109

Lessons from ~~Forty~~ Plant-Months of "Co-Benefit" Mercury Abatement Using Existing Pollutant Control Equipment

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Multi-Pollutant Control, Session C4

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Motivation and Outline

Mercury MACT rule proposal expected March 2011

Will plants meet potential MACT limits with only "co-benefit" Hg control?

How variable is "co-benefit" mercury control?

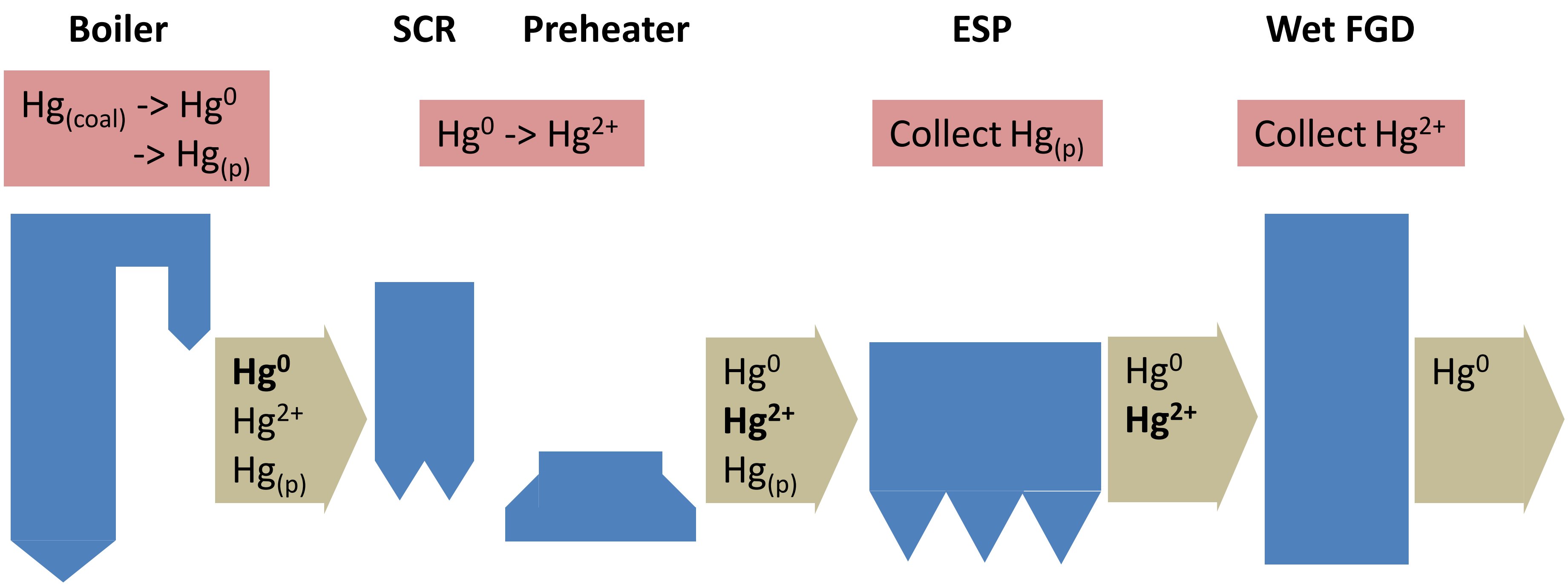
How can "co-benefit" mercury control be improved?

- Study plants and methods
- Variability of Hg emissions
- Statistical analysis of Hg emissions
- Conclusions

Study Plants

- Five Flagship Coal-Fired Units
- Capacities: 750 – 950 MW
- Single Boiler with SCR, cold-side ESP, wet FGD
- Central Appalachian Eastern Bituminous coals
  - Cl: 724 [84 – 2352] ppm
  - Hg: 86.7 [20 – 190] ppb
  - Hg: 6.56 [1.5 – 14.5] lb/TBtu potential emissions

Hg Oxidation and Wet Capture



- Processes across multiple units that are largely unengineered and uncontrolled for Hg

Study Method

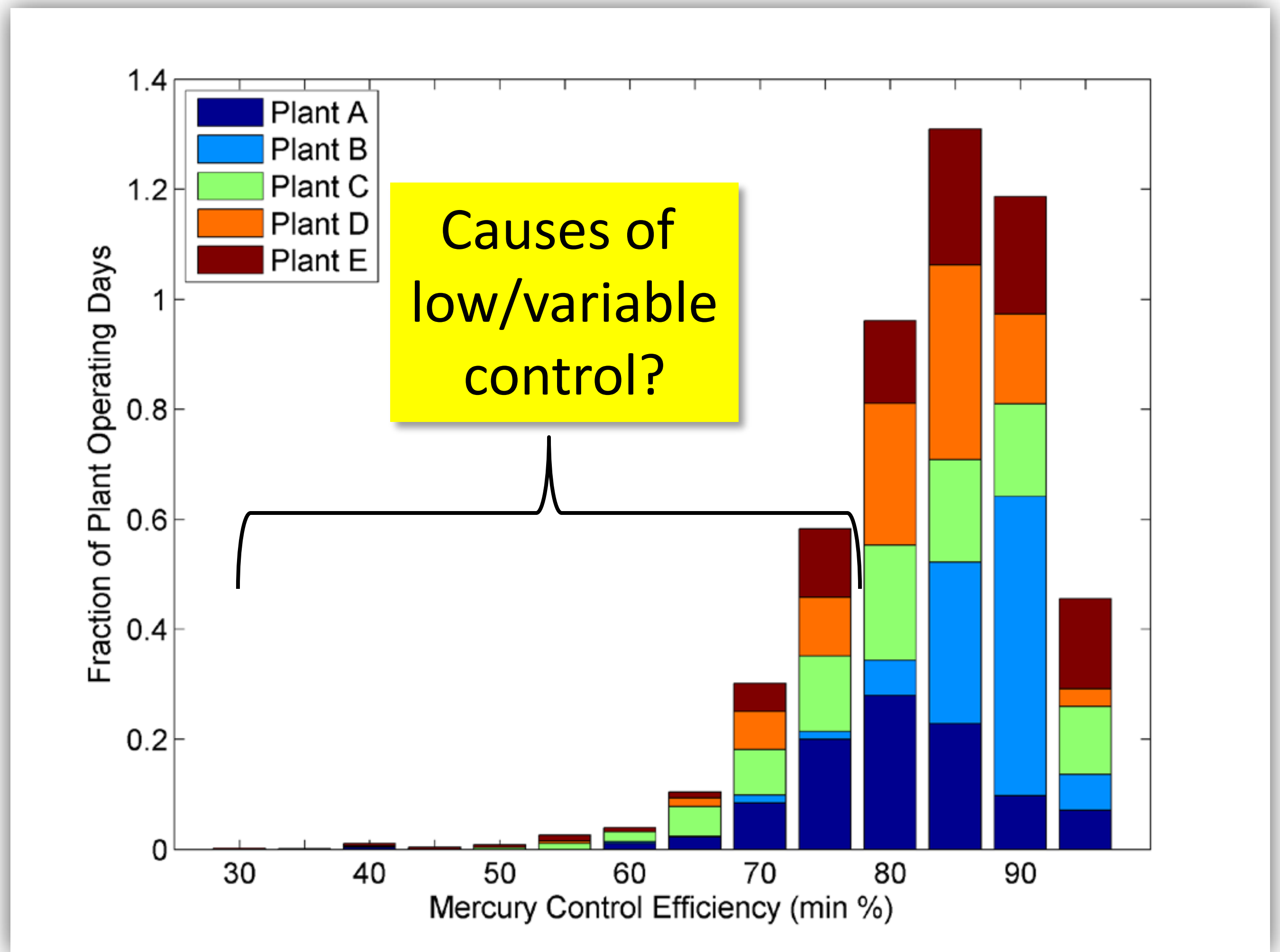
- Retrieve operational and emissions data
  - Approx. 40 variables for each plant:
    Boiler, SCR, ESP, wFGD, CEMS
  - 109 plant-months of data in 2008 - 2010
  - 1-min data, ~$2x10^8$ data points
  - Hg and Cl inputs from coal deliveries
- Robust quality assurance
  - Inspected every data point
  - Screened CEMS calibrations
  - Compared high emission events with plant logs
- **Retrospective data analysis**
  - Coincidental and correlated observations
  - Develop physically consistent explanations

Mercury Oxidation and Wet Capture Works

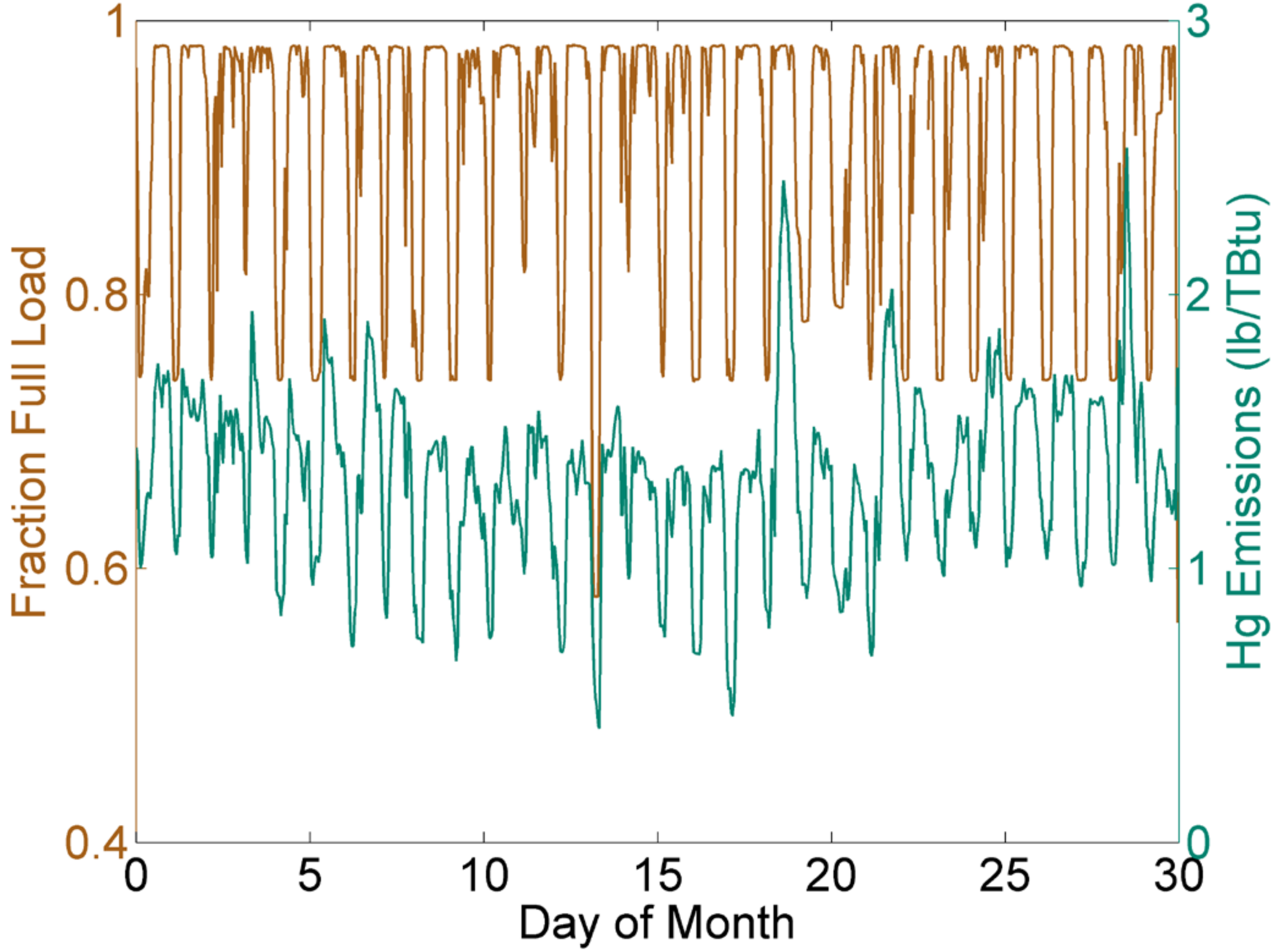
Average 85.5% Hg control for $0 marginal cost

Hg control > 90% achieved on 34% of the study days

Control < 80% for some days for every plant

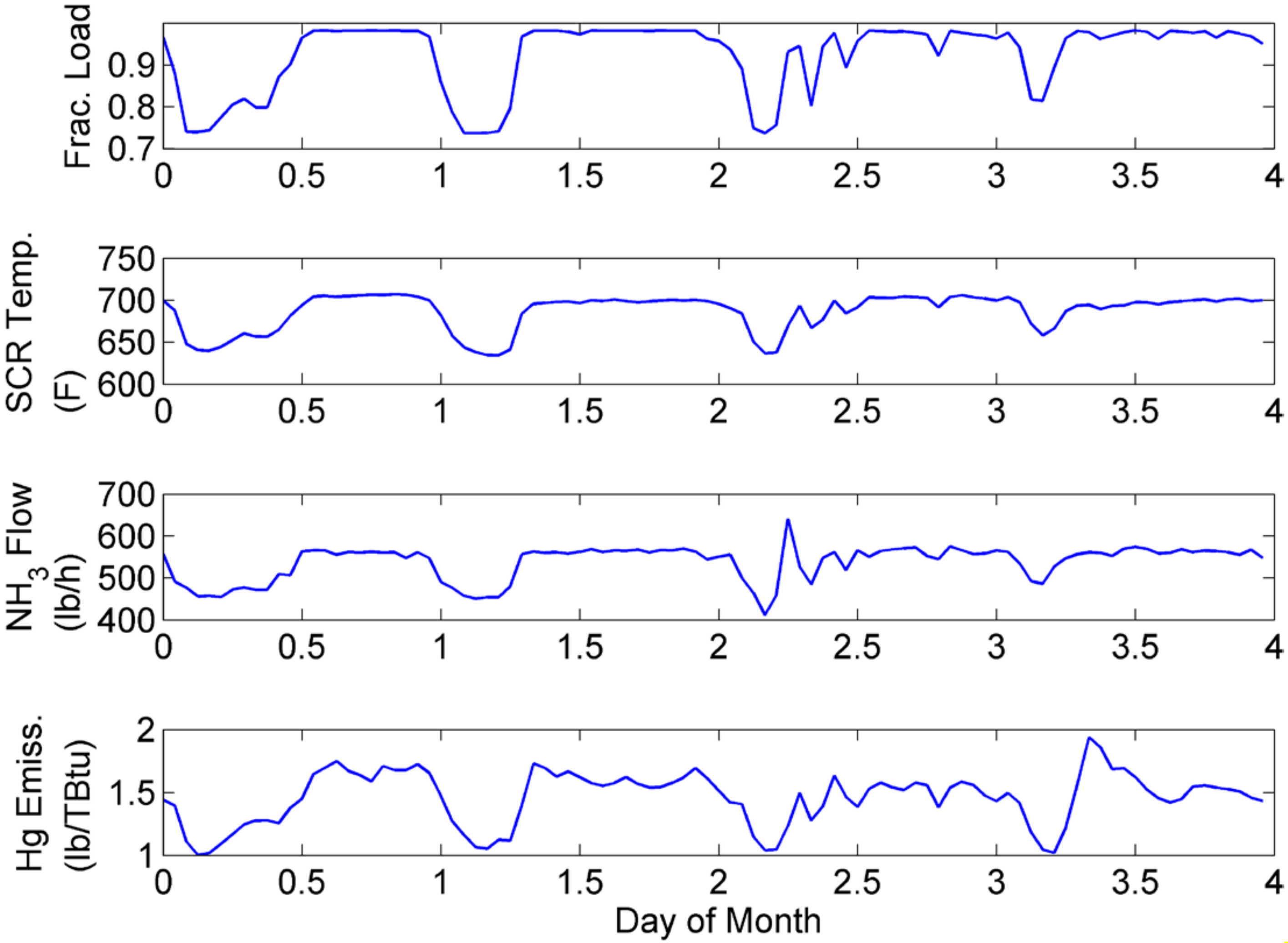


Mercury Control Varied with Load



Load affects downstream AQCS; likely Hg oxidation in SCR

Load Affected SCR Operation



We suggest that Hg oxidation efficiency decreases at full load due to:
↓ residence time, ↑ NH_3 flow, ↑ SCR temperature

Hg Oxidation

- Hg control limited by oxidation state exiting SCR

$$\eta \le \frac{[Hg^0]}{[Hg^0]+[Hg^{2+}]+[Hg_{(p)]}}$$

- Hg oxidative capacity appears to limit co-benefit control
- Engineered Hg oxidation process
  - Catalyst modification
  - Monitor oxidation state
  - Control process parameters
- Southern Co. continues Hg oxidation research efforts

Parametric Statistics

- 6-h emission data at full load with AQCS operating
  - load ≥ 90%, NO_x control ≥ 80%, SO_2 control ≥ 90%
  - 5000 "stack test" data points
- Upper Performance Limit (UPL) equation

$$\overline{x}_{2,0.99} = \overline{x}_1 + t\,s\,\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

  - Past emissions mean: $\overline{x}_1$, std dev: s, elements: n_1
  - Future emissions (99% percentile): $\overline{x}_{2,0.99}$, elements: n_2
  - t-statistic (99%, $n_2 - 1$ degrees of freedom): t

  - Assumes independent emissions data
  - Assumes (log)normally distributed emissions data

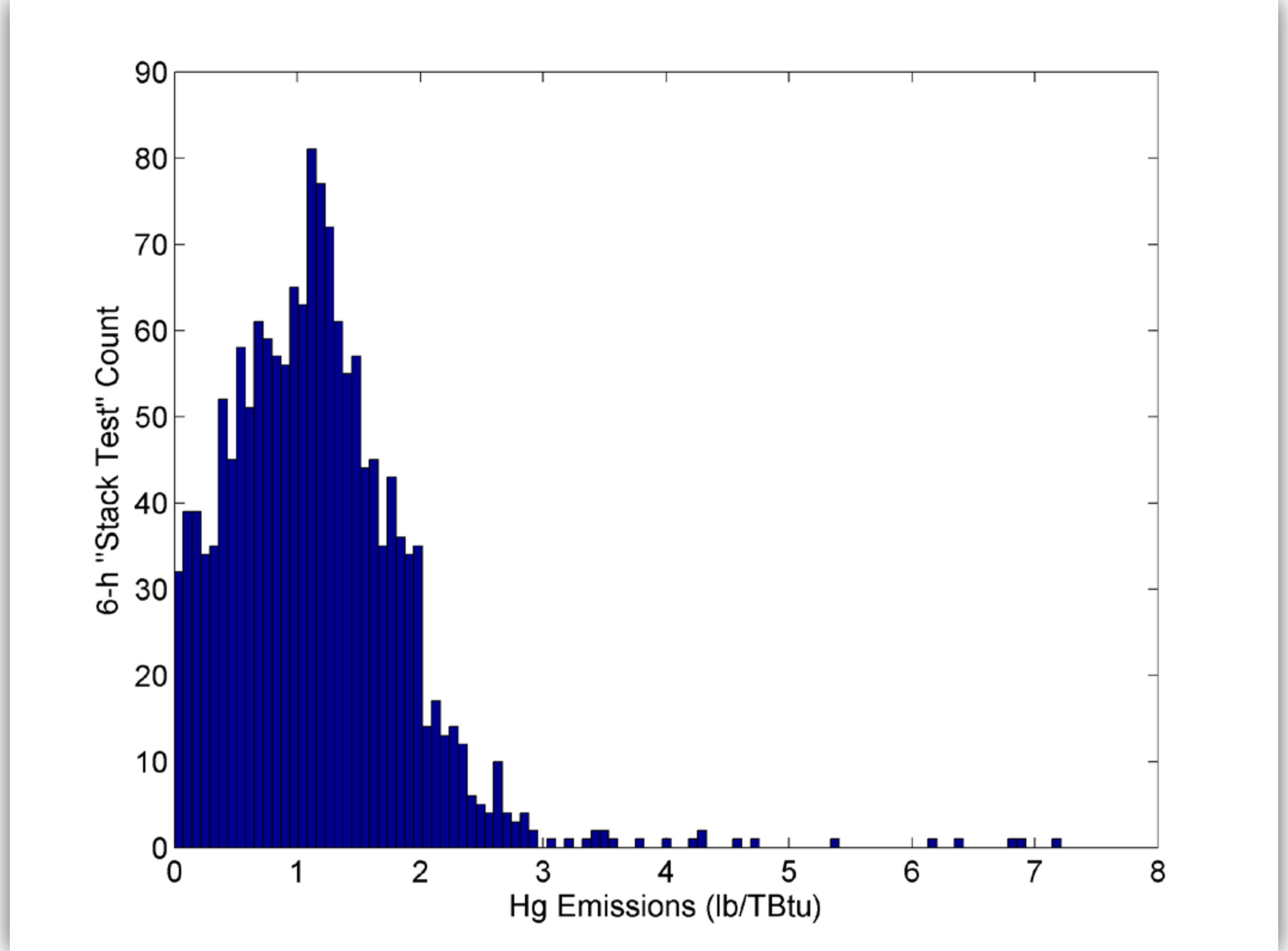
Upper Performance Limits

Plant	"Tests"	Hg Emissions (lb/TBtu)		Upper Performance Limit (99% CI)			
				Normal Distribution		Lognormal Distribution	
		Mean	σ	Monthly Average (120)	Annual Average (1350)	Monthly Average (120)	Annual Average (1350)
A	1460	1.14	0.52	1.26	1.19	1.15	1.05
B	234	0.95	0.47	1.07	1.03	0.97	0.92
C	1547	1.16	0.74	1.32	1.22	1.09	0.97
D	285	1.24	0.65	1.40	1.34	1.31	1.23
E	1541	0.92	0.73	1.08	0.98	0.823	0.74

Test parametric statistical assumptions:

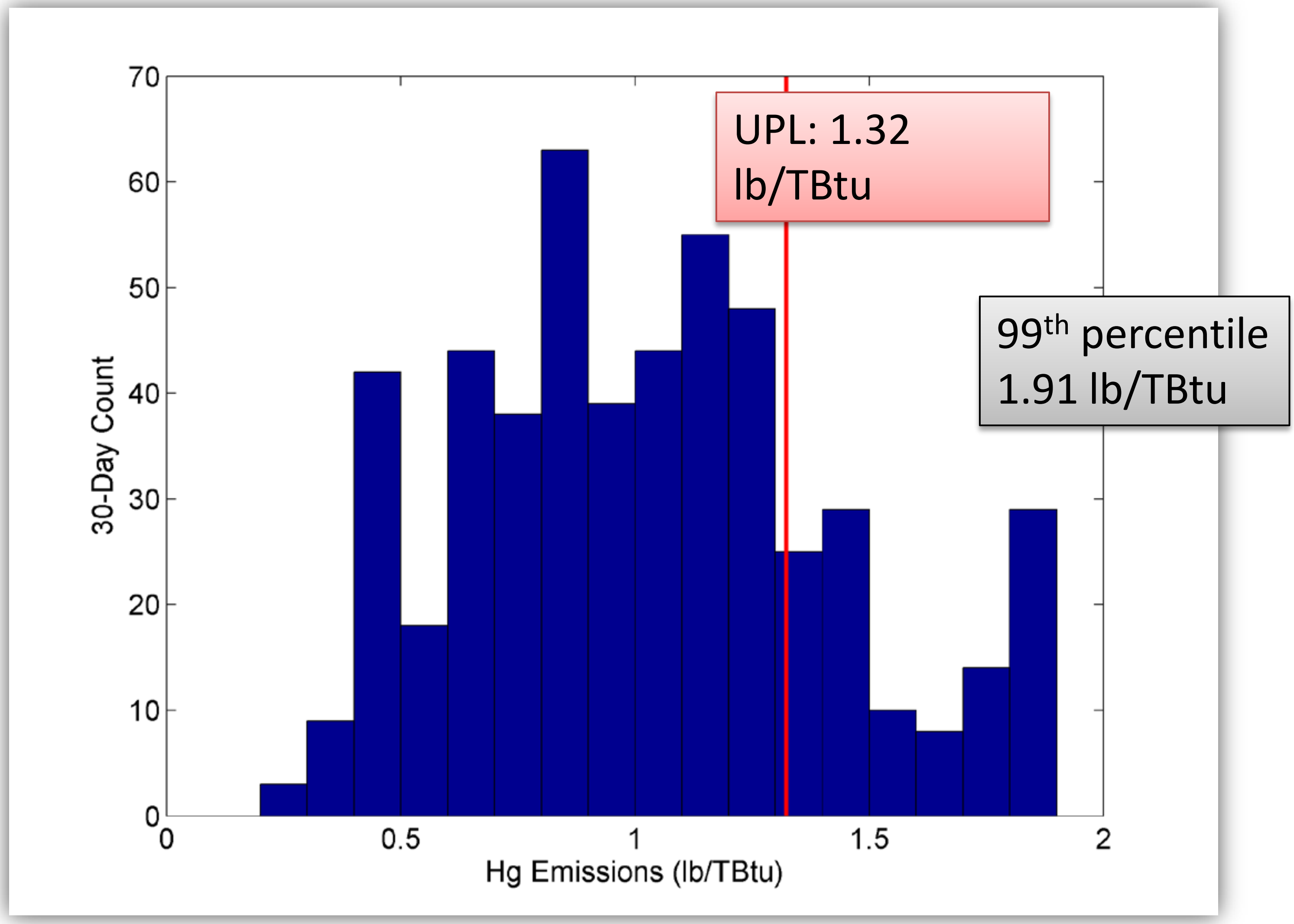
How well to 99% UPLs match emissions data?

Nonparametric Statistics – Plant C



- Data not normally distributed; $p < 0.001$ from Jarque-Bera test
- Normal distribution does not capture hours of low control
- Low control hours not independent (i.e. multi-day re-emission events)

30-Day Emissions – Plant C



Parametric statistics UPL is 78th percentile

Annual Emissions – Plant C

Annual averages starting at each calendar month (N = 253 – 286)

1.28
1.21
1.18
1.10
1.03
1.02
1.00
0.92
0.90
0.89
0.88

← Annual UPL 1.22 lb/TBtu

One of 44 rolling annual averages > UPL

13 of 44 within 10% of UPL.

Conclusions – Co-Benefit Technology

- Analyzed long-term data from 5 plants with co-benefit controls (SCR+ESP+wFGD)
- The "co-benefit" process works (85.5% Hg control) but is variable due to variations in:
  - Hg oxidation, Hg re-emission, coal composition, SCR startup, seasonal NO_x control, and others
- Results informing upcoming technology decisions at Southern Company
  - i.e. can Plant *X* meet Hg emission limit of *y* over period *z*?
- To reduce variability and periods of low control: engineer and control oxidation and wet capture processes - *these are engineering science projects*

Conclusions - Statistics

- Parametric statistics proposed to estimate long term emission limits (UPL) from stack tests
- Emissions do not fit normal (or lognormal) distribution
- Top-performing plants may not meet long term emission limits based on their stack tests
- Consider:
  - CEMS data to scale stack tests to long term emission limits
  - Long-tailed distribution to describe stack test data

See also: Tyree and Allen, "Determining AQCS Mercury Removal Co-Benefits", *Power Magazine*, 154(7):26-32, July 2010.

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Questions?