The Greenidge Multi-Pollutant Control Project: Demonstration Results and Deployment of Innovative Technology for Reducing Emissions from Smaller Coal-Fired Power Plants

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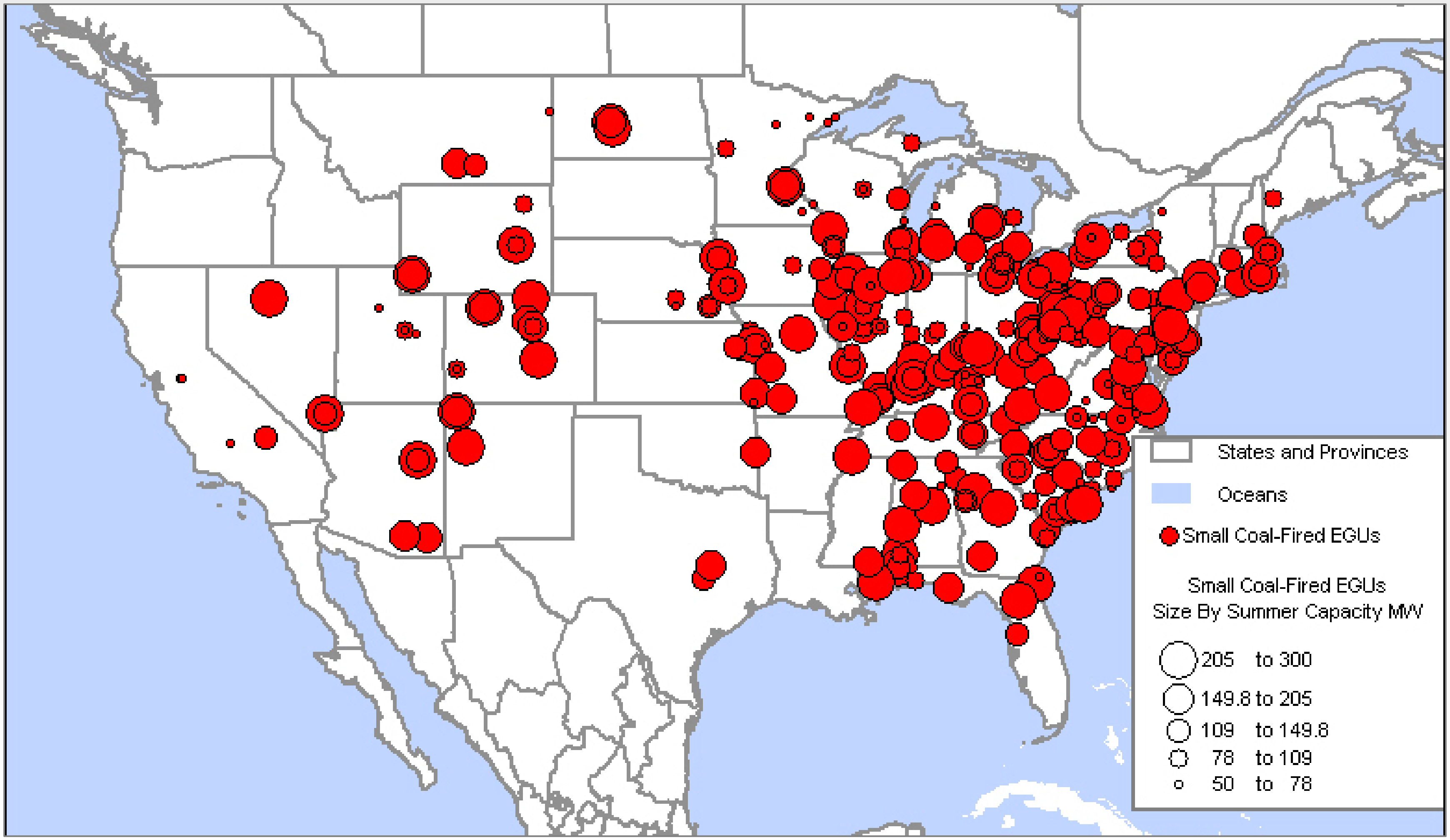
Greenidge Multi-Pollutant Control Project

- Part of U.S. DOE's Power Plant Improvement Initiative
- Participants
  - CONSOL Energy Inc. (administration, testing, reporting)
  - AES Greenidge LLC (host site, operations)
  - Babcock Power Environmental Inc. (EPC contractor)
- Funding
  - U.S. Department of Energy, National Energy Technology Laboratory
  - AES Greenidge LLC
- Goal: Demonstrate a multi-pollutant control system that can cost-effectively reduce emissions of NO_x, SO_2, mercury, acid gases (SO_3, HCl, HF), and particulate matter from smaller coal-fired EGUs

Existing U.S. Coal-Fired EGUs

50-300 MW_e

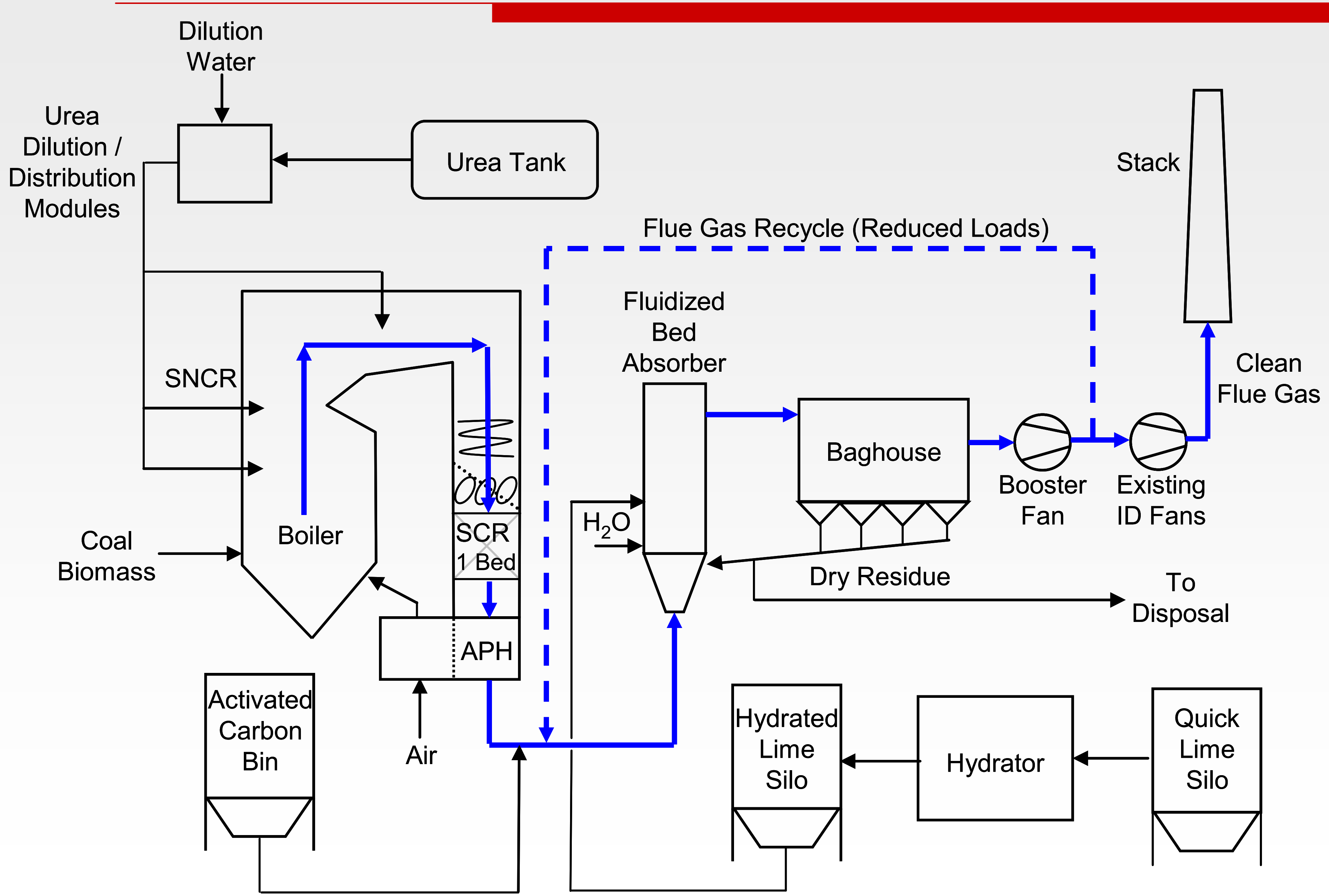


- About 420 units (almost 60 GW) not equipped with FGD, SCR, or Hg control technology

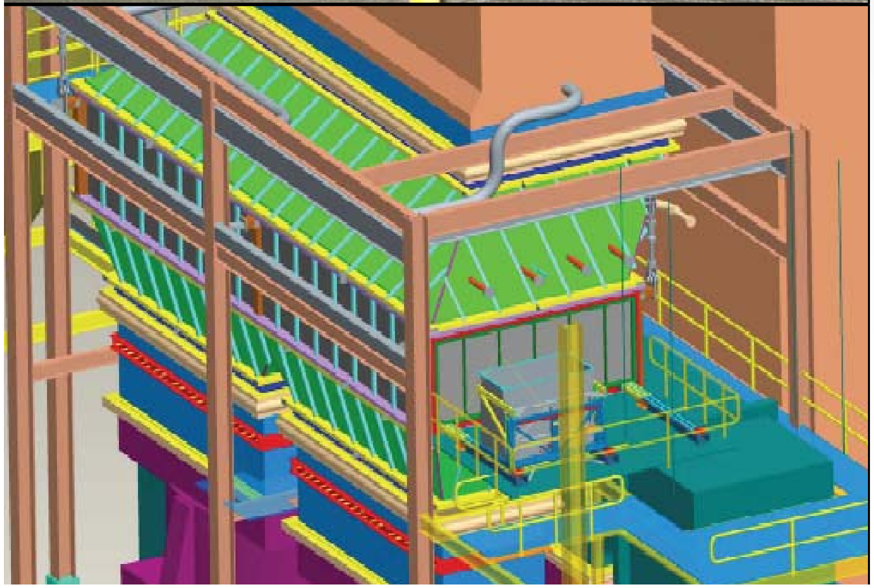
AES Greenidge Unit 4 (Boiler 6)

- Dresden, NY
- Commissioned in 1953
- 107 MW_e (EIA net winter capacity)
- Reheat unit
- Boiler:
  - Combustion Engineering tangentially-fired, balanced draft
  - 780,000 lb/h steam flow at 1465 psig and 1005 ^oF
- Fuel:
  - Eastern U.S. bituminous coal
  - Biomass (waste wood) – up to 10% heat input
- Existing emission controls:
  - Overfire air (natural gas reburn not in use)
  - ESP
  - No FGD – mid/high-sulfur coal to meet permit limit of 3.8 lb SO_2/mmBtu

Process Flow Diagram

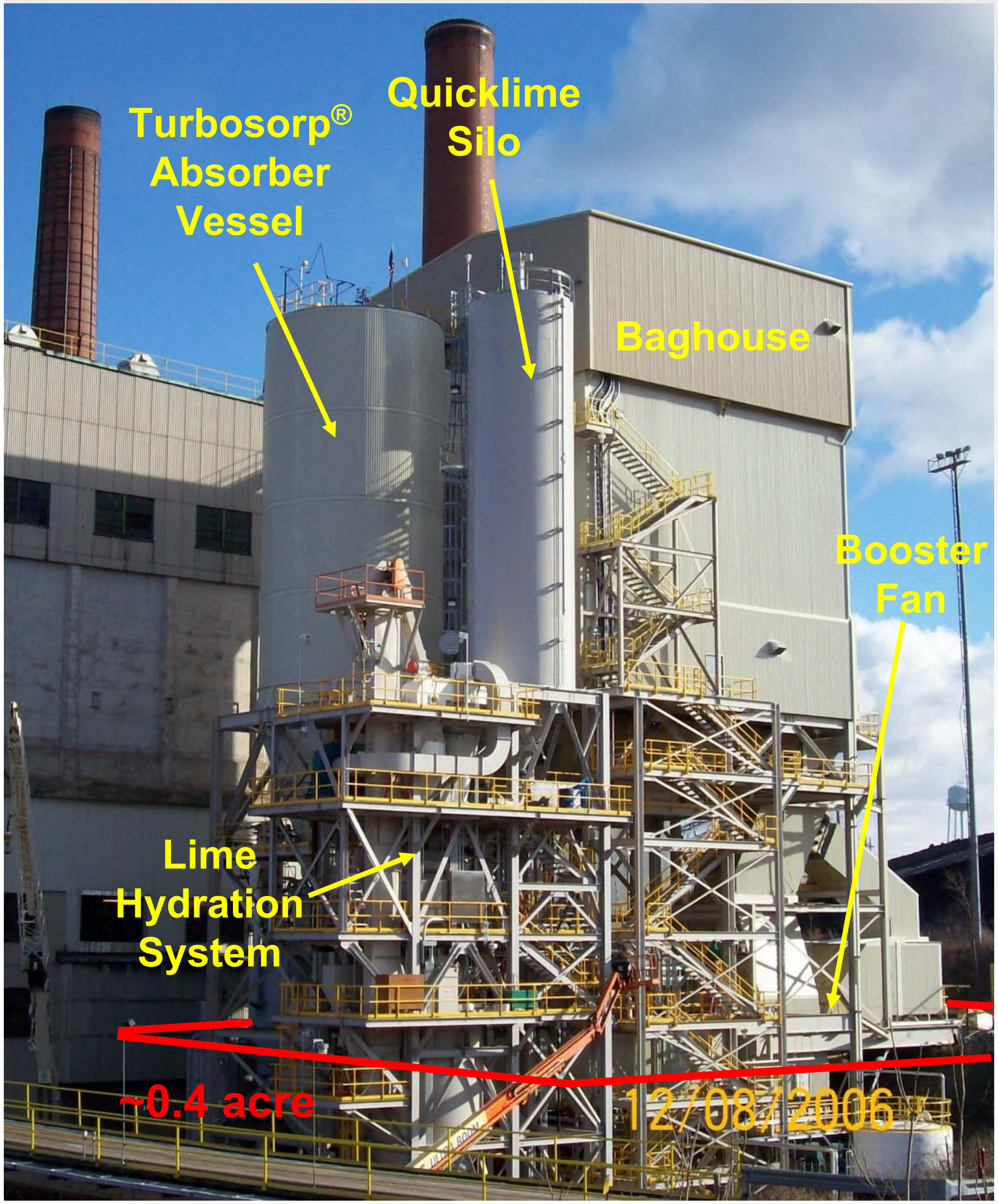


Hybrid NO_x Control System



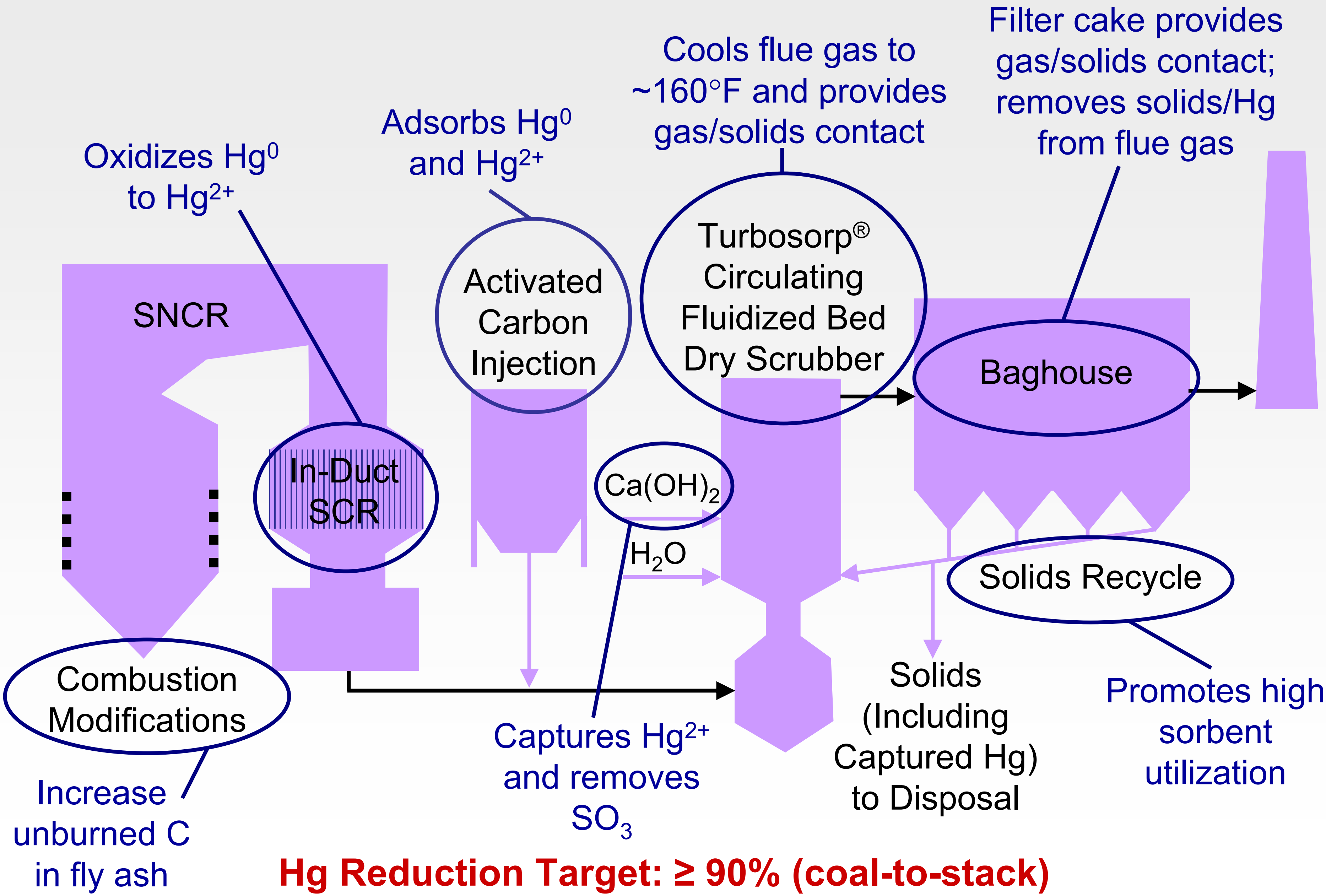
- Combustion Modifications
  - Low-NO_x burners, SOFA
  - Reduce NO_x to 0.25 lb/mmBtu
- SNCR
  - Three zones of urea injection
  - Provide NH_3 slip for SCR (NO_xOUT CASCADE®)
  - Reduce NO_x by ~ 42.5% (to 0.14 lb/mmBtu)
- SCR
  - Single catalyst layer (1.3 m)
  - Cross section = 45’ x 14’
  - Fed by NH_3 slip from SNCR
  - Reduce NO_x by ≥ 30% (to ≤ 0.10 lb/mmBtu)

Turbosorp® Circulating Dry Scrubber



- Completely dry
- Separate control of hydrated lime, water, and recycled solids injection
- High solids recirculation
- Small footprint
- Carbon steel construction
- No wet stack
- Few moving parts
- Projected Ca/S is 1.6-1.7 mol/mol for design fuel

Design Features for Mercury Control



Hg Reduction Target: ≥ 90% (coal-to-stack)

Guarantee Testing Results

March-May 2007, 2.4-3.2% Sulfur Eastern U.S. Bituminous Coal

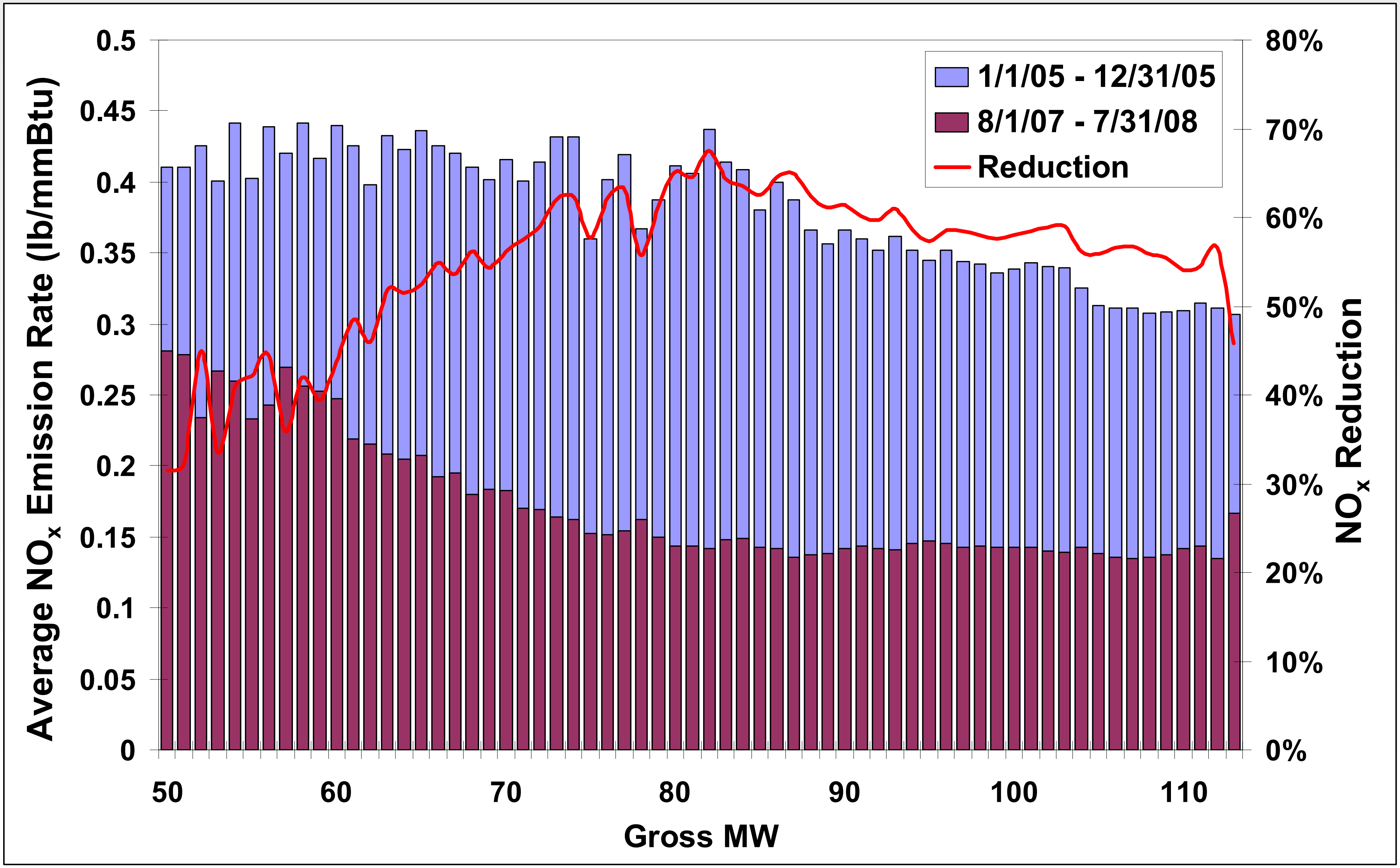
Parameter	Performance Target	Measured Performance
NO_x emission rate (high load)	≤ 0.10 lb/mmBtu	0.10 lb/mmBtu
SO_2 removal	≥ 95%	96%
Hg removal	≥ 90%	
ACI		≥ 94%
No ACI		≥ 95%
SO_3 removal	≥ 95%	97%
HCl removal	≥ 95%	97%
HF removal	≥ 95%	Indeterminate

Long-Term Performance Results

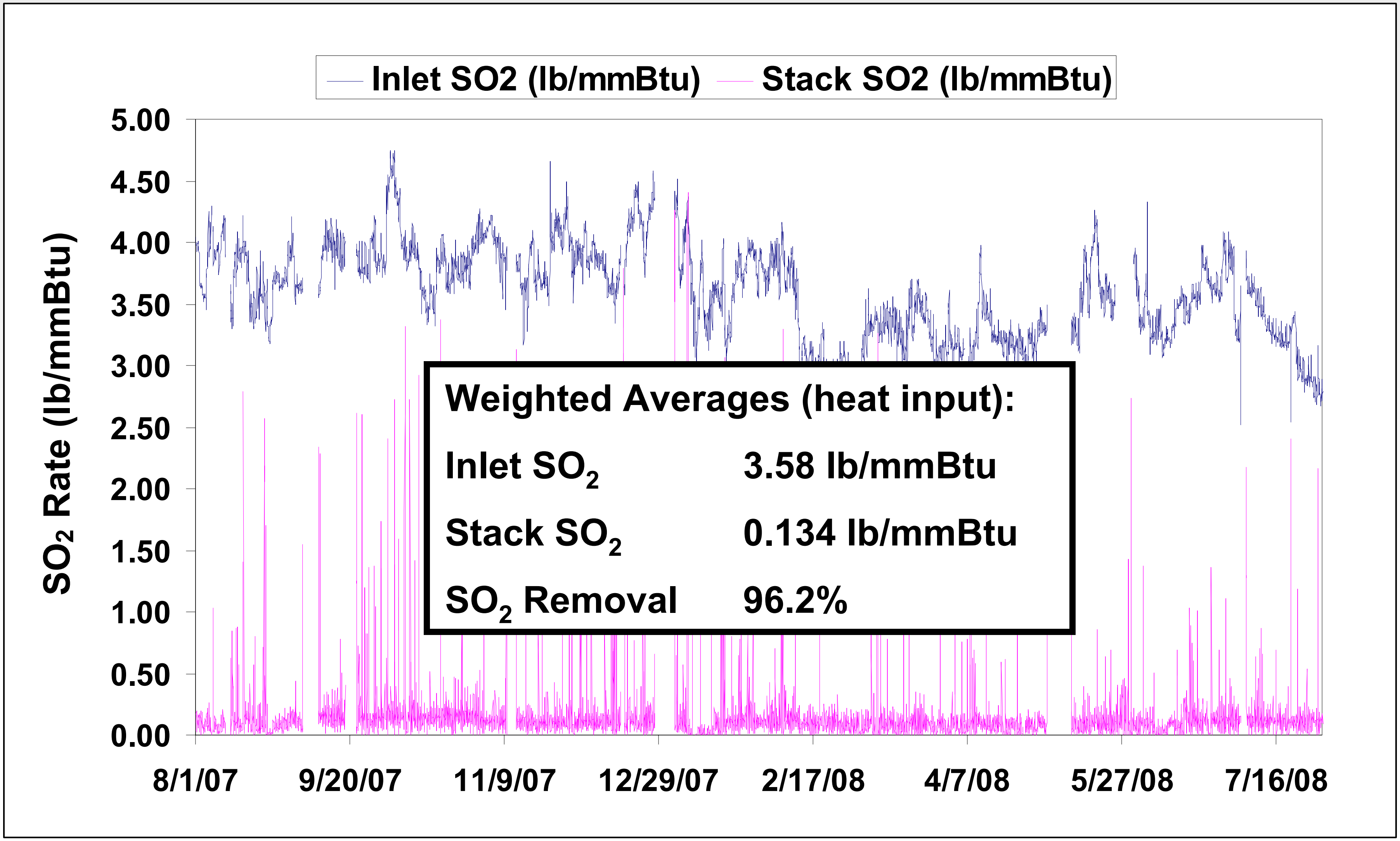
Parameter	Test Period	Number of Tests	Measured Performance
NO_x emission rate (high load)	Aug 07 – Jul 08	continuous	0.14 lb/mmBtu
SO_2 removal	Aug 07 – Jul 08	continuous	96%
Hg removal			
ACI	Mar 07 – Oct 07	5	94%
No ACI	Mar 07 – Jun 08	28	98%
SO_3 removal	May 07 – Jun 08	42	95%
HCl removal	Mar 07 – Jun 08	30	97%
HF removal	Mar 07 – Jun 08	31	Indeterminate

Performance of hybrid NO_x control system has been affected by large particle ash and ammonia slip. Plant typically operates at 0.10-0.15 lb/mmBtu to maintain acceptable combustion characteristics.

NO_x Reduction Performance

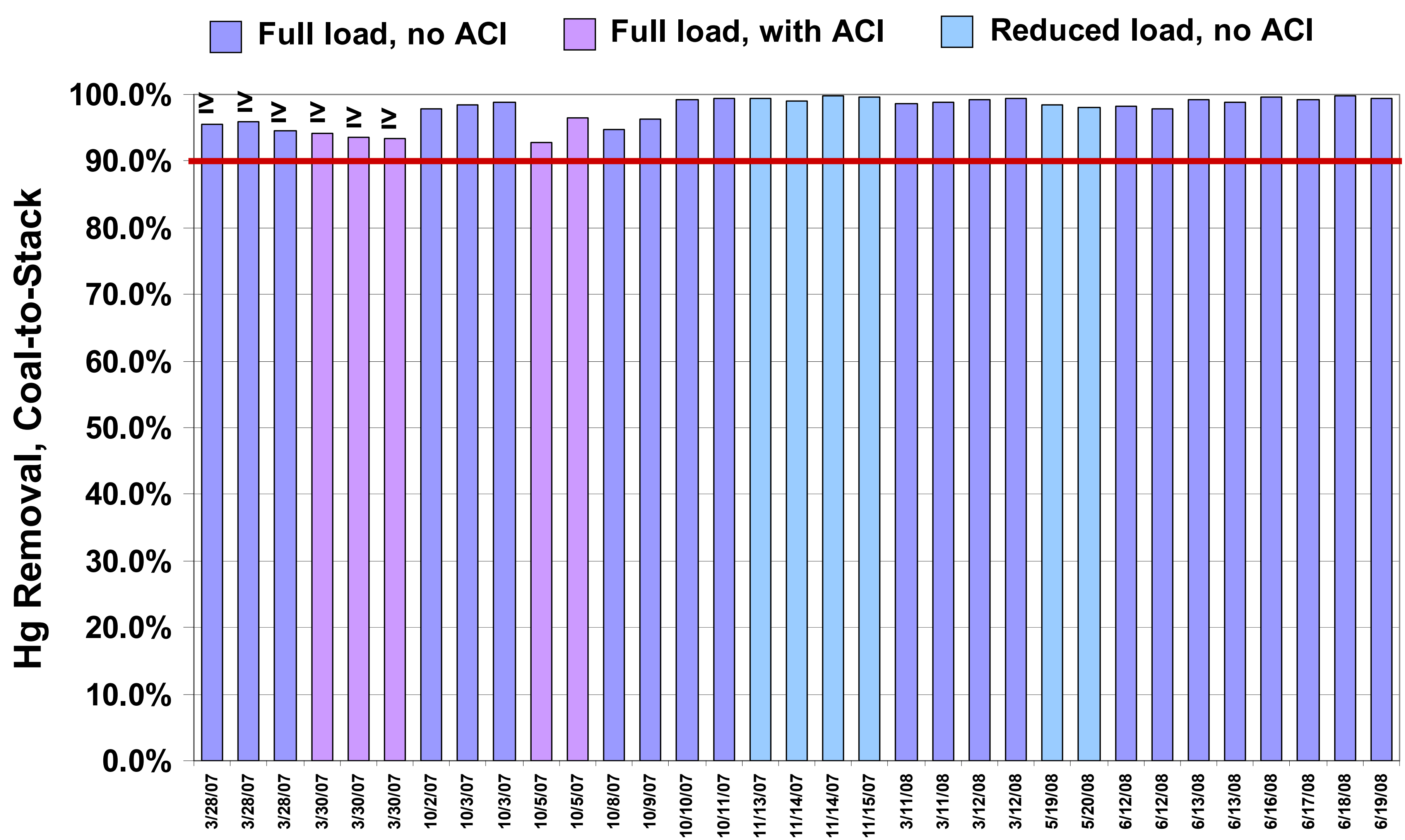


SO_2 Removal Performance



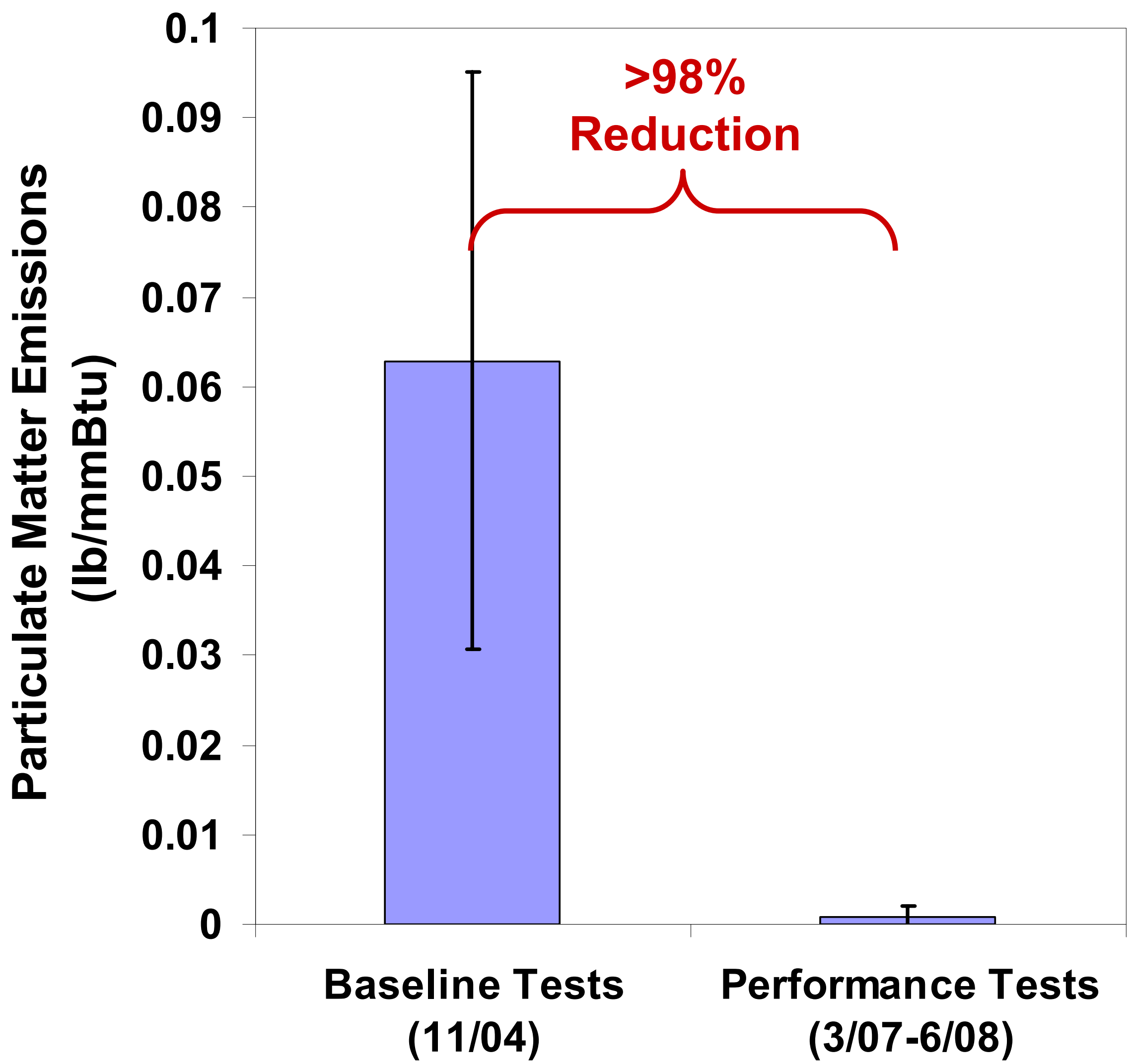
Mercury Testing Results

Ontario Hydro Method or U.S. EPA Method 30B



Particulate Testing Results

EPA Method 5/17, Full Load



New baghouse significantly reduces particulate matter emissions relative to old ESP, in spite of increased particle loading from Turbosorp® scrubber

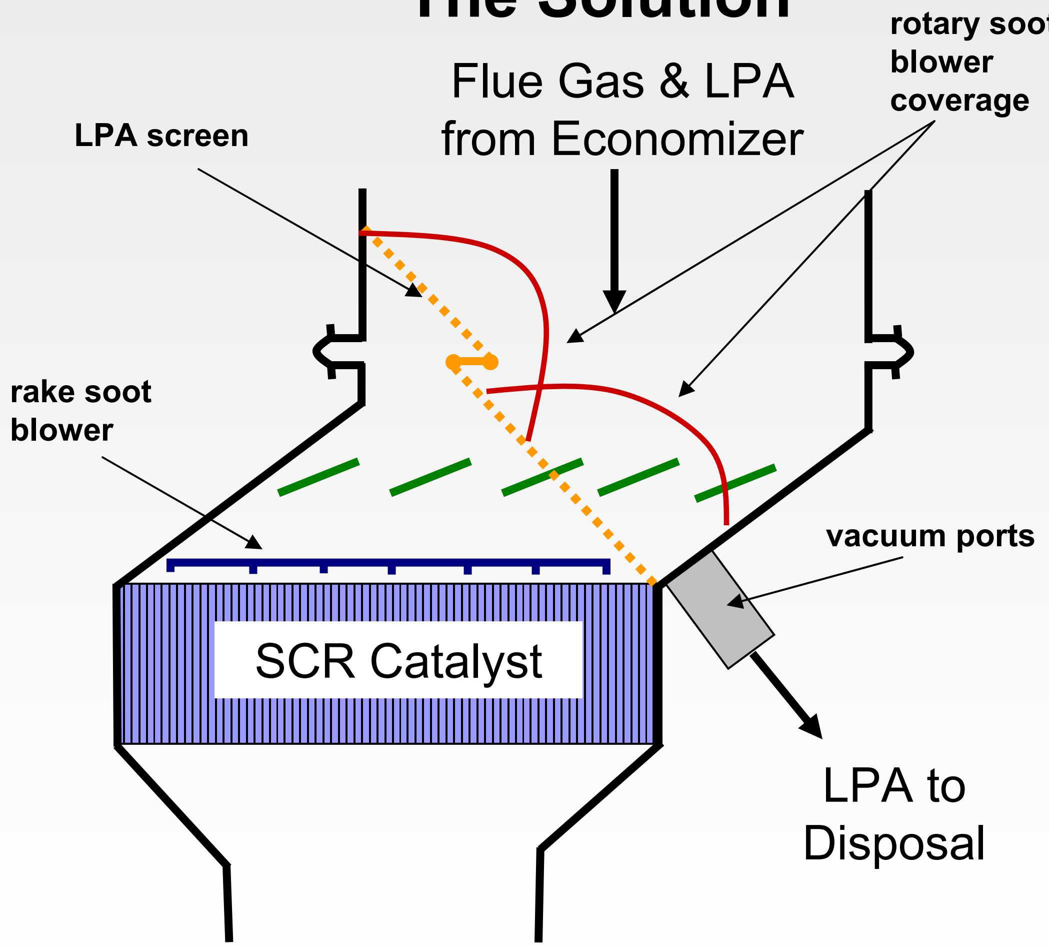
Error bars represent ± 1 standard deviation

Large Particle Ash

The Problem

- More pressure drop
- Less NO_x removal
- More urea consumption
- More ammonia slip

The Solution



Operating and Maintenance Experience

- O&M handled by existing plant staff
- Ammonia slip is higher than expected
- Lime hydration system is most maintenance-intensive part of process
  - Use delivered / stored hydrated lime to allow offline maintenance
  - Most problems involve ball mill and classifier
- Flue gas recycle not used because of problems with reverse flow
- Occasional issues with plugging in the ash recirculation / disposal system

- No condensation issues in the scrubber or baghouse

Process Economics

AES Greenidge Unit 4 Design Case

Constant 2005 Dollars

	EPC Capital Cost ($/kW)	Fixed O&M Cost ($/MWh)	Variable O&M Cost ($/MWh)	Total Levelized Cost ($/MWh)
NO_x Control	114[a]	0.40	0.85	3.49
SO_2 Control	229[b]	0.87	5.41	10.82

[a]Includes combustion modifications, SNCR, in-duct SCR, static mixers, and LPA removal system

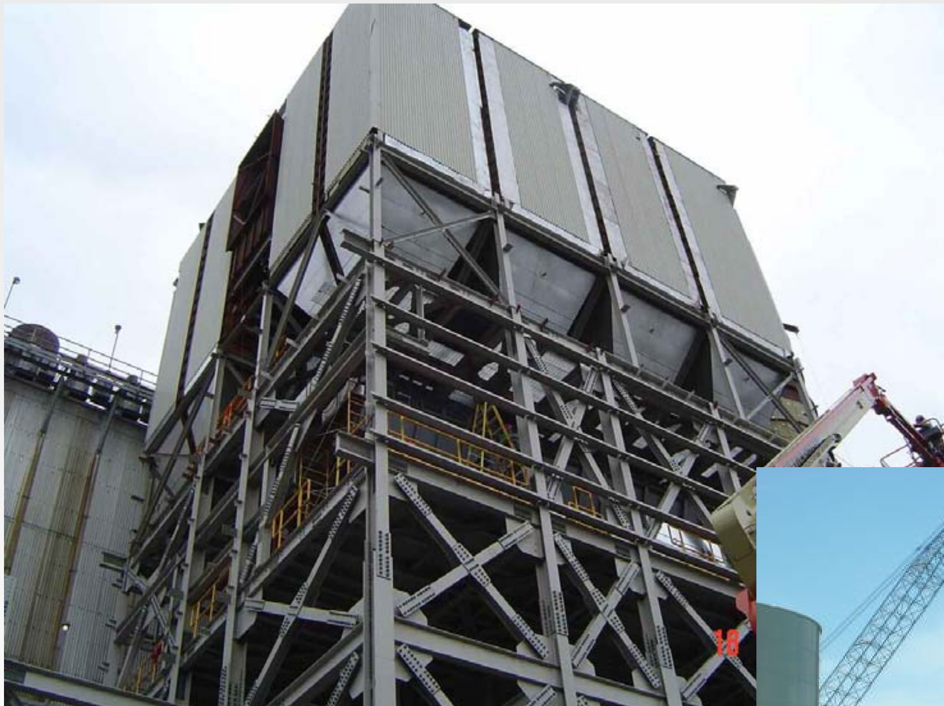
[b]Includes scrubber, process water system, lime storage and hydration system, baghouse, ash recirculation system, and booster fan

Assumptions: Plant size = 107 MW net, Capacity factor = 80%, Coal sulfur = 4.0 lb SO_2/mmBtu, SNCR NSR = 1.35, Ca/S = 1.65, 50% Urea = $1.35/gal, Quicklime = $115/ton, Waste disposal = $17/ton, Internal COE = $40/MWh, Plant life = 20 years, Fixed charge factor = 13.05%, AFUDC = 2.35%, Other assumptions based on AES Greenidge design basis, common cost estimating practices, and market prices

Additional Turbosorp® System Deployments

	AES Westover 8	GRU Deerhaven 2	First Light Mt. Tom 1
Unit Capacity (MWe)	84 (net)	248 (gross)	155 (gross)
Start-Up	Fall 2008	Spring 2009	Fall 2009
Inlet SO_2 (lb/mmBtu)	3.4	2.3-3.9	2.7-4.6
SO_2 Removal Goal (%)	≥ 95	≥ 95.6-97.4	≥ 95
Hydrator	No	2 x 100%	No
Existing ESP	Cold Side Abandon	Hot Side Retain	Cold Side Retain
New Baghouse	Yes	Yes	Yes
ACI System	No	Provisions	Yes
SCR	Yes	Yes	Existing

Additional Turbosorp® System Deployments



AES Westover

GRU Deerhaven

Summary

Results from AES Greenidge Unit 4 (107 MW)

- EPC capital cost = $343/kW (2005)
- Footprint < 0.5 acre
- Performance tests have shown:
  - > 95% SO_2 removal
    (for coals up to 4.8 lb SO_2 / mmBtu)
  - 98% Hg removal
    (no activated carbon required)
  - PM emissions < 0.001 lb / mmBtu
  - ≥ 95% SO_3 and HCl removal

- NO_x emission profile significantly improved
- O&M handled by existing plant staff
- Plant continues to operate profitably (20-30 year life extension)
- Success has led to additional Turbosorp® deployments

Disclaimer