Initial Cost and Performance Results from the Greenidge Multi-Pollutant Control Project

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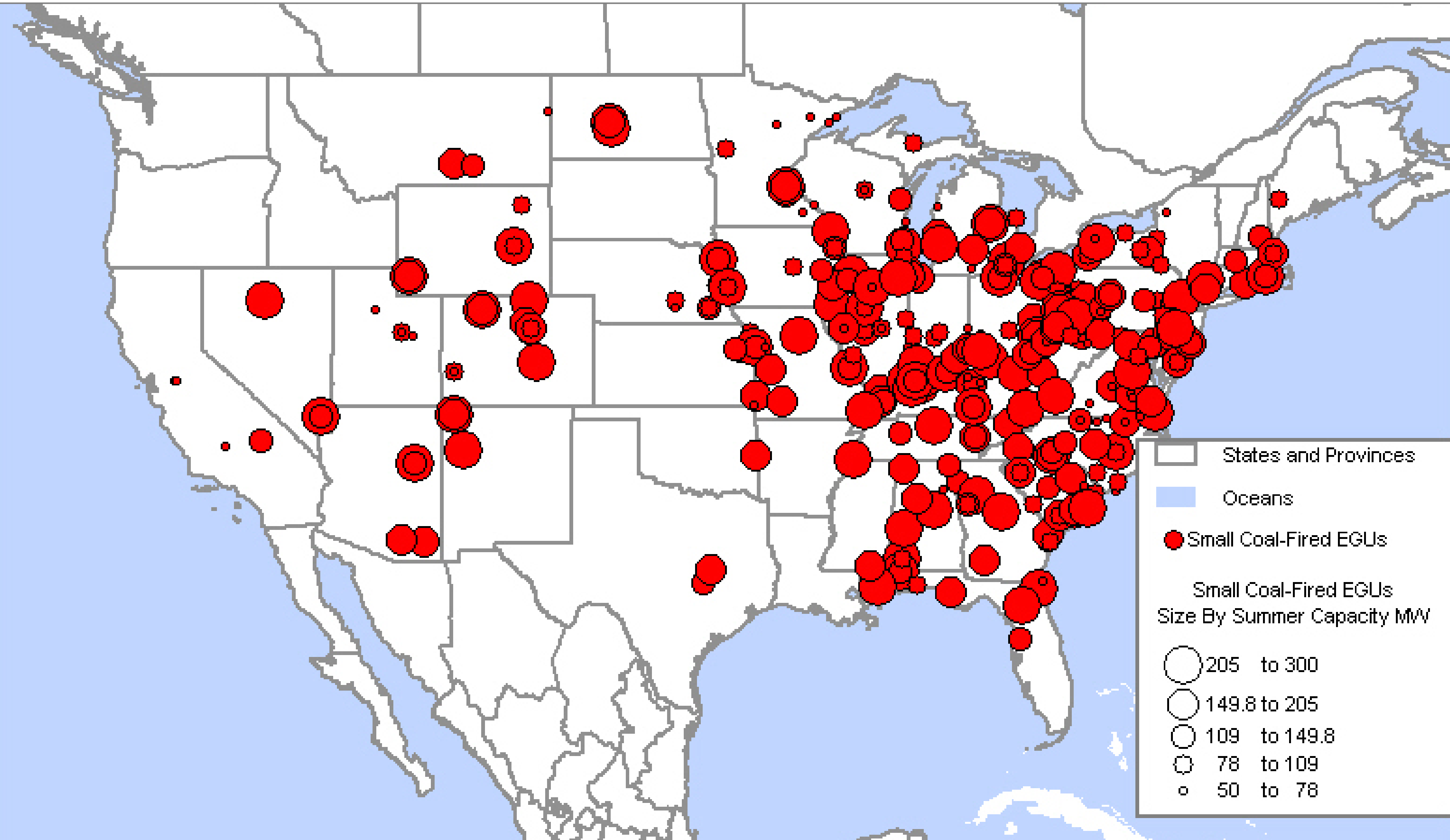
Greenidge Multi-Pollutant Control Project

- 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 power plants

Existing Coal-Fired EGUs
50-300 MW_e

ELECTRIC POWER
CONFERENCE & EXHIBITION



Existing Coal-Fired EGUs
50-300 MW_e

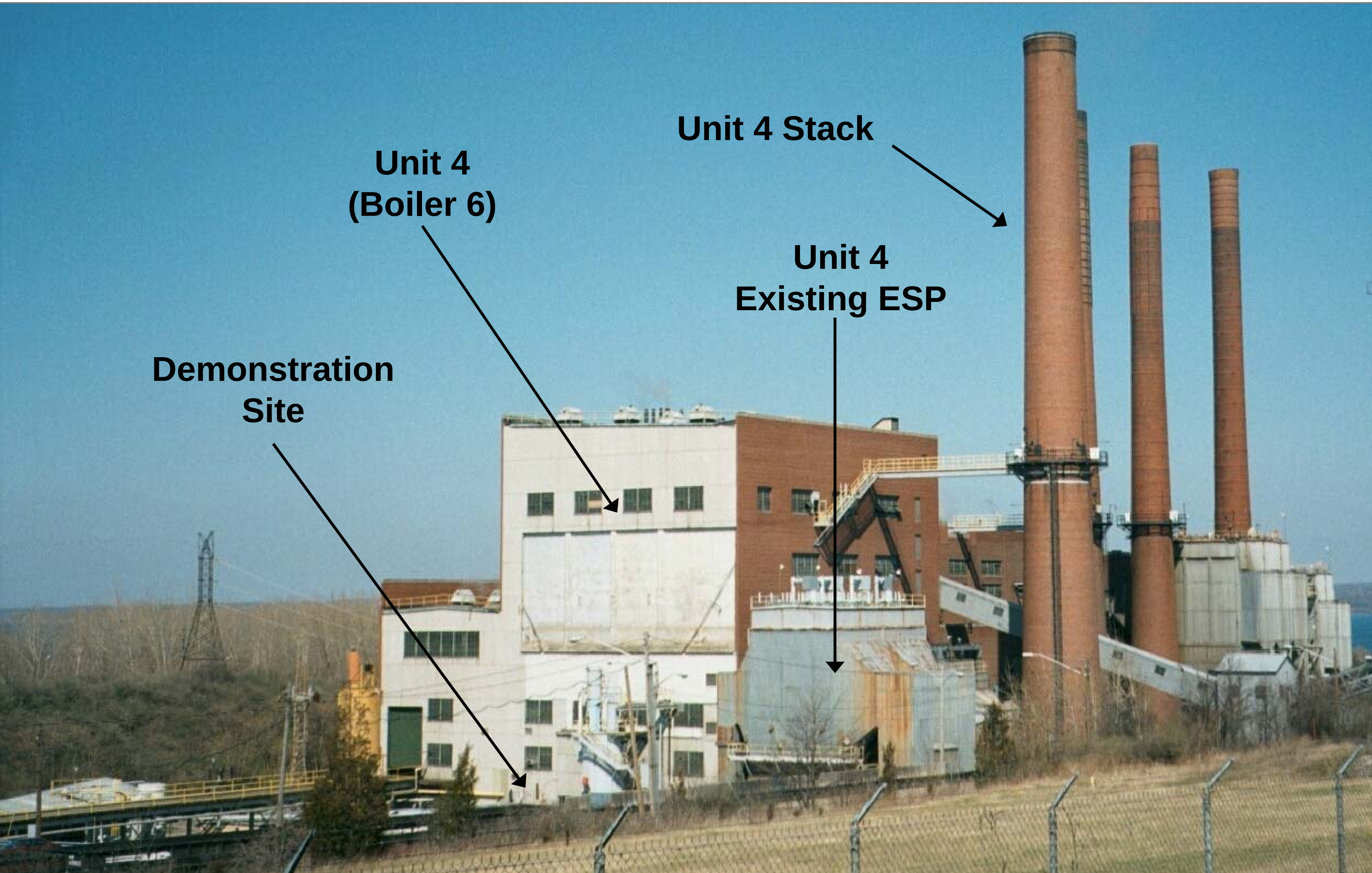
- ~ 440 units not equipped with FGD, SCR, or Hg control
  - Represent ~ 60 GW of installed capacity
  - Greater than 80% are located east of the Mississippi River
  - Most have not announced plans to retrofit
- Increasingly vulnerable to retirement or fuel switching because of progressively more stringent environmental regulations
  - CAIR, CAMR, CAVR, state regulations
- Difficult to retrofit for deep emission reductions
  - Large capital costs
  - Space limitations
- Need to commercialize technologies designed to meet the environmental compliance requirements of these units

AES Greenidge Unit 4
(Boiler 6)

- Dresden, NY
- Commissioned in 1953
- 107 MW_e (net) 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-sulfur coal to meet permit limit of 3.8 lb SO_2/MMBtu

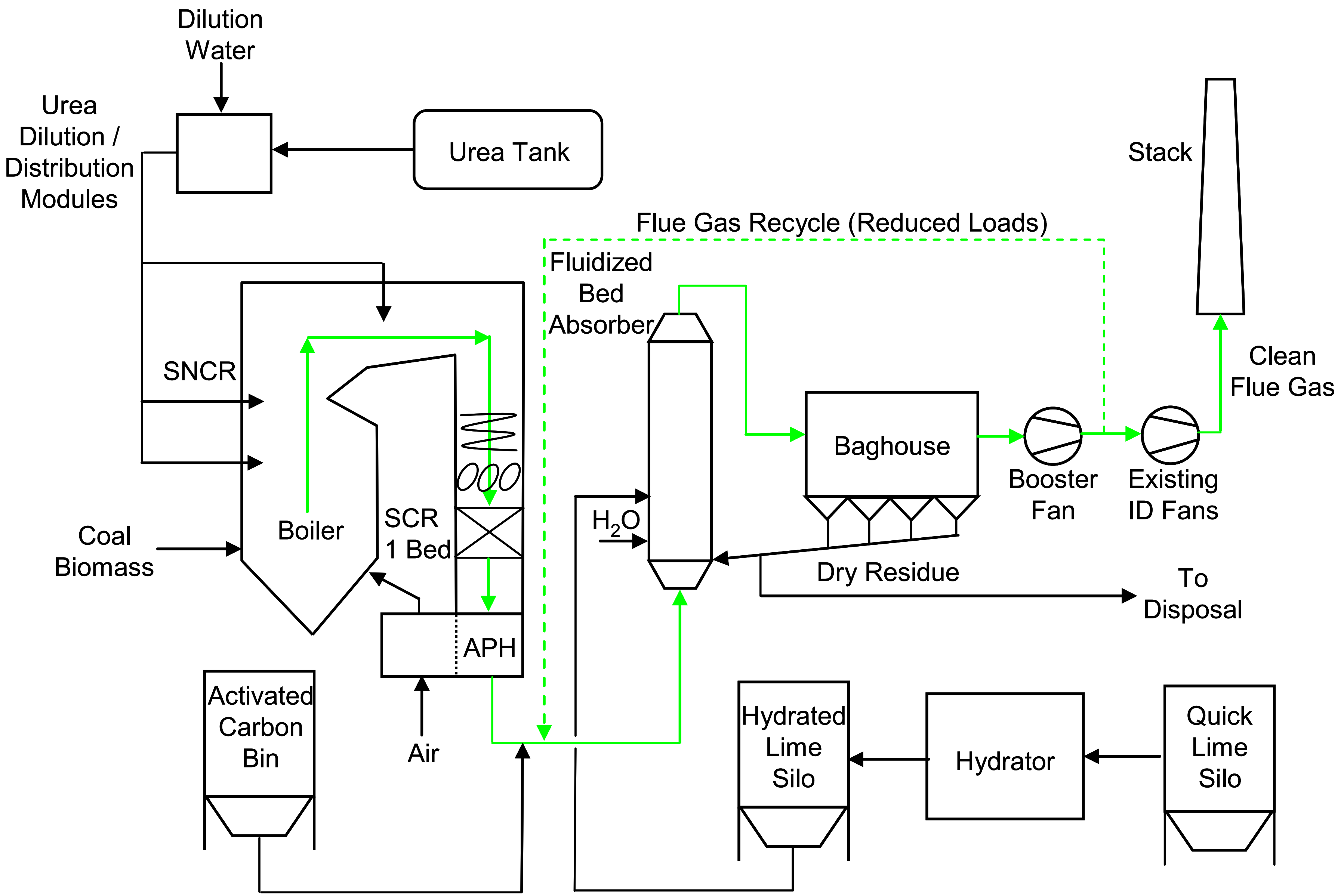
AES Greenidge Unit 4
(Boiler 6)



Multi-Pollutant Control Process

- Combustion modifications (outside DOE scope)
- Hybrid SNCR / SCR
  - Urea-based, in-furnace selective non-catalytic reduction
  - Single-bed, in-duct selective catalytic reduction
- Activated carbon injection
- Turbosorp® circulating fluidized bed dry scrubber
- Baghouse

Process Flow Diagram



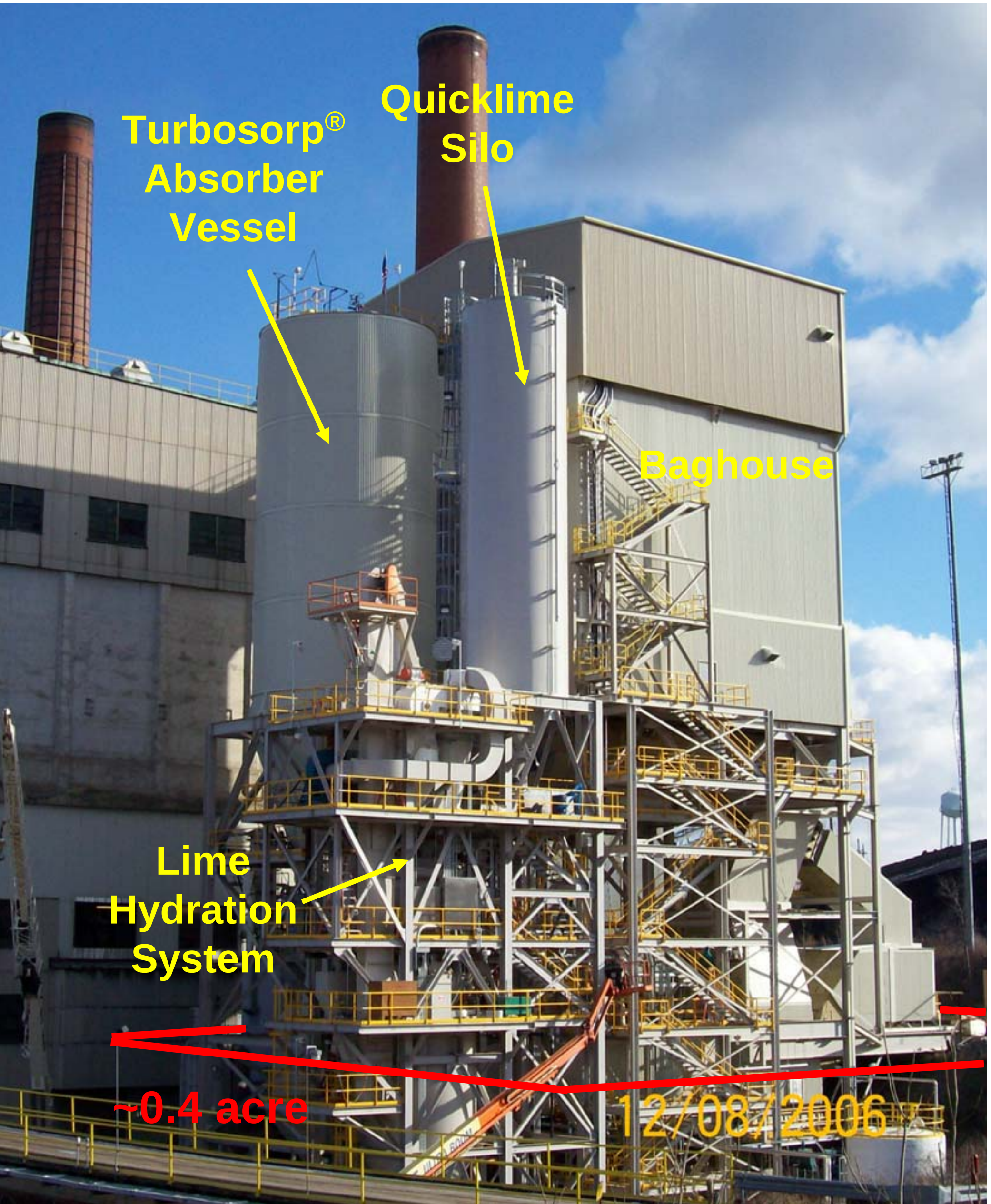
Single-Bed SCR

Reactor Cross Section: 45’ x 14’

Bed Depth: 1330 mm

- Fed by NH_3 slip from SNCR
- NO_x Reduction: $\geq$ 30%
- $SO_2 \rightarrow SO_3$: $\leq$ 1.0%
- NH_3 slip from SCR: $\leq$ 2 ppmv

Turbosorp® System



- Completely dry
- Separate control of reagent, water, and recycled solid injection
- High solids recirculation
- Applicable to high-sulfur coals
- 15-25% lower reagent consumption than SDA
- Low capital and maintenance costs relative to other FGD technologies

Performance Targets

Fuel: 2-4% sulfur bituminous coal, up to 10% biomass

Parameter	Goal
NO_x	≤ 0.10 lb/MMBtu (full load)
SO_2	≥ 95% removal
Hg	≥ 90% removal
SO_3, HCl, HF	≥ 95% removal

Assumptions
Base Plant

Plant Size	107 MW_e (net)
Fuel	90% coal / 10% biomass
Fuel HHV	12,426 Btu/lb
Fuel Sulfur Content	2.5% (w/w as fired)
Baseline NO_x Emissions	0.30 lb/MMBtu (as NO_2)
Annual Capacity Factor	80%

Assumptions
Financing

- Constant 2005 dollars
- 20-year plant life
- 1.67-year construction period
- 7.09% discount rate (before tax)
  - 45% debt @ 9% nominal return
  - 10% preferred stock @ 8.5% nominal return
  - 45% common stock @ 12% nominal return
  - 3.0% inflation
- Tax Rates
  - 35% federal, 4% state, 2% property

Fixed Charge Factor: 13.05%
AFUDC: 2.35%

Assumptions
O&M Costs

Urea (50% w/w, $/gal)	$1.25
Quicklime ($/ton)	$110
Powdered Activated Carbon ($/lb)	$0.45
Electricity ($/MWh)	$30
Plant Service Water ($/1000 gal)	$0.20
Replacement Catalyst ($/layer)	$300,000
Baghouse Bags/Cages ($/bag+cage)	$140
Waste Disposal ($/ton)	$12
Operating Labor ($/hr)	$35

Economic Projections
Overall System – Summary

	$MM/y	$/MWh
Levelized Capital	$5.02	$6.70
Fixed O&M	$0.88	$1.17
Variable O&M	$4.23	$5.64
Total Levelized Cost	**$10.13**	**$13.51**

Economic Projections
Overall System – Capital

	$MM	$/kW$_{net}$
Total Plant Cost (TPC)	$36.3	$339
Total Plant Investment (TPI)	$37.2	$347
Total Capital Requirement (TCR)	$38.5	$360

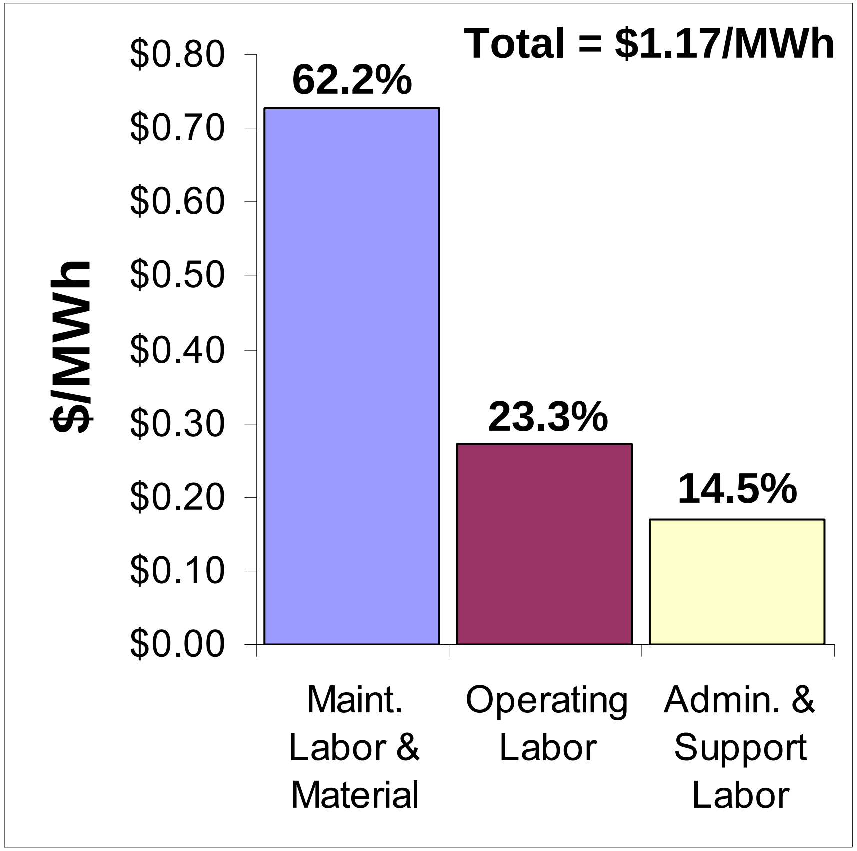
- ~40% less than estimated cost of $540/kW$_{net}$ for full SCR + wet scrubber

Notes:
TPI = TPC x (100% + AFUDC), TCR = TPI + Pre Production Cost + Inventory Capital,
Pre-Production Cost = 0.02 x TPI + (Annual O&M Cost) ÷ 12, Inventory Capital = 0.005 x TPC,
Full SCR + wet scrubber cost estimated using Integrated Environmental Control Model

Economic Projections
Overall System – Fixed O&M

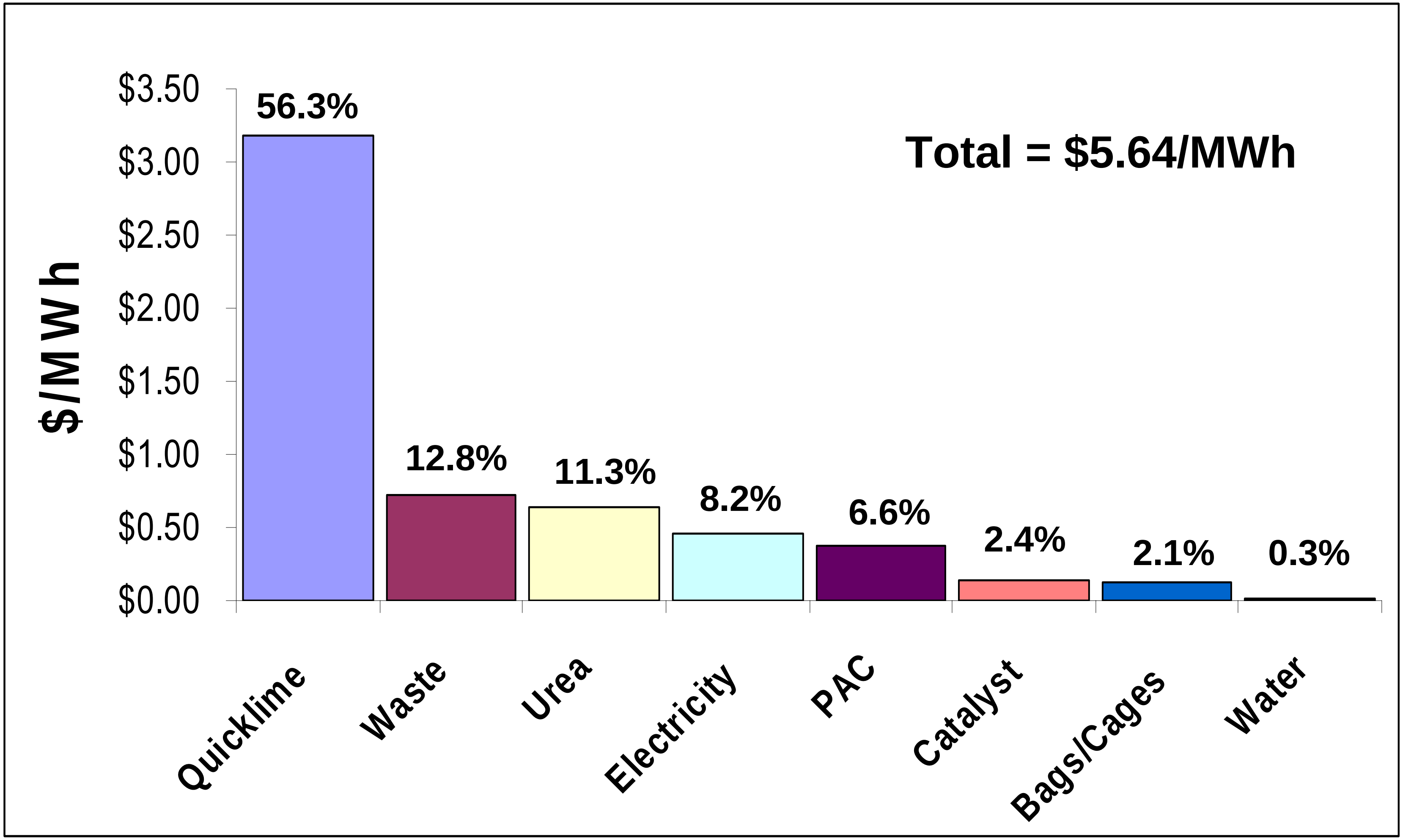
Assumptions

- Operating Labor
  - 16 h/day
- Maintenance Labor & Materials
  - 1.5% of TPC
  - 40% labor, 60% materials
- Administrative & Support Labor
  - 30% of total labor



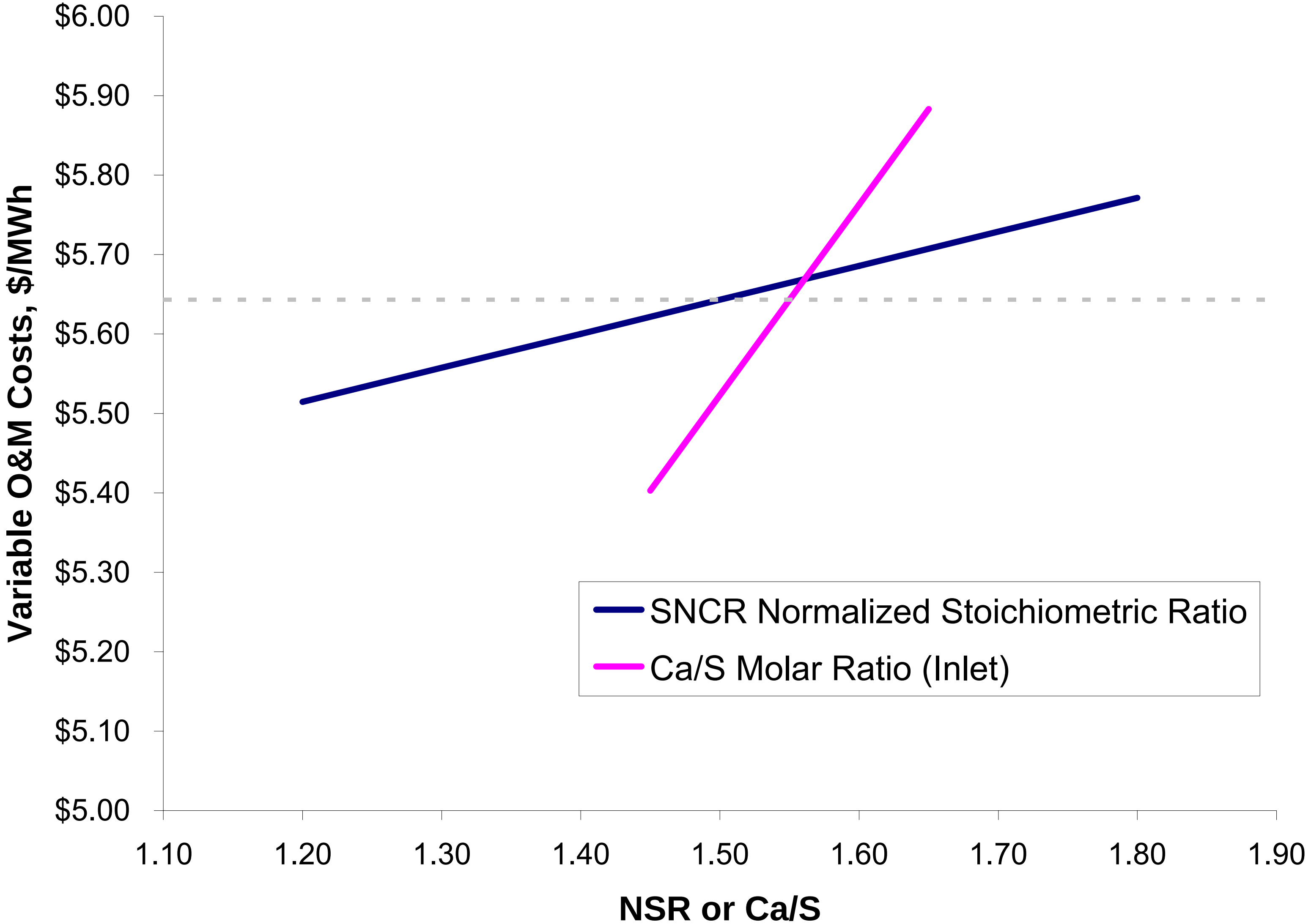
- Fixed O&M costs expected to be less than for competing technologies
- Actual costs will be determined during 20-month operation period

Economic Projections
Overall System – Variable O&M



Assumptions: SNCR NSR = 1.50, catalyst life = 3 yr, Ca/S molar ratio (inlet SO_2) = 1.55, CaO purity = 95% (w/w), PAC feed rate = 3.5 lb/MMacf, baghouse bag / cage life = 5 yr

Variable O&M Costs
Sensitivity to Urea and Lime Consumption



Variable O&M Costs
Mercury Control

- System design favors high baseline Hg removal without activated carbon injection
  - Hg oxidation across in-duct SCR catalyst
  - Low temperature (~170 ^{o}F) in scrubber / baghouse
  - High residence time for fly ash and $Ca(OH)_2$ in scrubber / baghouse
  - Similar to SCR / SDA / FF with bituminous coal
    - Field sampling shows 90% Hg removal often achieved with no ACI
- Expect $\geq$ 90% removal with low carbon injection rate
  - Projected activated carbon requirement: 0.0 – 3.5 lb/MMacf
- Economic projections assume maximum rate
  - Activated carbon accounts for $0.37/MWh of variable O&M cost
  - Actual cost likely to be less than this - will be determined as part of DOE demonstration project

Economic Projections

NO_x Control Only

	$/MWh	$/ton NO_2 removed
Levelized Capital	$2.08	$2,086
Fixed O&M	$0.36	$365
Variable O&M	$0.83	$839
Urea	$0.64	$643
Replacement Catalyst	$0.13	$134
Power/Water	$0.06	$62
Total Levelized Cost	**$3.27**	**$3,290**

- Improved dispatch economics relative to purchasing allowances

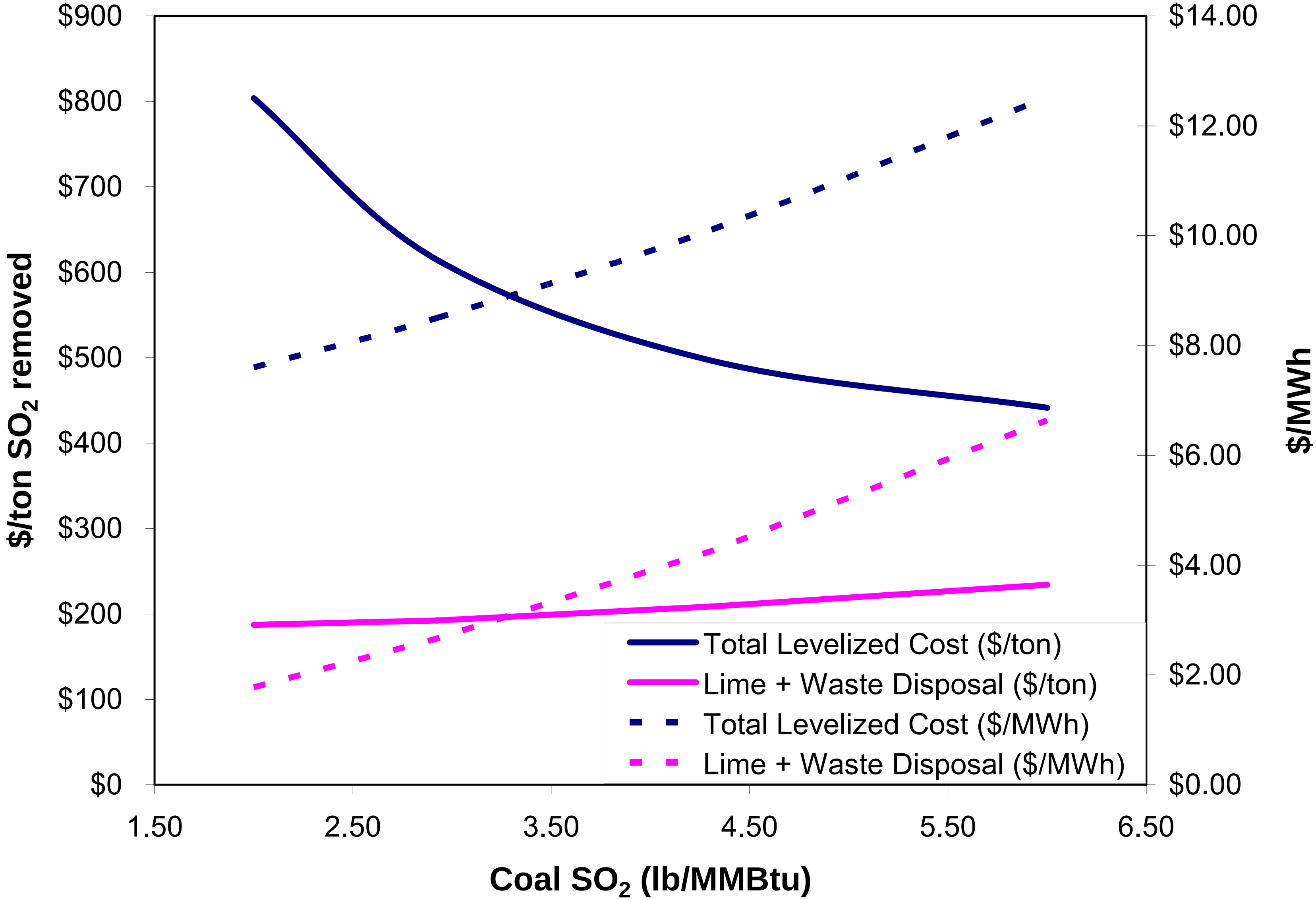
Economic Projections

SO_2 Control Only

	\$/MWh	\$/ton SO_2 removed
Levelized Capital	\$4.52	\$238
Fixed O&M	\$0.79	\$42
Variable O&M	\$4.44	\$233
Lime + Waste Disposal	\$3.90	\$205
Power/Water	\$0.42	\$22
Baghouse Bags/Cages	\$0.12	\$6
Total Levelized Cost	**\$9.75**	**\$513**

- Improved dispatch economics relative to purchasing allowances
- Acid gas control and improved primary particulate control for “free”

SO_2 Control Costs
Sensitivity to Coal Sulfur Content



Conclusions

Greenidge Multi-Pollutant Control System

- Capital cost of $339/kW$_{net}$ for 107 MW unit (2005$)
  - About 40% less than estimated cost of full SCR + wet scrubber
- Projected total levelized cost of $13.51/MWh (2.5%-sulfur fuel)
- Footprint of < 0.5 acre
- Deep emission reductions
  - NO_x to $\leq$ 0.10 lb/MMBtu (full load)
  - SO_2 and acid gases by $\geq$ 95%
  - Hg by $\geq$ 90%
- Helps to enable 20-30 year life extension
- Improves dispatch economics

Project Status and Plans

- System started up in early 2007
- 20-month period of operation and testing underway
- Specific goals:
  - Confirm emissions reduction performance
  - Determine / optimize reagent consumption rates
  - Characterize Hg removal co-benefits, ACI requirements
  - Determine actual fixed O&M costs
  - Assess effects of fuel / load
  - Evaluate balance-of-plant impacts

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