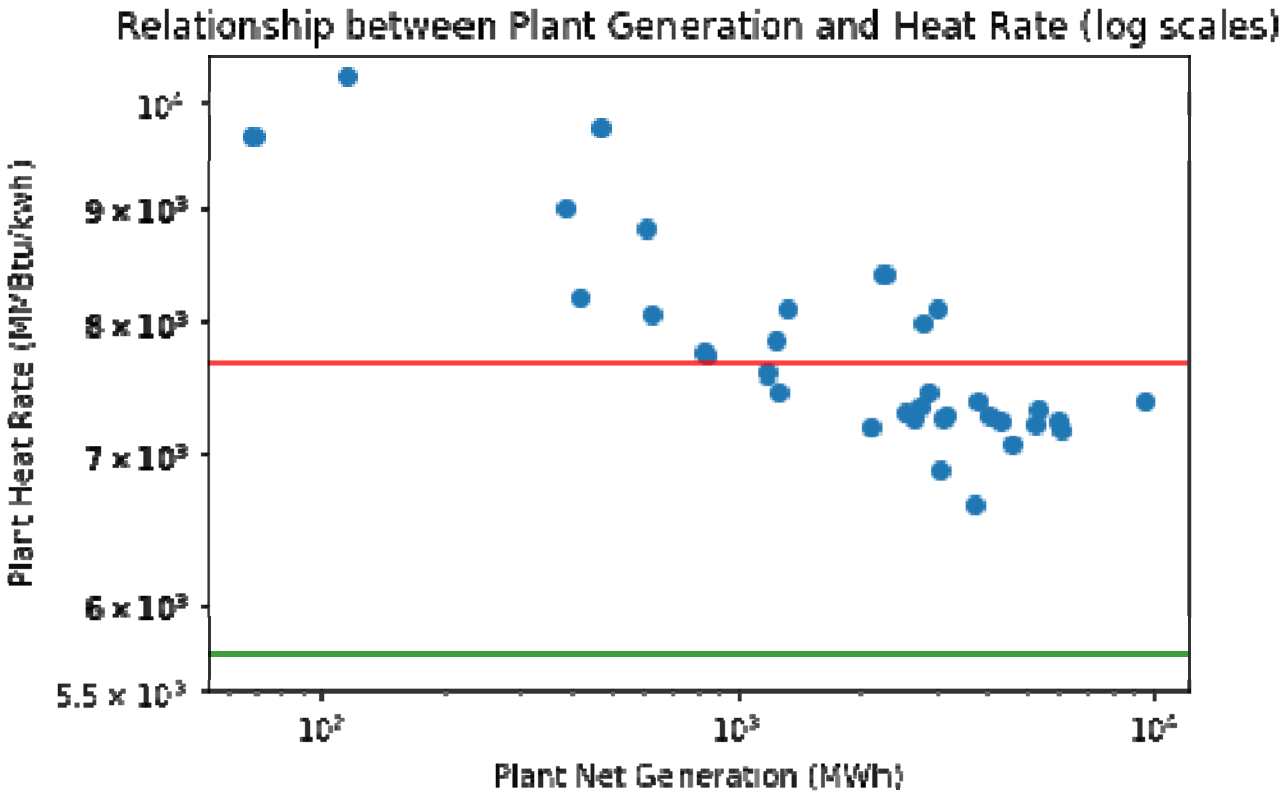
Histogram of Percent Change in Plant Heat Rate: 2016 vs 2006



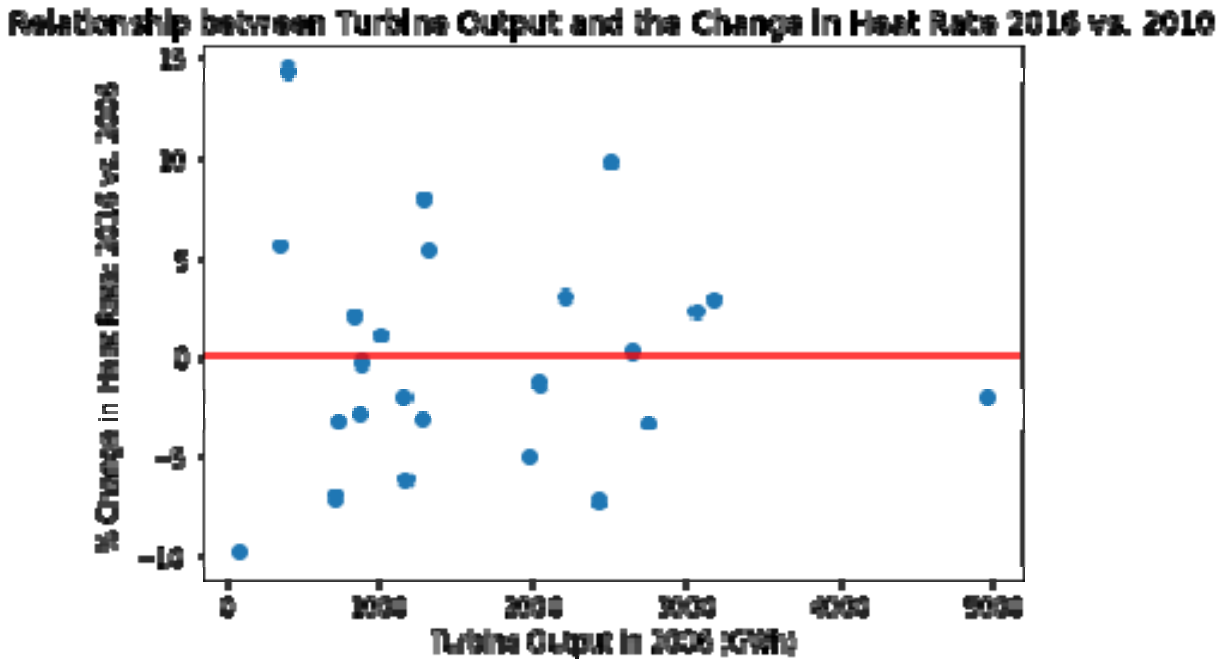
ERCOT CCGT Heat Rates Do Not Appear to Have Increased Systematically Since 2006



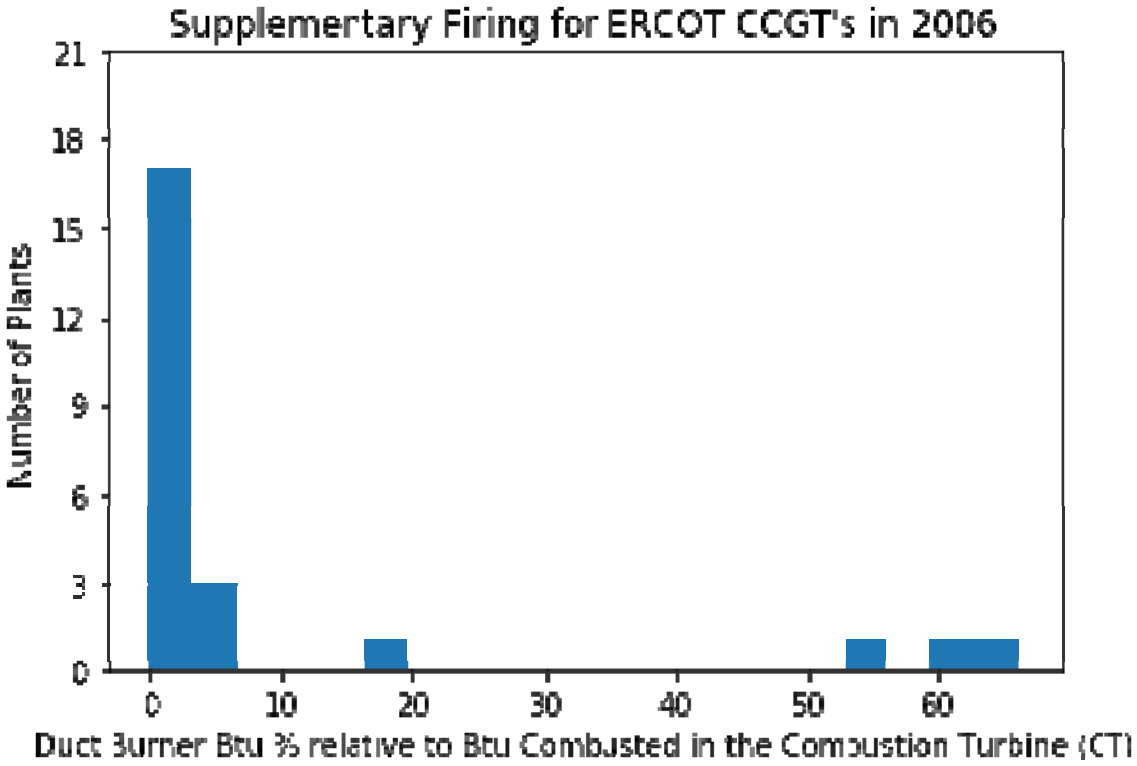
Larger Plants Tend to Have Lower Heat Rates



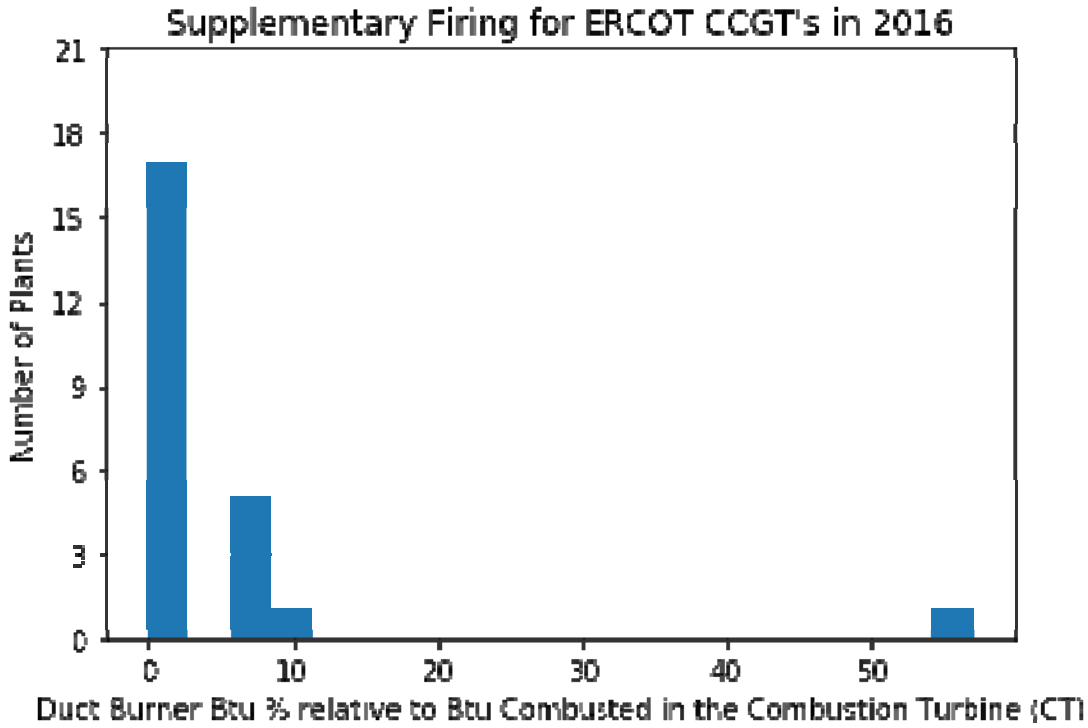
Changes in Plant Heat Rates Appear to be Independent of Plant Size



Supplementary Firing is Inefficient, but Allows Plants to Increase their Output Quickly



Although Wind has Grown 10x and the Need for Flexible Generation has Increased, Supplementary Firing Appears to have Decreased

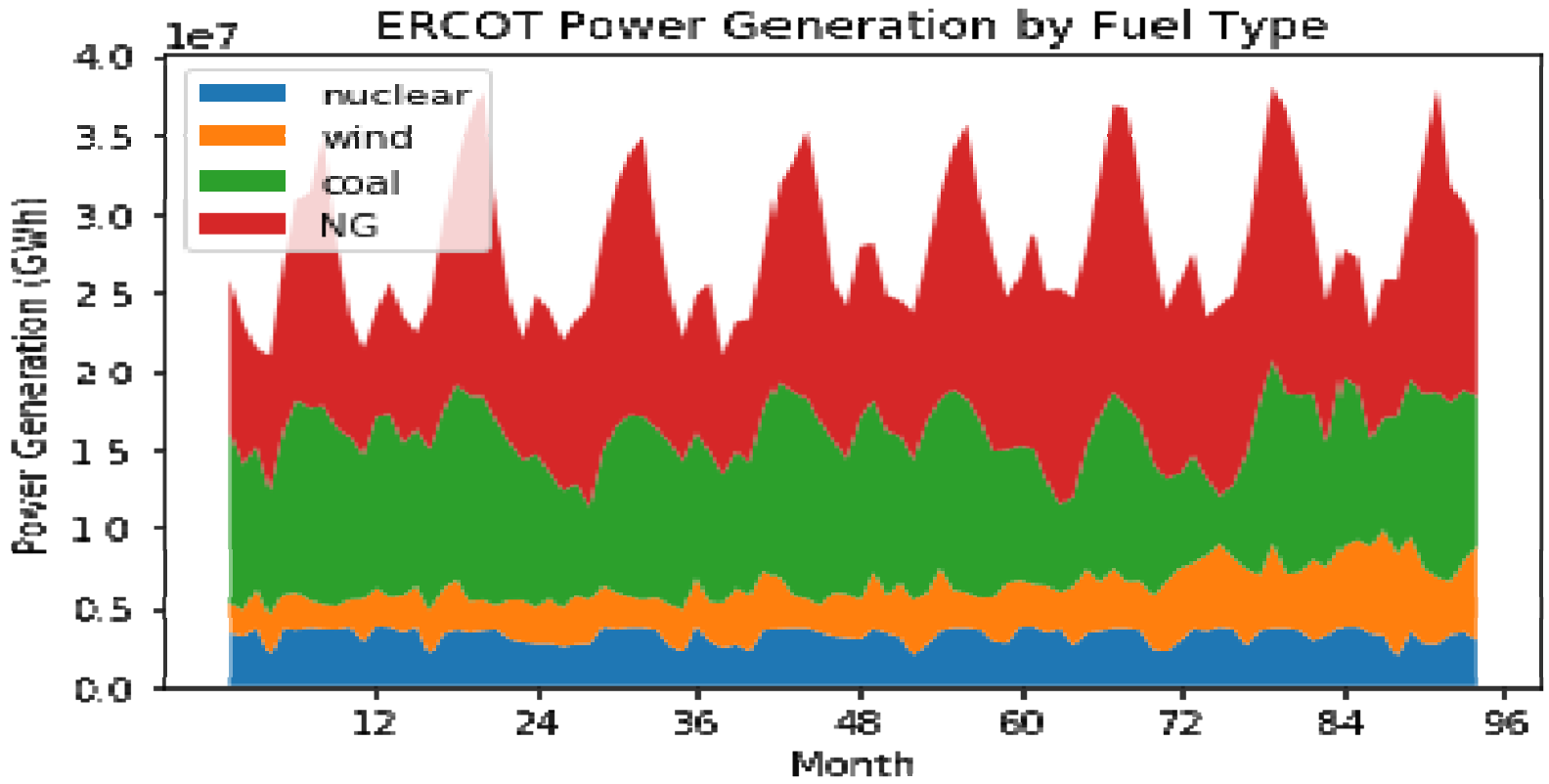


Summary of Initial Exploratory Analysis

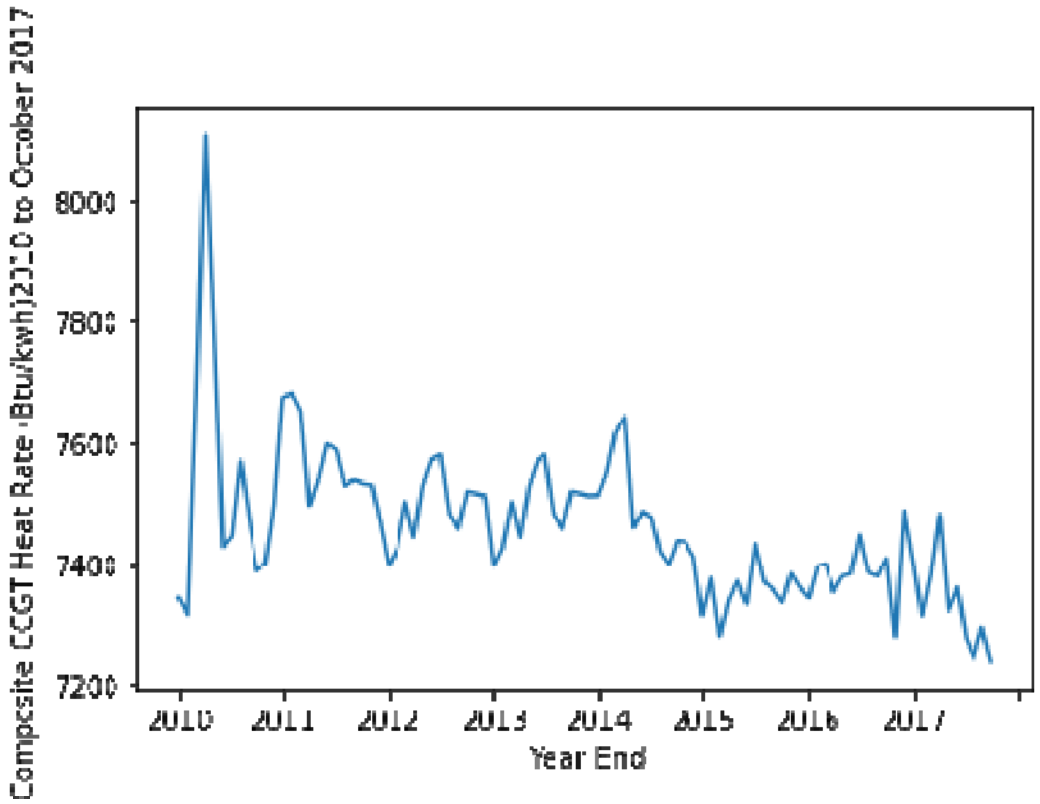
- It is theoretically possible for the Heat Rate of a CCGT to double when required to provide highly flexible generation to back-up intermittent Wind Energy.
- Any such material increase would offset the net CO2 reduction benefit of Wind Energy.
- However, at ERCOT Wind Energy has increased more than tenfold and Heat Rates appear to have remained essentially unchanged.
- Inefficient but flexible Supplementary Firing by CCGT's might be expected to have increased to accommodate intermittent Wind Generation, but it has not.
- No obvious evidence of any inefficiencies associated with the growth in Wind energy (which is verey contrary to German experience, for example).

II. Multivariate Regression Analysis of Plant Heat Rates

Generation from Coal and Natural Gas Flex to Meet ERCOT's Substantial Summer Air Conditioning Load



Heat Rates Vary Greatly from Month to Month:
The April Spikes are Due to Large Nuclear Plants Offline



Correlation Matrix: 2010 – 2017 YTD

	ng	coal	nuclear	wind	load	txgasprice	usgasprice	wind2	hr	time
ng	1.0	0.41	0.31	-0.14	0.091	-0.25	-0.35	-0.15	-0.18	0.21
coal	0.41	1.0	0.32	-0.42	0.0062	0.47	0.39	-0.38	0.32	-0.27
nuclear	0.31	0.32	1.0	-0.22	0.014	0.063	0.093	-0.19	0.087	-0.08
wind	-0.14	-0.42	-0.22	1.0	0.018	-0.43	-0.46	0.98	-0.41	0.79
load	0.091	0.0062	0.014	0.018	1.0	-0.088	-0.12	0.018	-0.042	-0.071
txgasprice	-0.25	0.47	0.063	-0.43	-0.088	1.0	0.91	-0.4	0.45	-0.52
usgasprice	-0.35	0.39	0.093	-0.46	-0.12	0.91	1.0	-0.43	0.48	-0.58
wind2	-0.15	-0.38	-0.19	0.98	0.018	-0.4	-0.43	1.0	-0.39	0.75
hr	-0.18	0.32	0.087	-0.41	-0.042	0.45	0.48	-0.39	1.0	-0.62
time	0.21	-0.27	-0.08	0.79	-0.071	-0.52	-0.58	0.75	-0.62	1.0

Correlation Matrix since 2014: (includes Heating & Cooling Days)

	ng	coal	nuclear	wind	load	txgasprice	usgasprice	dheat	dcool	windpct	wind2	hr	time
ng	1.0	0.43	0.25	-0.39	0.31	-0.27	-0.37	-0.4	0.79	-0.66	-0.4	-0.31	0.018
coal	0.43	1.0	0.15	-0.28	0.011	0.43	0.32	-0.23	0.67	-0.56	-0.26	0.29	-0.097
nuclear	0.25	0.15	1.0	-0.23	0.17	-0.044	0.047	0.25	0.081	-0.31	-0.22	-0.19	-0.057
wind	-0.39	-0.28	-0.23	1.0	0.24	-0.4	-0.38	-0.14	-0.17	0.91	0.99	-0.09	0.75
load	0.31	0.011	0.17	0.24	1.0	-0.23	-0.34	-0.28	0.36	0.13	0.23	-0.19	0.21
txgasprice	-0.27	0.43	-0.044	-0.4	-0.23	1.0	0.86	0.25	-0.09	-0.32	-0.36	0.65	-0.64
usgasprice	-0.37	0.32	0.047	-0.38	-0.34	0.86	1.0	0.5	-0.28	-0.27	-0.34	0.66	-0.66
dheat	-0.4	-0.23	0.25	-0.14	-0.28	0.25	0.5	1.0	-0.76	0.029	-0.14	0.15	-0.29
dcool	0.79	0.67	0.081	-0.17	0.36	-0.09	-0.28	-0.76	1.0	-0.48	-0.16	-0.089	0.11
windpct	-0.66	-0.56	-0.31	0.91	0.13	-0.32	-0.27	0.029	-0.48	1.0	0.9	-0.035	0.57
wind2	-0.4	-0.26	-0.22	0.99	0.23	-0.36	-0.34	-0.14	-0.16	0.9	1.0	-0.08	0.74
hr	-0.31	0.29	-0.19	-0.09	-0.19	0.65	0.66	0.15	-0.089	-0.035	-0.08	1.0	-0.52
time	0.018	-0.097	-0.057	0.75	0.21	-0.64	-0.66	-0.29	0.11	0.57	0.74	-0.52	1.0

To Come: groupby month mean