Design of an Integrated Multi-Pollutant Control System for Reducing Emissions of SO_2, NO_x, Hg, Acid Gases, and Particulate Matter from Smaller Coal-Fired Power Plants

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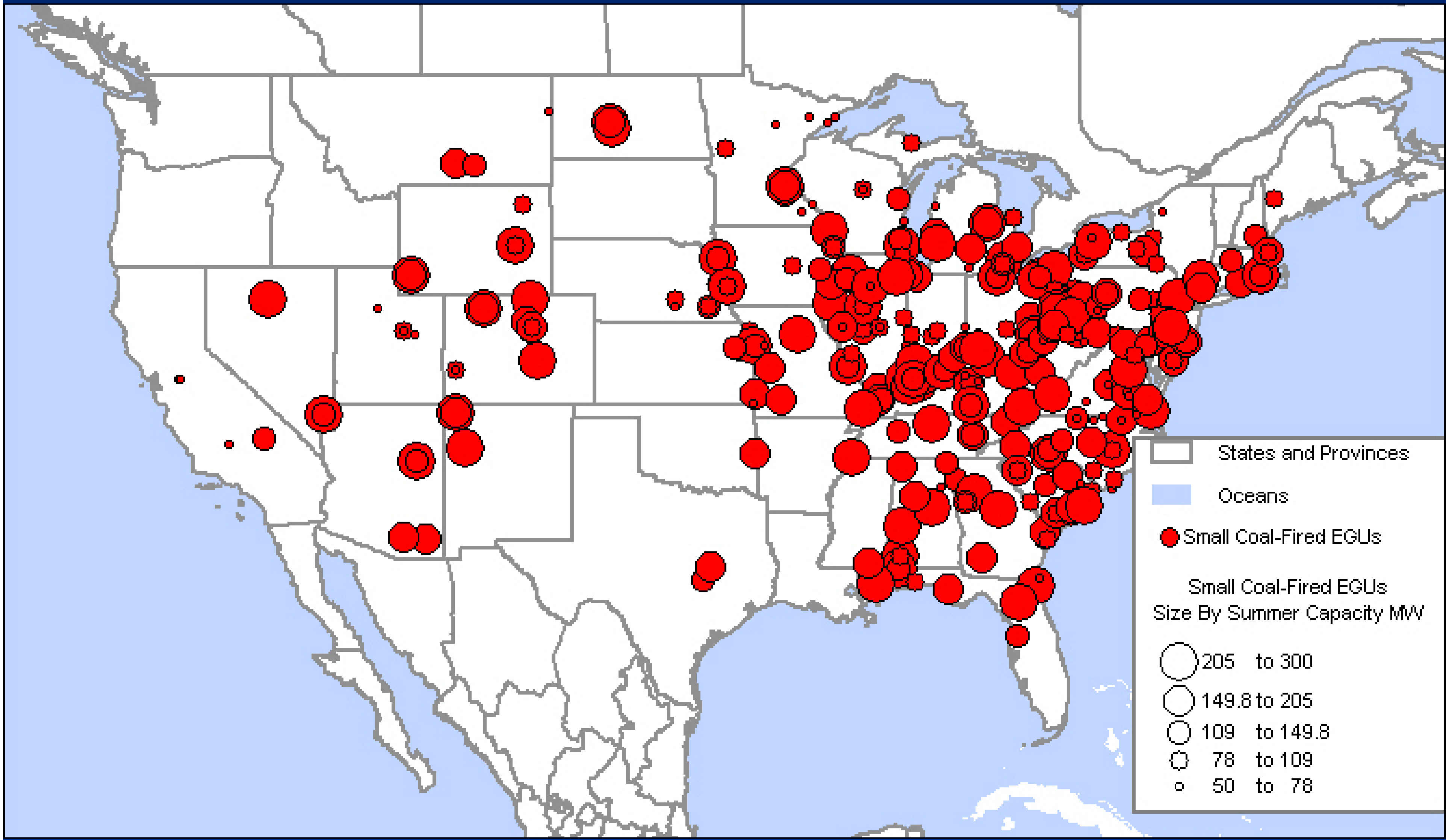
The Greenidge Multi-Pollutant Control Project

- Power Plant Improvement Initiative
  - Cost-shared collaboration between U.S. DOE and industry
  - Commercial demonstration of coal-based technologies
  - Goal: Help to ensure the reliability of the nation's energy supply by improving the efficiency, cost-competitiveness, and environmental performance of new and existing coal-fired electric generating facilities
- Greenidge Project
  - DOE Cooperative Agreement signed May 2006
  - 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 U.S. Coal-Fired EGUs

50-300 MW_e



Existing U.S. Coal-Fired EGUs

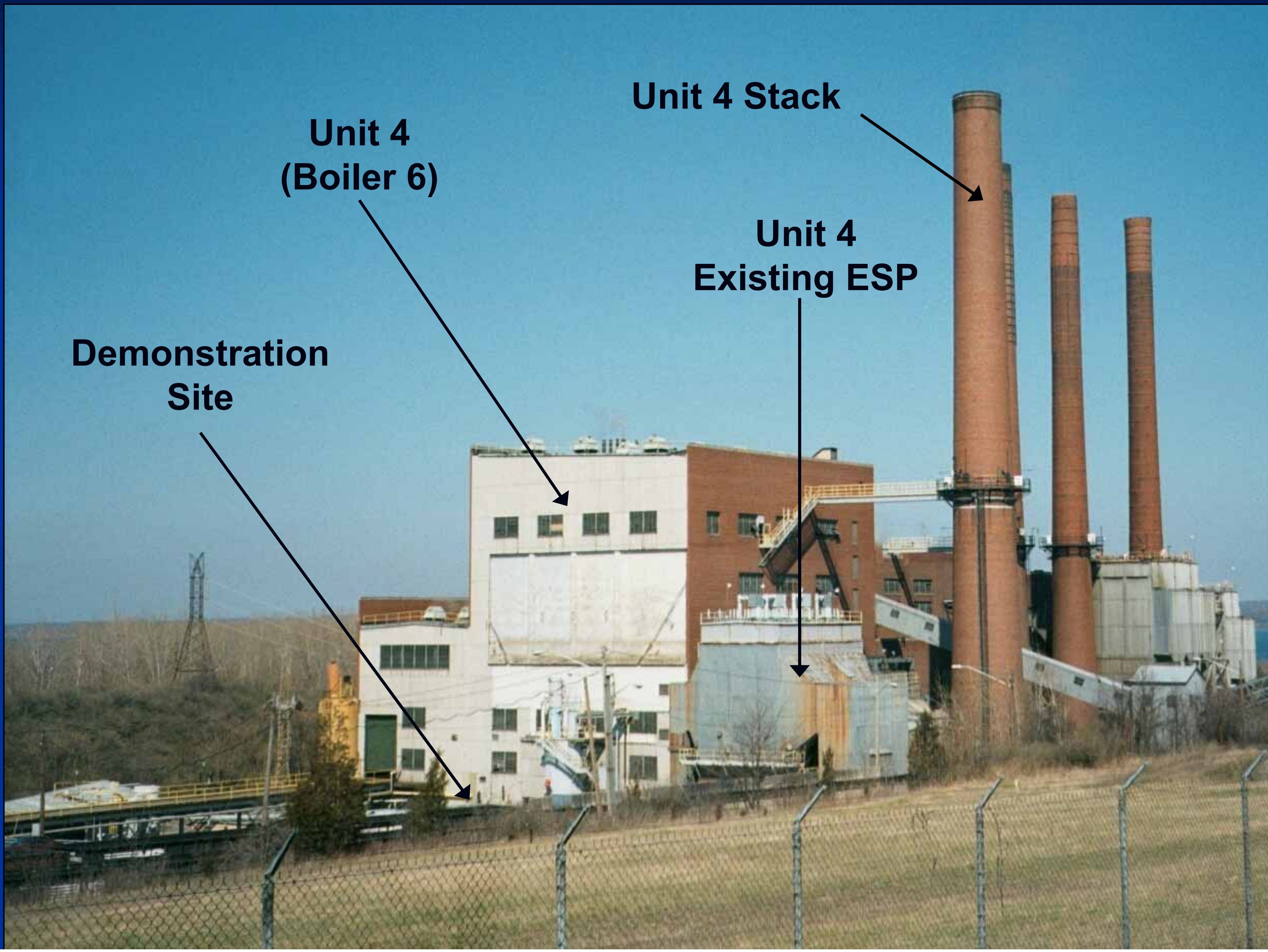
50-300 MW_e

- ~ 440 units not equipped with FGD or SCR
  - Represent ~ 60 GW of installed capacity
  - Greater than 80% are located east of the Mississippi River
  - Most have not announced plans to retrofit
- Difficult to retrofit for deep emission reductions
  - Large capital costs
  - Space limitations
- Increasingly vulnerable to retirement or fuel switching because of progressively more stringent environmental regulations
  - CAIR, CAMR, state regulations
- 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 MWe (net) reheat unit
- Boiler:
  - Combustion Engineering tangentially-fired, balanced draft
  - 780,000 lb/h steam flow at 1465 psig and 1005 ºF
- Fuel:
  - Eastern bituminous coal
  - Biomass (waste wood) – up to 10% heat input
- Current emission controls:
  - Overfire air (natural gas reburn not in use)
  - ESP
  - No FGD - mid-sulfur coal to meet permit limit of 3.8 lb/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

Greenidge Project Performance Targets

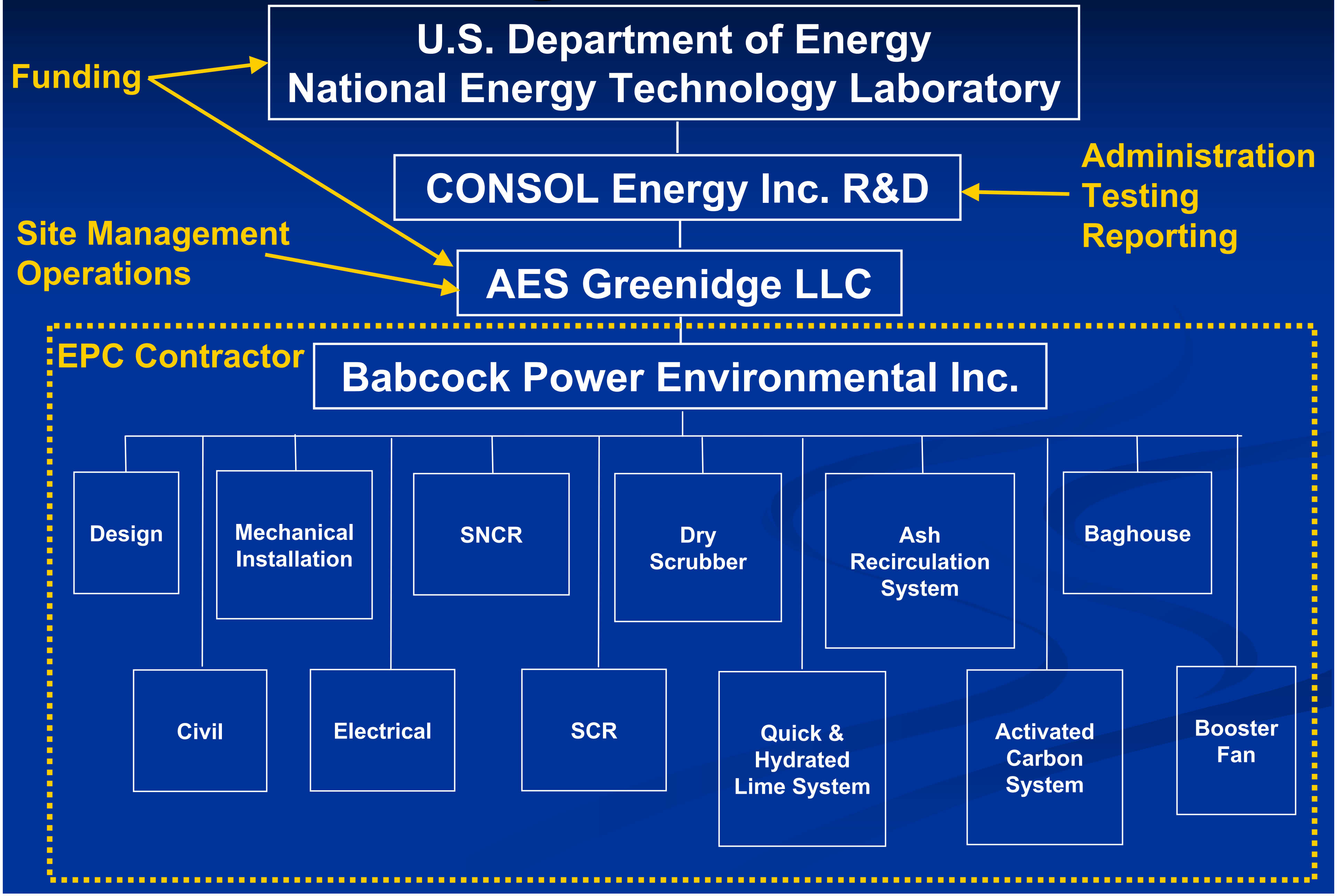
Fuel: 2-4% sulfur bituminous coal, up to 10% biomass

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

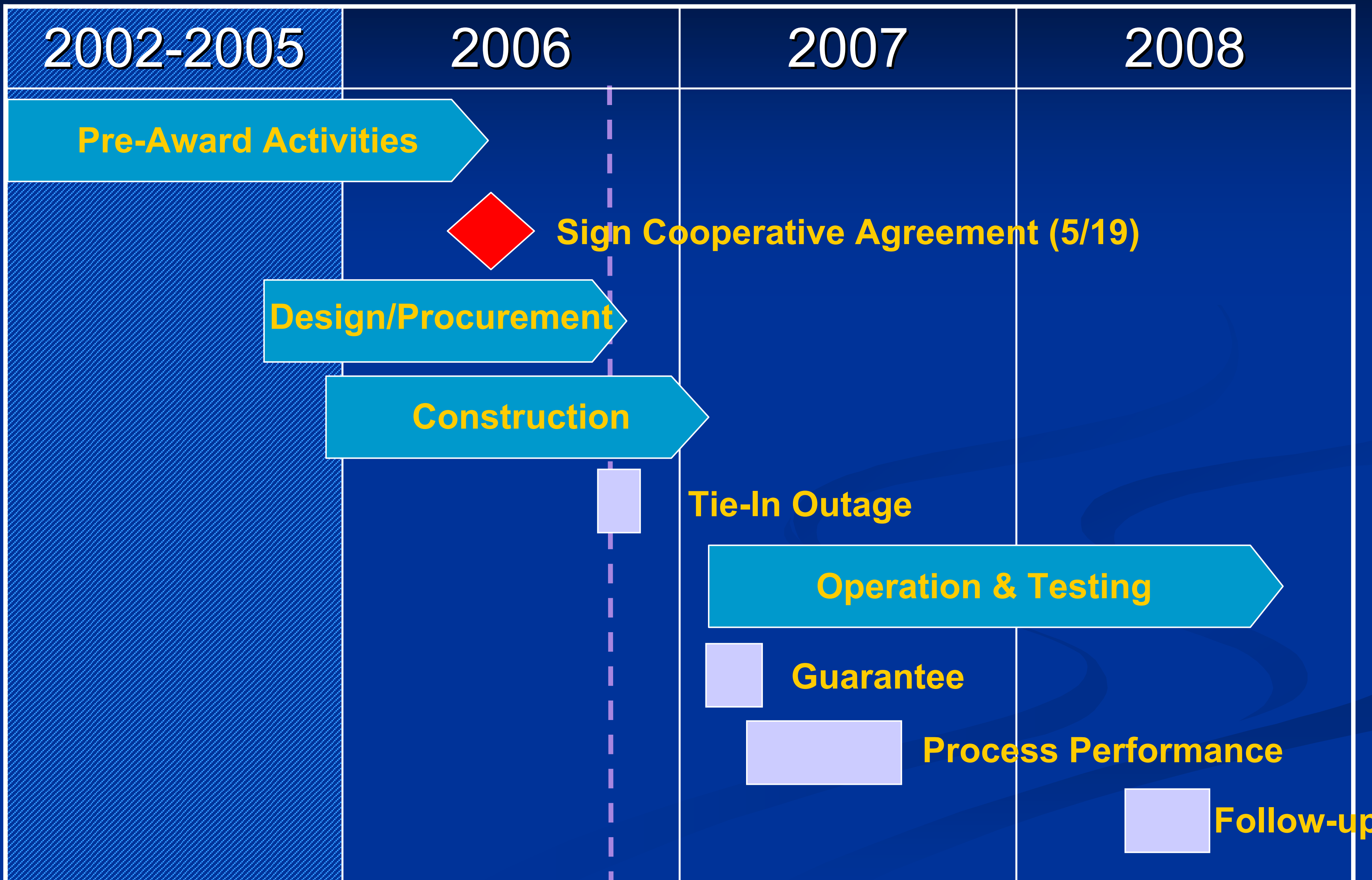
Capital (EPC) Cost: ~ $330 / kW

Footprint: ~ 0.4 acre

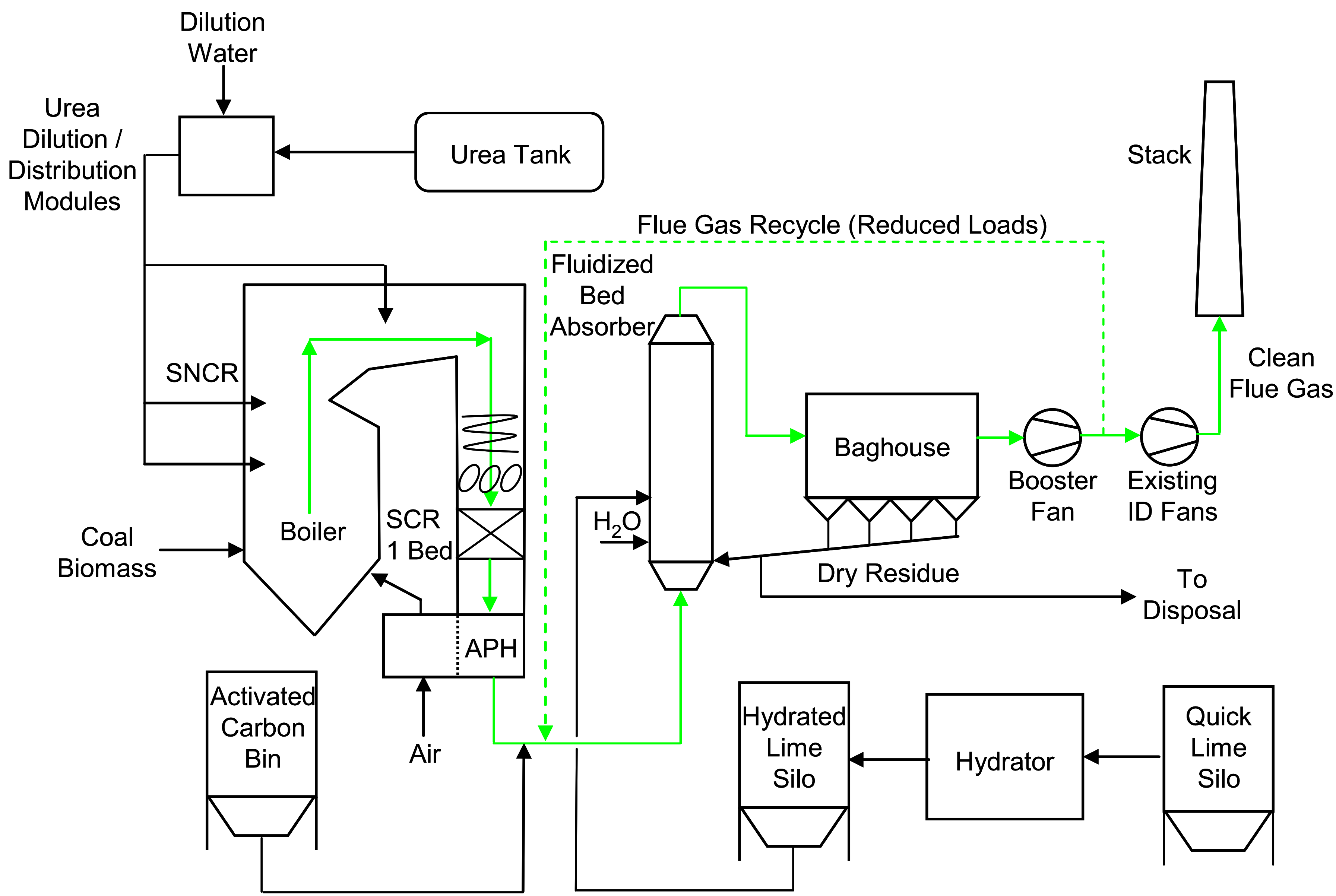
Organization



Project Schedule



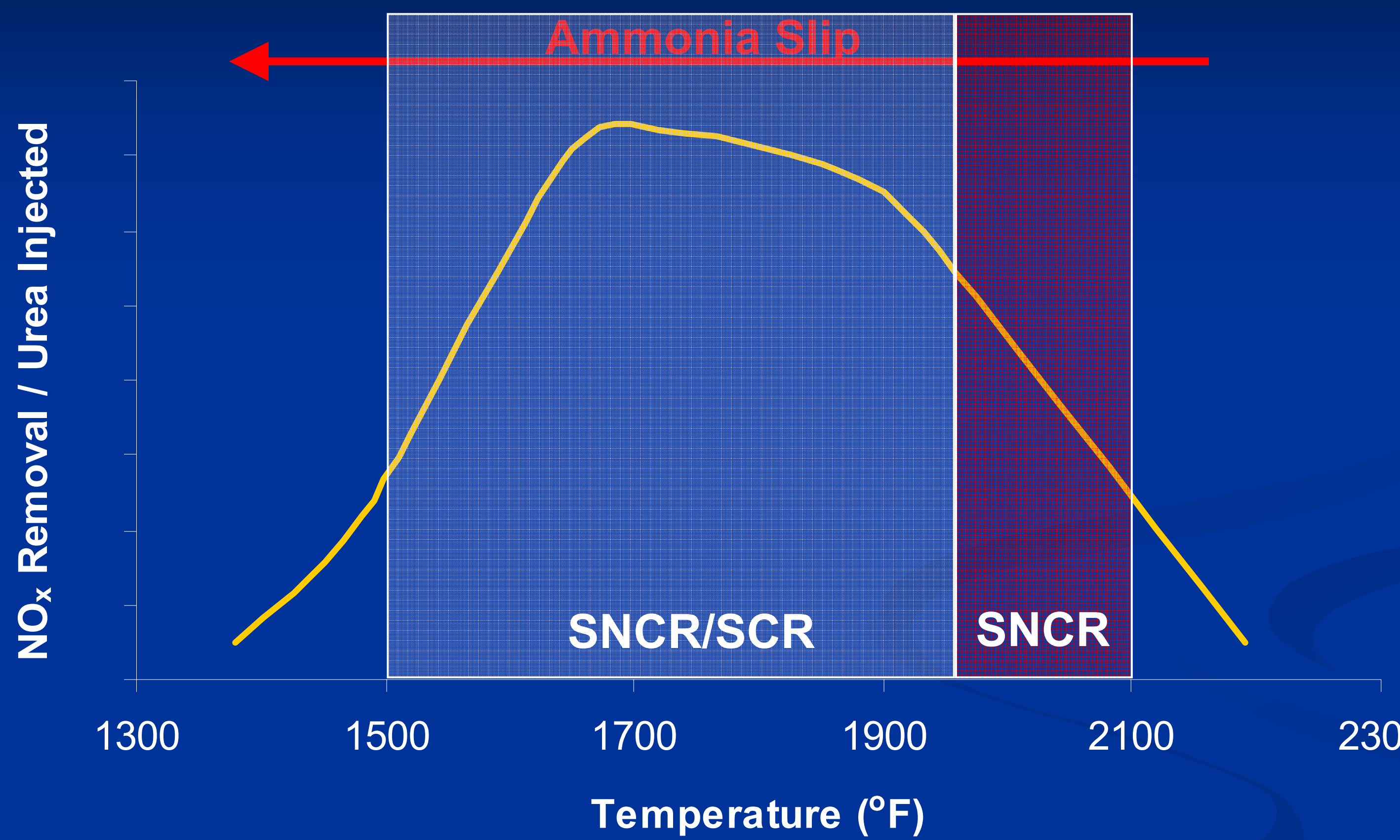
Process Flow Diagram



Hybrid NO_x Control

- Combustion Modifications
  - Replace coal, combustion air, and overfire air nozzles
  - Improve fuel/air mixing, burner exit velocity, secondary airflow control, and upper furnace mixing; reduce CO
  - Reduce NO_x to 0.25 lb/MMBtu
- SNCR
  - $CO(NH_2)_2 + 2\ NO + \frac{1}{2}\ O_2 \rightarrow 2\ N_2 + CO_2 + 2\ H_2O$
  - Reduce NO_x by ~ 42.5% (to 0.144 lb/MMBtu)
- SCR
  - $4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$
  - $6\ NO_2 + 8\ NH_3 \rightarrow 7\ N_2 + 12\ H_2O$
  - Reduce NO_x by > 30% (to ≤ 0.10 lb/MMBtu)

SNCR for Hybrid System

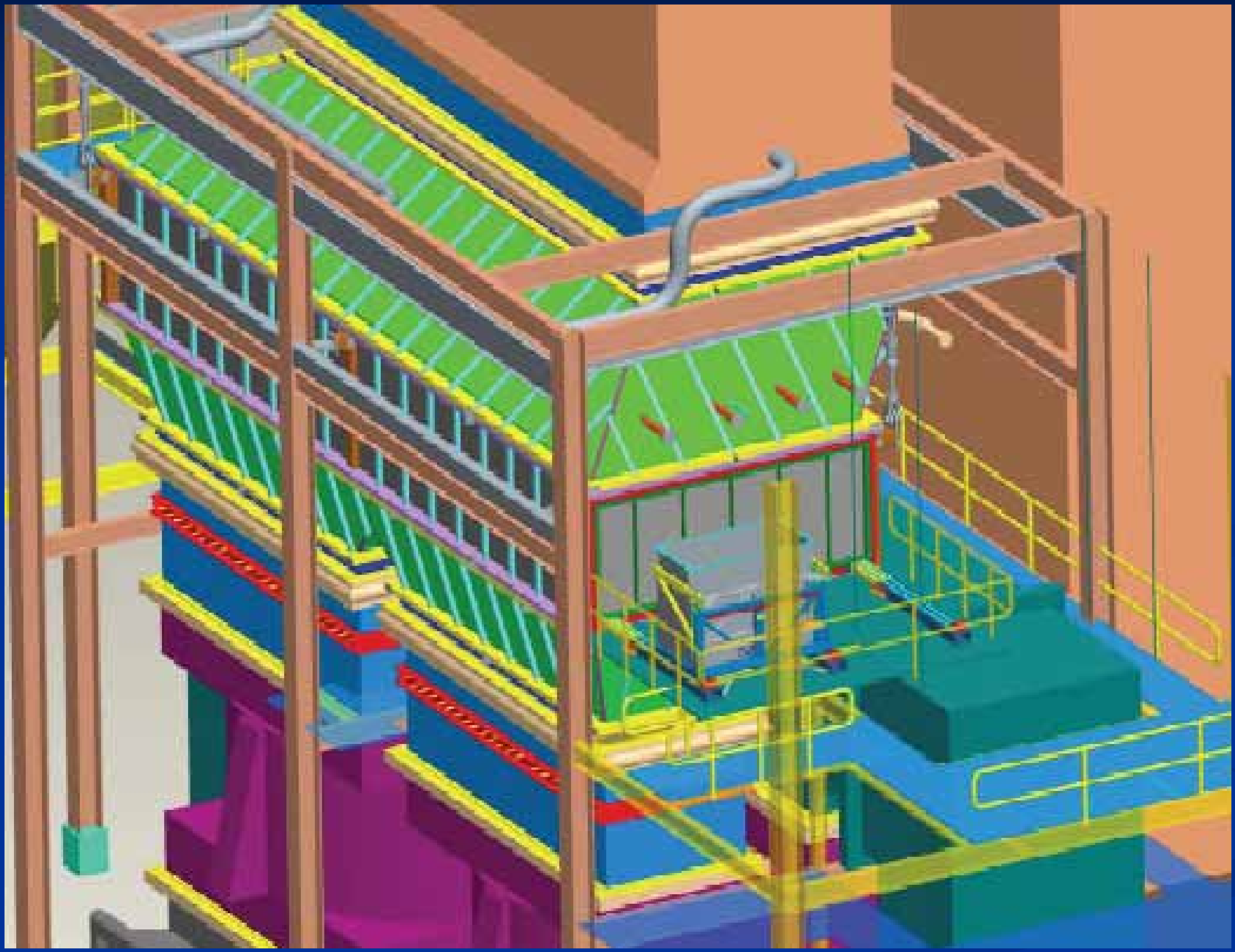


- Greenidge Design:
  - 2 Levels of Wall Injectors (Higher Temperature)
  - 2 Multiple Nozzle Lances in Convective Pass (Lower Temperature)

Delta Wing™ Static Mixers

- Homogeneous flue gas at catalyst face
  - NO_x / NH_3 mole ratio ± 5% RMS deviation
  - Velocity ± 12% RMS deviation
  - Temperature ± 30 ^oF
- Minimize NH_3 slip
- Maintain mixing at reduced load operation
- Maintain ash entrainment and distribution

Single-Bed, In-Duct SCR



Bed Depth

~ 1.3 m

$SO_2 \rightarrow SO_3$

< 1.0 %

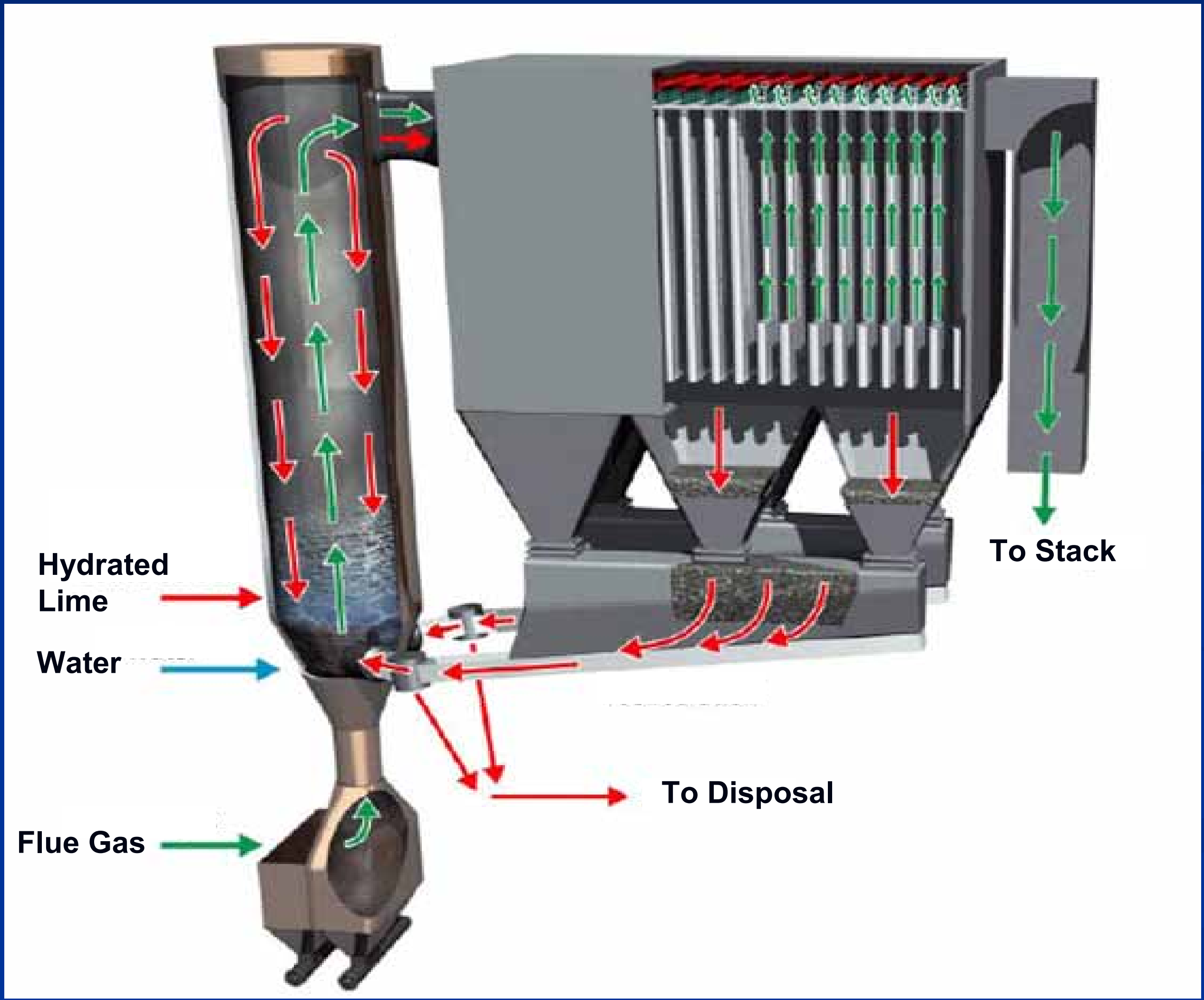
NH_3 Slip

< 2 ppmv

NO_x Removal

> 30%

Circulating Fluidized Bed Dry Scrubber Process Concept



- 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

Circulating Fluidized Bed Dry Scrubber Chemistry

$$Ca(OH)_2 + SO_2 \leftrightarrow CaSO_3 \cdot \tfrac{1}{2} H_2O + \tfrac{1}{2} H_2O$$

$$Ca(OH)_2 + SO_3 \leftrightarrow CaSO_4 \cdot \tfrac{1}{2} H_2O + \tfrac{1}{2} H_2O$$

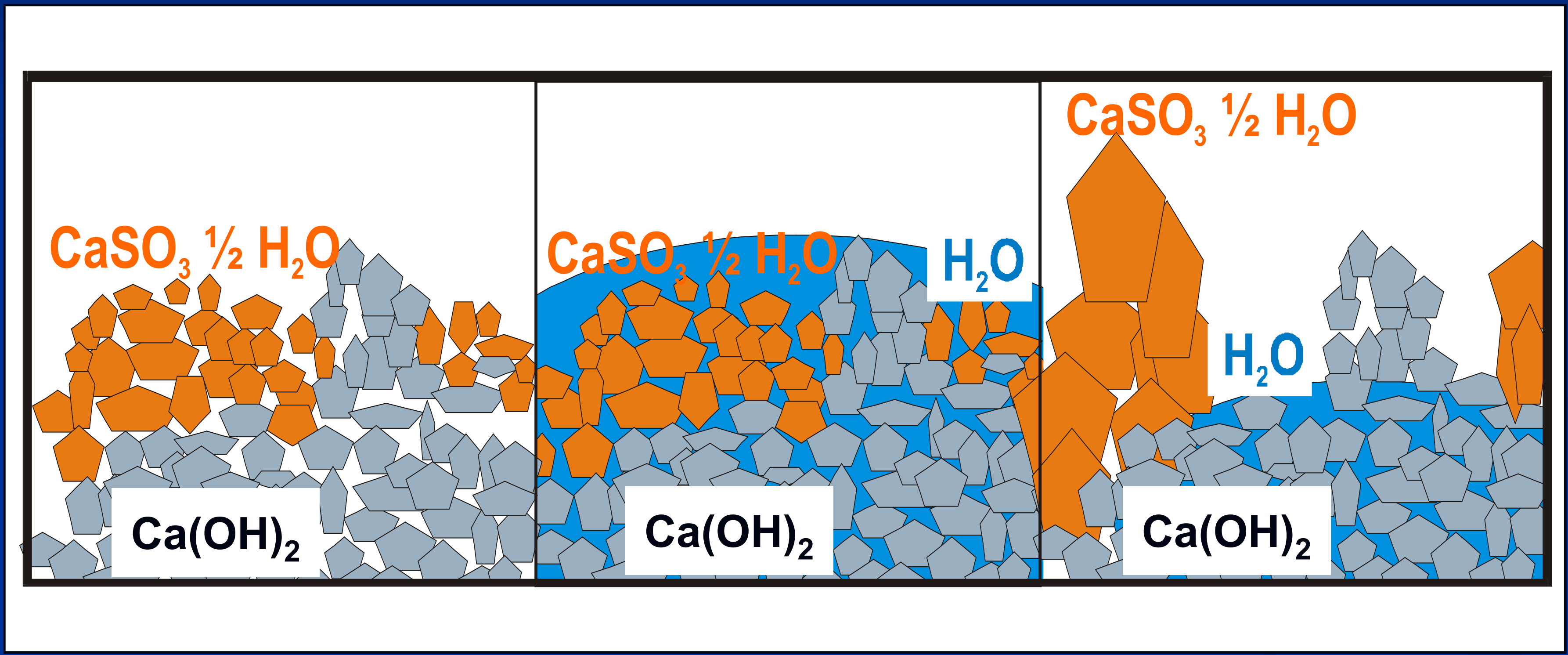
$$CaSO_3 \cdot \tfrac{1}{2} H_2O + \tfrac{1}{2} O_2 \leftrightarrow CaSO_4 \cdot \tfrac{1}{2} H_2O$$

$$Ca(OH)_2 + 2\,HCl \leftrightarrow CaCl_2 + 2\,H_2O$$

$$Ca(OH)_2 + 2\,HF \leftrightarrow CaF_2 + 2\,H_2O$$

$$Ca(OH)_2 + CO_2 \leftrightarrow CaCO_3 + H_2O$$

Reactivation of Recycled Reagent



Reaction after first pass

Water added to surface during recirculation

Sulfite crystal forms, exposing fresh surfaces

Turbosorp® System at AES Greenidge

- On-site lime hydration system
- 8-compartment pulse jet fabric filter
- Projected Ca/S of 1.5-1.6

Mercury Control

- Expect ≥ 90% removal with low carbon injection rate
  - Similarity to SCR / SDA / FF with bituminous coal
    - Field sampling shows 90% Hg removal often achieved with no ACI
  - Projected activated carbon requirement: 0 – 3.5 lb/MMacf
- SCR catalyst
  - Oxidize Hg^0 to Hg^{2+}
- Activated carbon injection
  - Adsorb Hg^0 and Hg^{2+}
- Circulating fluidized bed dry scrubber / baghouse
  - Reduce temperature (~ 170 ^oF)
  - Facilitate contact between Hg and carbon, fly ash, $Ca(OH)_2$
    - Filter caking
    - Recirculation = high sorbent residence time

Challenges / Uncertainties

- Performance with 2-4% sulfur eastern bituminous coal
  - Ammonium bisulfate formation / fouling
  - SO_2 capture and required Ca/S ratio
- Hg removal performance
  - Extent of Hg^0 oxidation at high space velocities in single-bed catalyst
  - Carbon injection requirements
- Control of integrated system, especially during load swings / cycling
  - Effect of NH_3 slip on unit operability
- Effect of biomass co-firing

Concluding Thoughts

- Innovative approach to multi-pollutant control that provides a low-capital-cost retrofit option for smaller coal-fired units
  - Emission reduction targets:
    (2-4% sulfur coal, up to 10% biomass)
    - NO_x to ≤ 0.10 lb/MMBtu
    - SO_2 and acid gases by > 95%
    - Hg by > 90%
    - Improved control of fine particulate matter
  - Capital cost: ~ $330/kW (delivered + erected) for 100 MW unit
  - Footprint: ~ 0.4 acres for 100 MW unit
  - Operational flexibility

- Actual performance data will be available soon
  - System fully operational by beginning of 2007
  - Initial performance results in early-to-mid 2007
  - Long-term performance results and actual operating costs in mid-2008