Reinhold Environmental Ltd.

2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

Activated Carbon Injection for Mercury Control

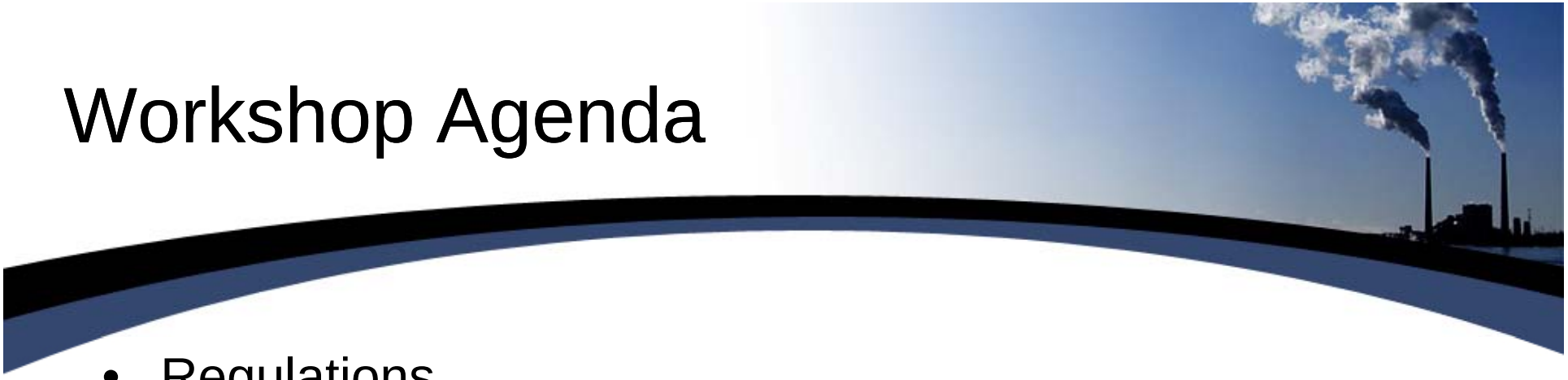
An Overview

Reinhold APC/PCUG 2009

NASDAQ:ADES

A Leader in Clean Coal Technology

Workshop Agenda



- Regulations
- Activated Carbon Basics
- Review of Results from Demonstrations
- Commercial Status
- Options to Reduce Costs
- Sorbent Supply
- Commercial Equipment
- Open Discussion

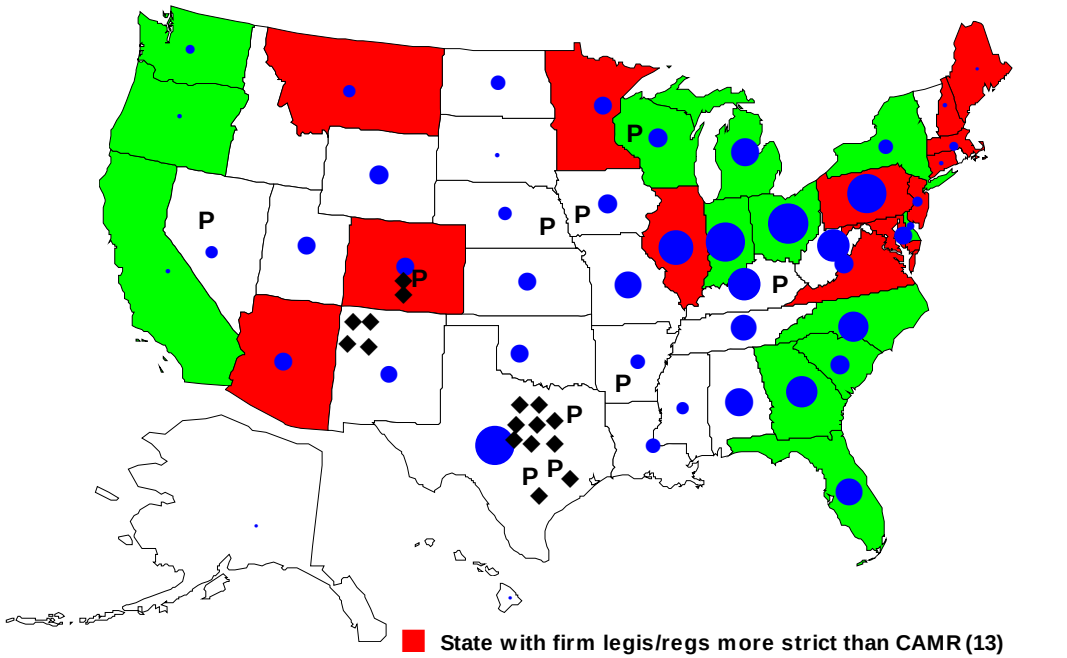
Drivers for Mercury Control

- ~~EPA Clean Air Mercury Rule~~
- State Rules
- New Power Plants
- Consent Decrees

State Mercury Rules

- In advance of federal legislation, 20 states and 4 Canadian provinces have already enacted mercury legislation requiring a significant reduction of mercury emissions.

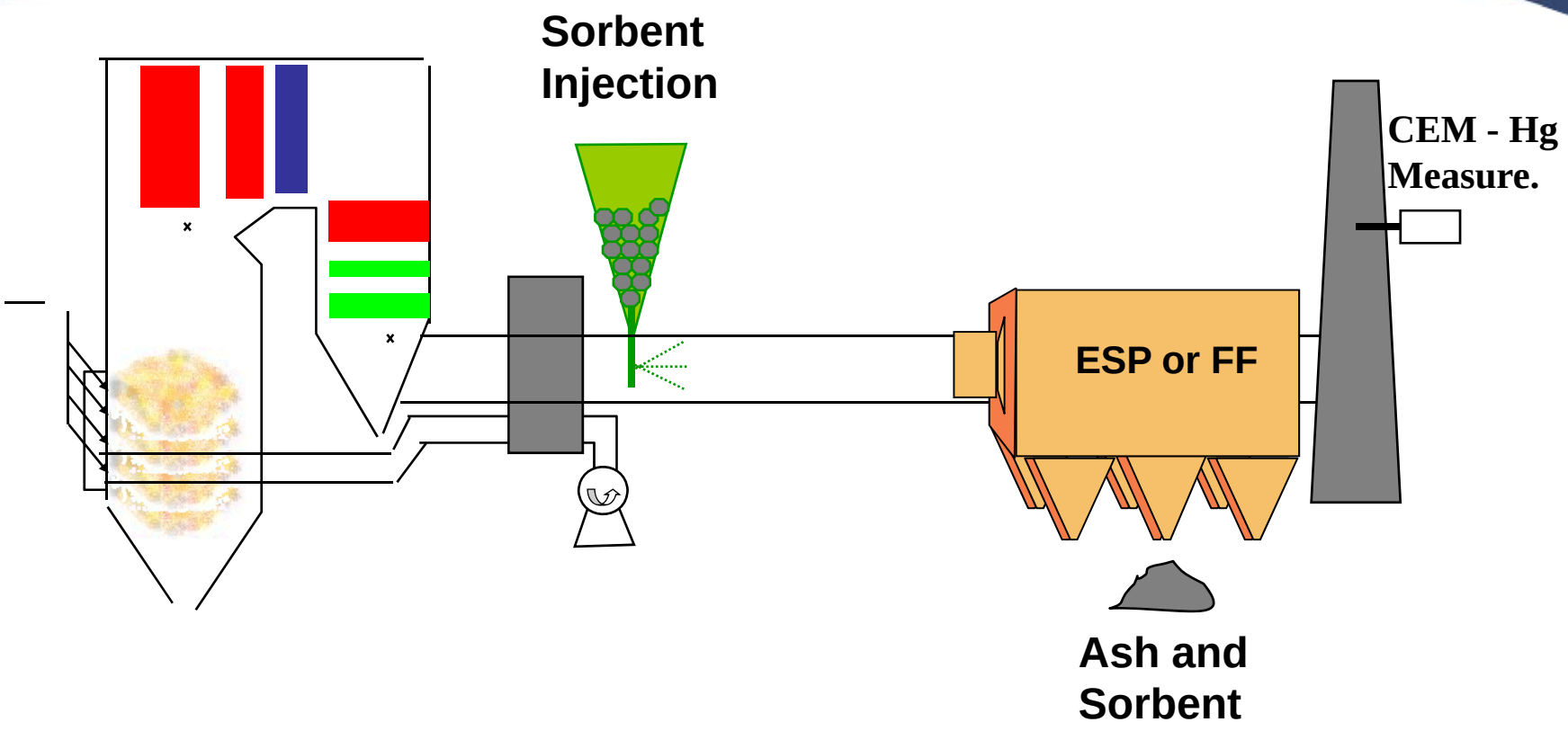
- Companies that are currently complying under consent decree of voluntary mandate



Primary Options Readily Available Today for Reducing Mercury Emissions

1. Co-Benefits
   - LNB, SCR, scrubbers, FF, etc.
   - Enhanced co-benefits
     - Chemical oxidants, catalysts
2. Sorbent Injection
   - Activated Carbon – standard and chemically enhanced

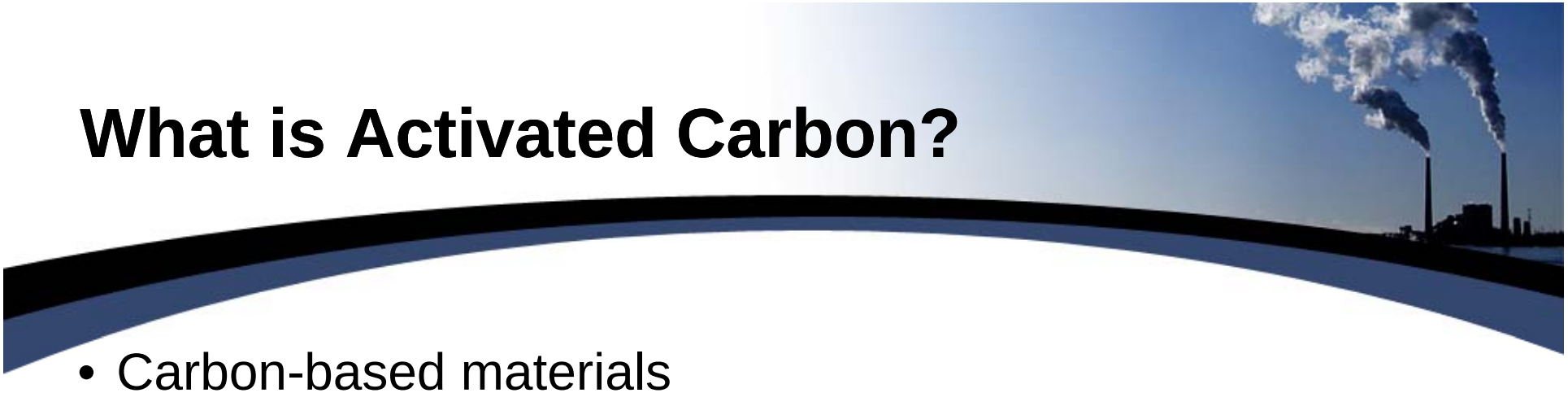
Activated Carbon Injection Technology for Controlling Mercury Emissions



ACI Configurations

- **ACI as primary mercury control**
  - Injection upstream of ESP (airheater inlet preferred)
  - Injection upstream of FF
  - Injection upstream of dry scrubbers (SDA, CDS)
  - TOXECON™ (injection between ESP and polishing FF)
- **ACI as supplementary or “trim” mercury control**
  - Injection upstream of ESP or FF followed by WFGD
  - TOXECON II™ followed by WFGD

What is Activated Carbon?



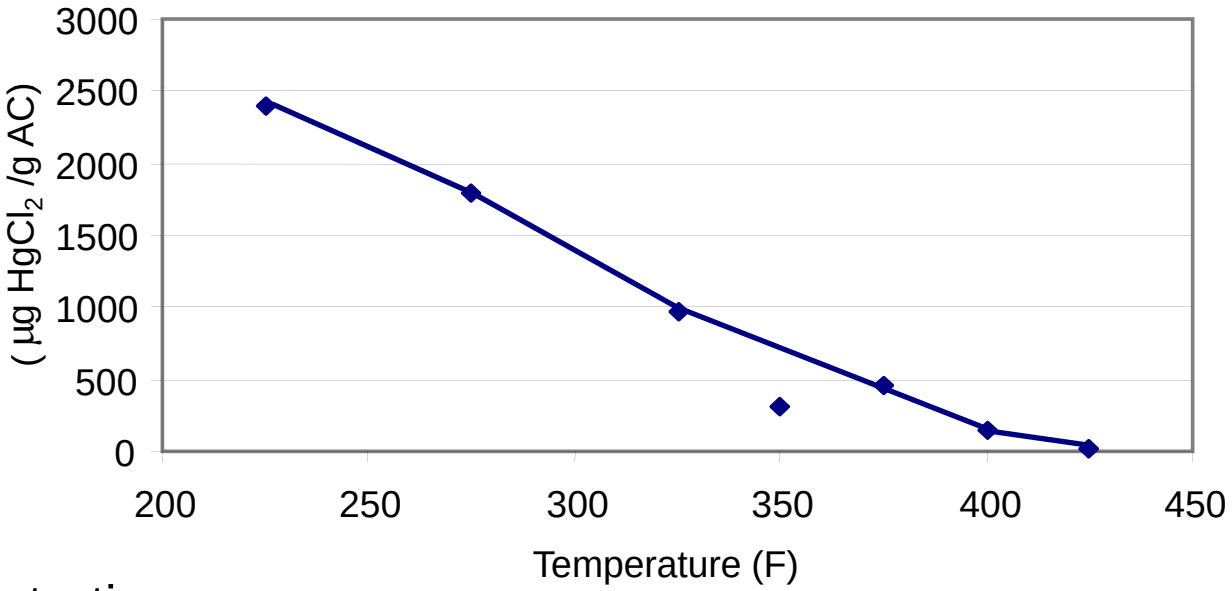
- Carbon-based materials
  - Lignite, coal, wood, coconut shells
- Treated with heat and steam
- A highly porous material
- Highly capable of adsorbing or entrapping contaminants out of a liquid or gas stream
- Can be treated with other chemicals to enhance performance

PAC Sorbents for Hg Control

- Most economic PAC derived from coal
- Ash fraction 4 to > 30%
  - Ash component can promote more effective Hg capture in flue gas
- Typical Particle Size is 17-20μ MMD
- Typical Surface Area is 400-700 m^2/gram
- Hg Adsorption capacities 300 – 5,000 μg/g
- Specialty PACs
  - Brominated for use in low halogen flue gas (low chlorine coals, dry scrubber applications)
  - Ash Compatible
- Commercially manufactured in several countries

What Affects Sorbent Capacity?

- Sorbent characteristics (surface area, capacity, reactivity)
- Temperature



- Mercury concentration
- Flue gas concentrations of SO_3 and other contaminants

Technology Development Approach

Phase I: Viability

Phase II: Pilot Testing (1 to 5 MW)

Phase III: Demonstration (> 30 MW)

Commercial Implementation

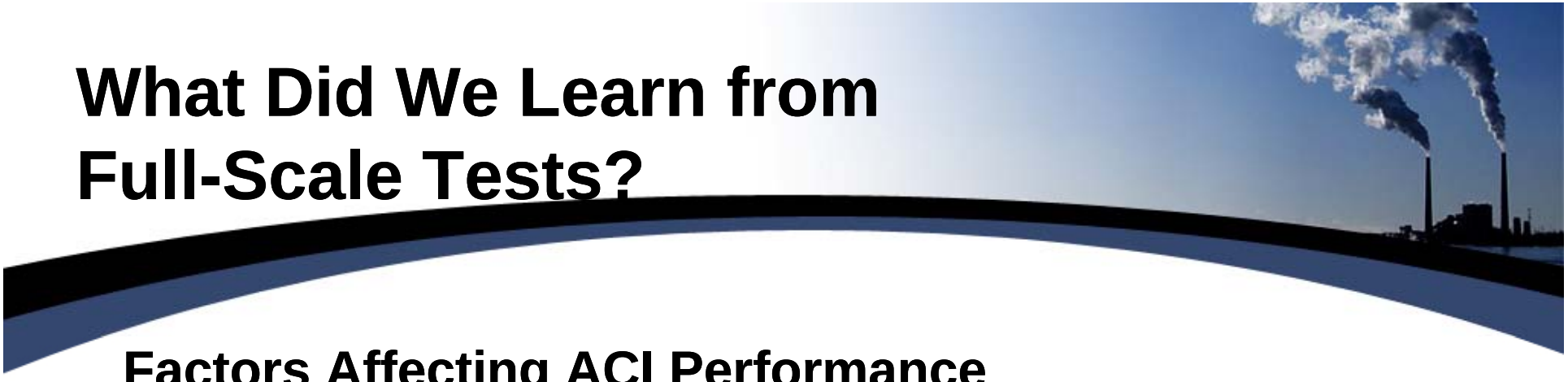
Engineering Services

Equipment

Sorbent

ADA has tested ACI at full-scale on more than 40 coal plants burning a variety of fuels

What Did We Learn from Full-Scale Tests?



Factors Affecting ACI Performance

- APC Configuration
  (ESP, FF, Wet Scrubber, SDA, LNB, SCR, SNCR)
- Coal Type
  - Halogen content (Cl, Br, other)
  - Sulfur content (SO_3)
- Acid Gases (SO_3)
- Flue Gas Temperature
- Injection Location
- ACI Design
  - Distribution
- Sorbent Type and Characteristics

ACI Development Milestones

Ash Compatible

Stanton 10
SDA FF
<u>Improved Performance</u>
Iodine-treated PAC

Bromine-Treated Sorbents

1991 **2001** **2002** **2006** **2007**

Alkaline-Treated Sorbents

Alkali/PAC Co-Injection

APH Inlet Injection

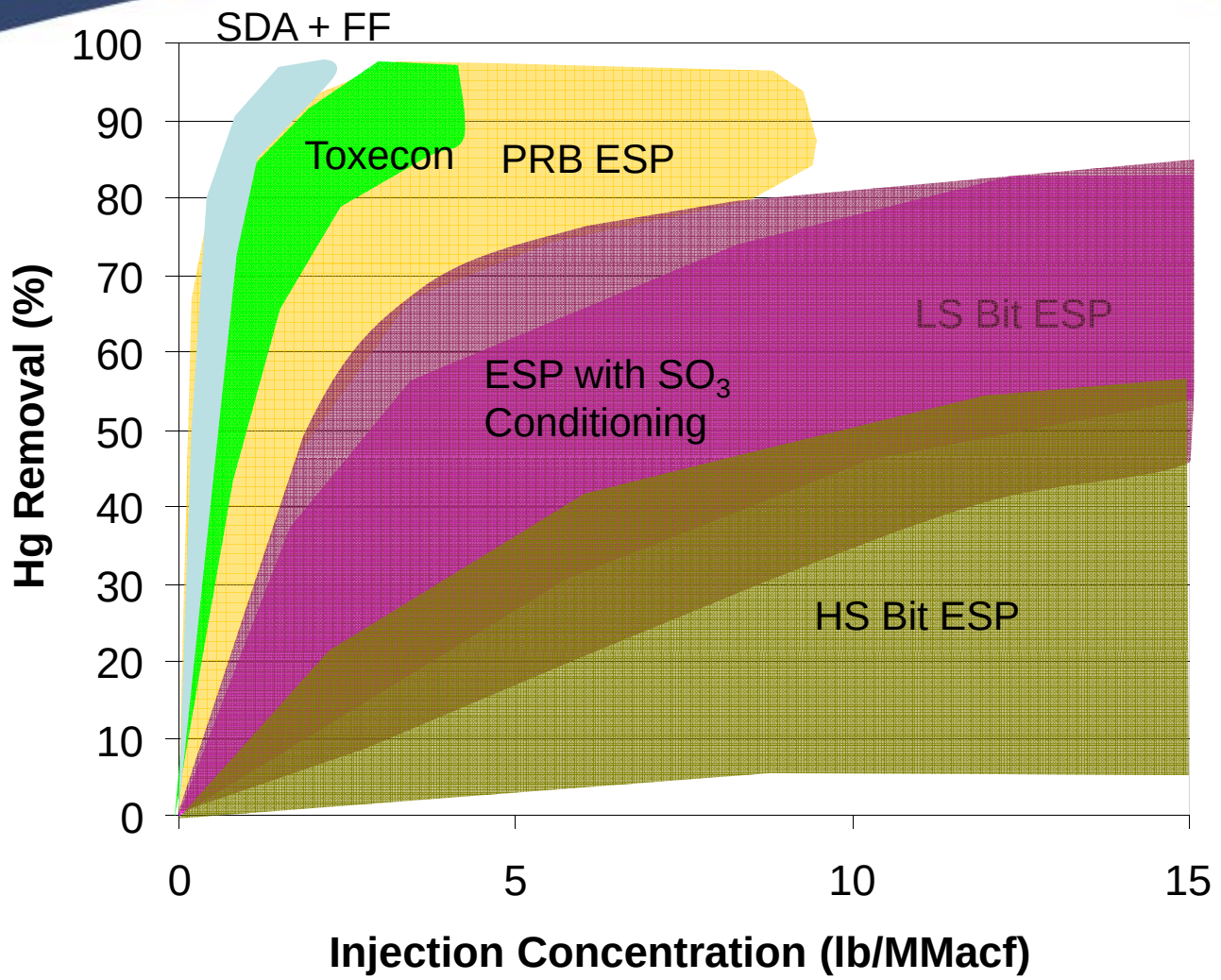
Comanche
Pilot testing
PRB FF
>90% Hg removal

Abbott
<15MW
H.S. Bit ESP
<50% Hg removal

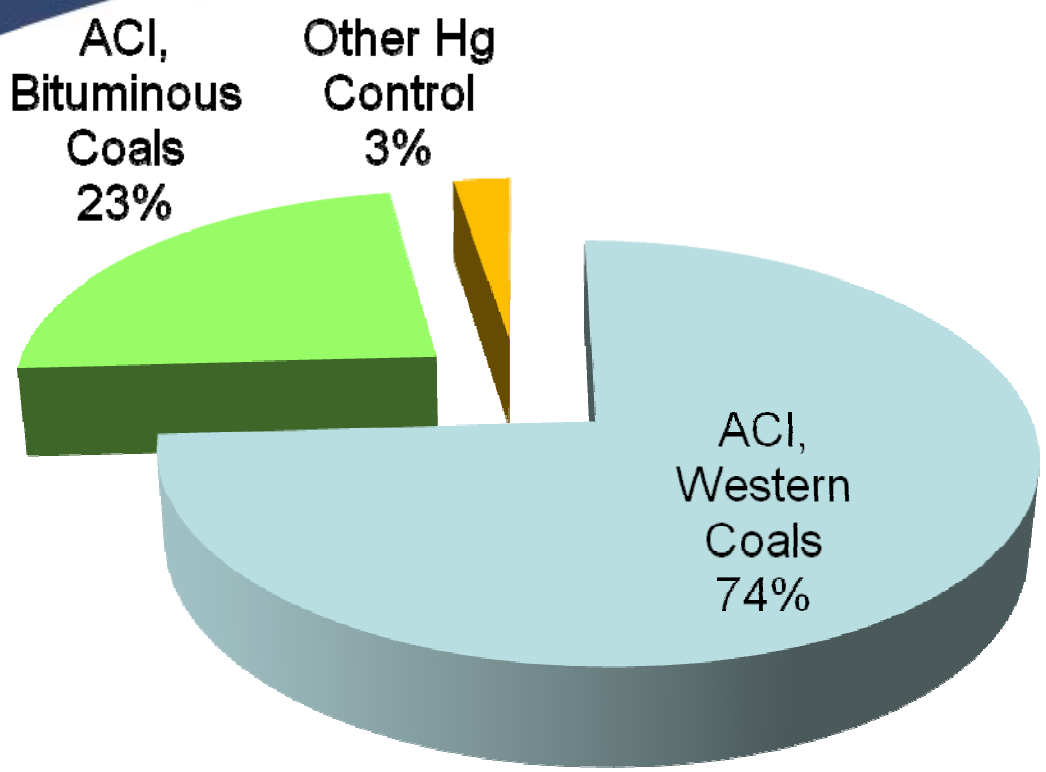
PPPP
PRB ESP
<u>Hg Removal Limited</u>
<70% Hg removal

Conesville
HS Bit ESP
<u>Hg Removal Limited</u>
<35% Hg removal

ACI: Summary of Results



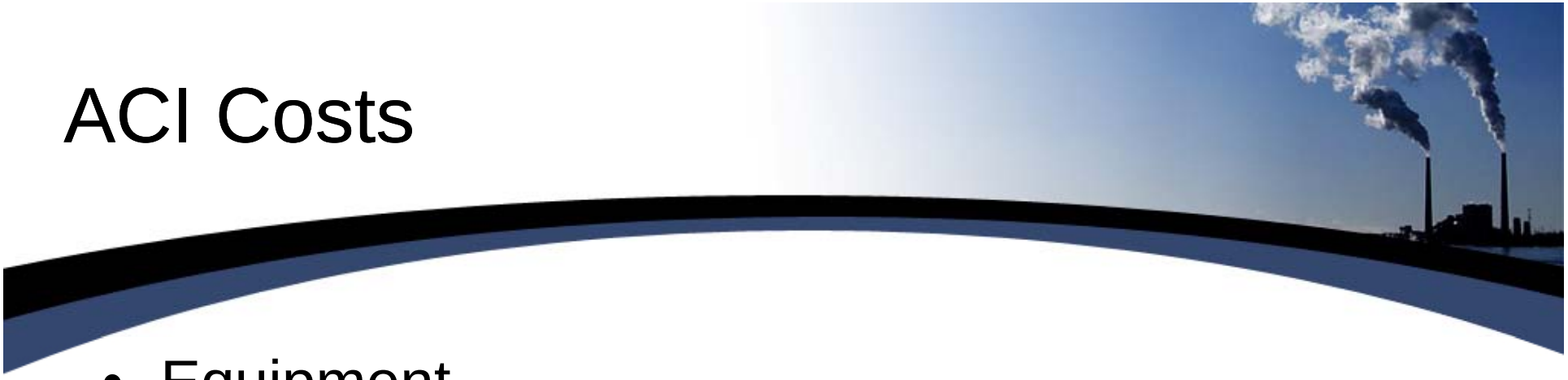
Commercial Mercury Control Status



Under Contract: 135 plants, >55 GW
~ 8 Equipment Suppliers

Institute of Clean Air Companies (ICAC), March 2009

ACI Costs



- Equipment
  - One time fixed cost plus O&M
  - CAPEX typically < $1M
- Sorbent
  - Variable and **primary cost component**

Designing for Optimized Performance

- Advanced Process Control
  - Feedback Control from CEMS
  - Fabric Filter Cleaning Optimization
- Optimize PAC Distribution

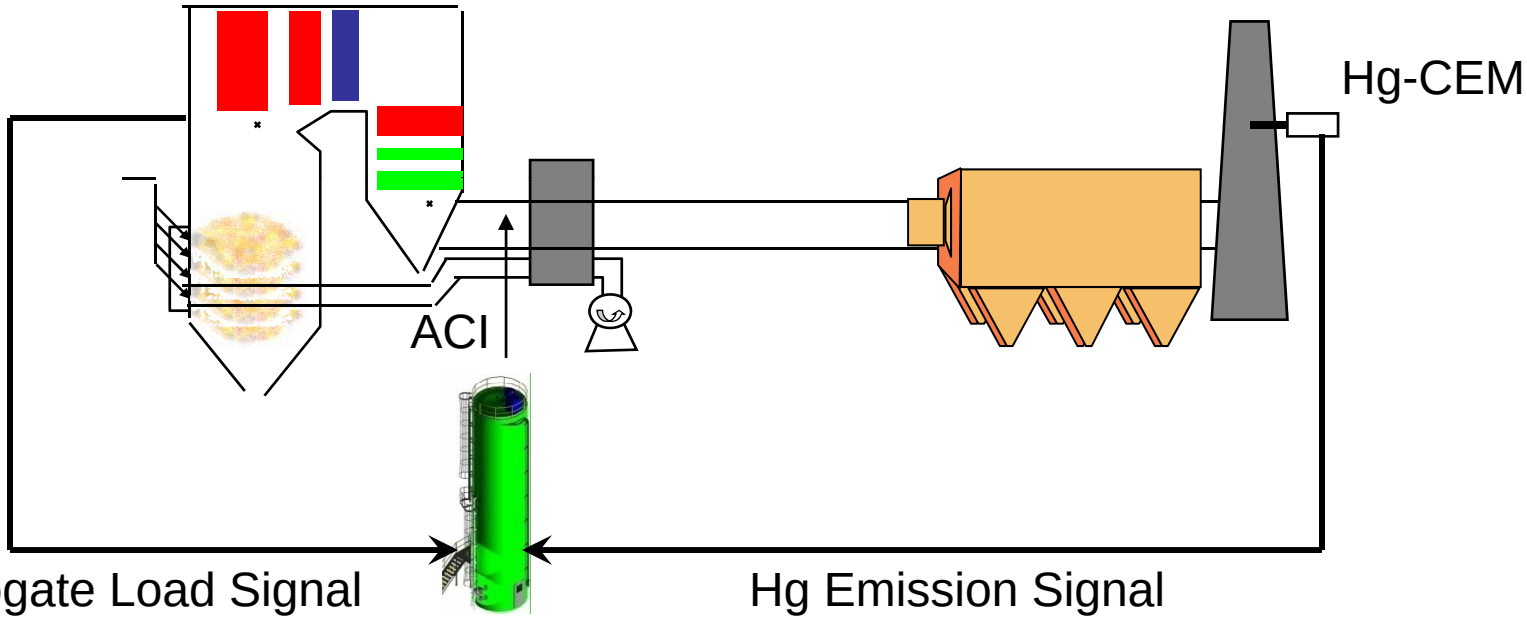
  Good distribution is critical for maximizing capture and minimizing sorbent requirements
- Air Preheater Inlet Injection

  Residence time is important for in-flight capture
- On-Site Milling

  Reducing the particle size can significantly improve effectiveness
- Eliminate Interferences

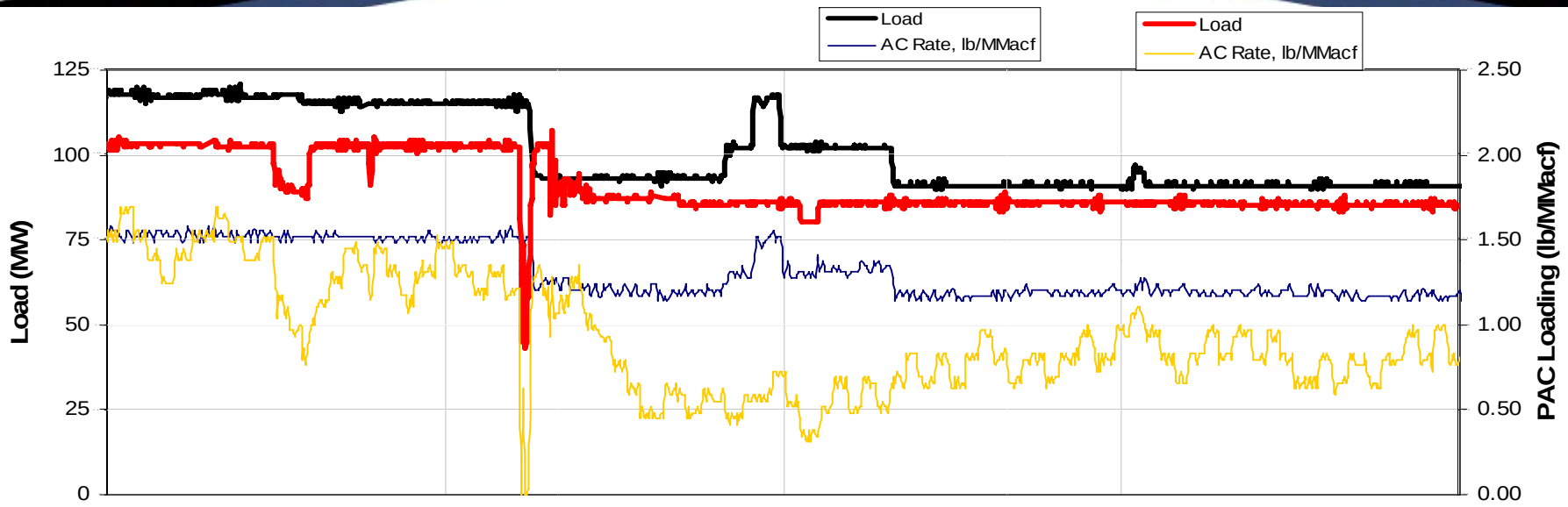
  The presence of SO_3 is detrimental to PAC performance

Feedback Control Logic from Hg CEMS



Cost-Effective Alternative to Gravimetric Feeders

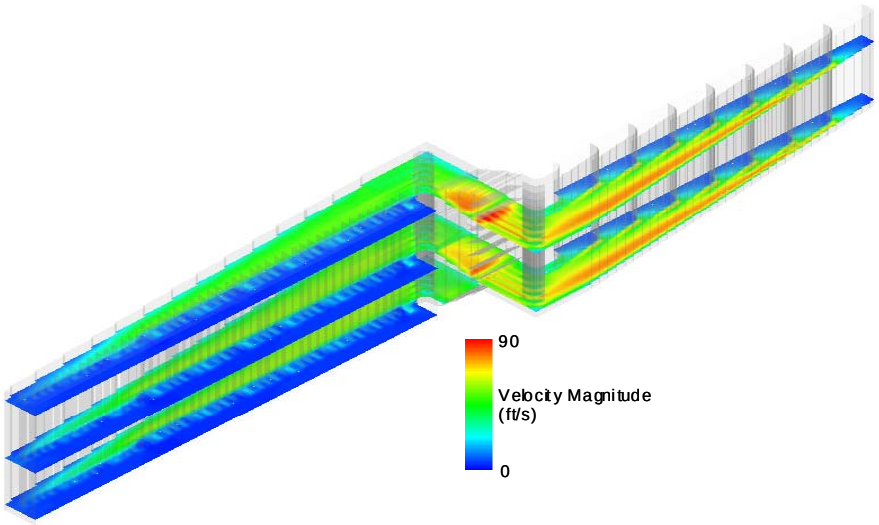
Control Scheme Options



- Standard Feedforward/Proportional Flow
- Targeting 90% Hg Capture
- Integrate Feedback from Hg CEM located in Stack
  - 45% Reduction in Sorbent Usage during low load
  - Adjust to Hg variability in coal
  - Real-time monitoring for sorbent quality

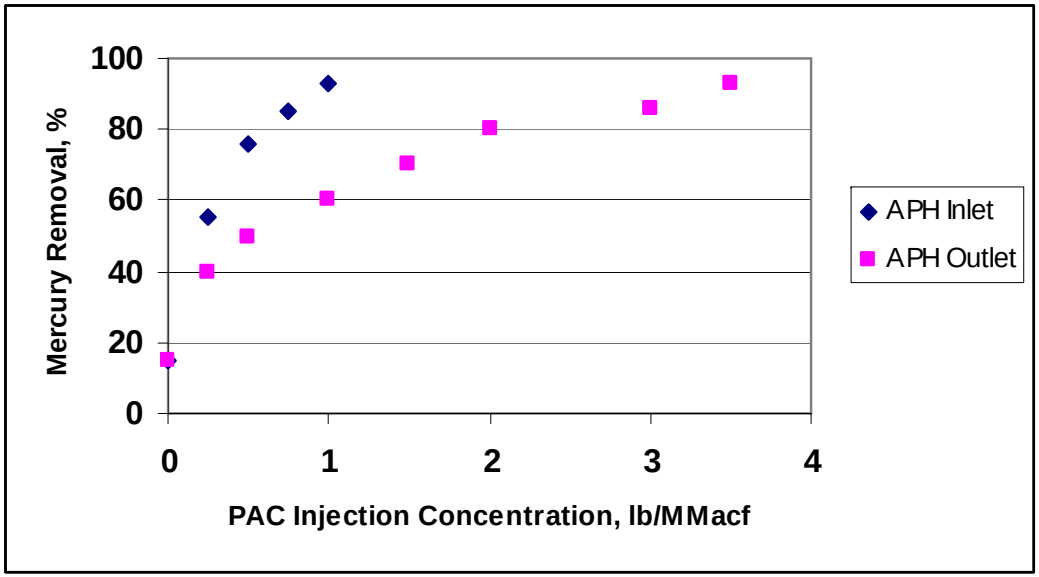
ACI Design: Lances

- Multiple open ended lances can perform as well as multi-nozzle lances *in most cases*
- Complicated lance designs can cause operational issues (e.g. plugging)



ACI Design: Injection Location

- Residence time is important for in-flight capture
  - Critical for an ESP where capture is mostly in-flight
  - Less critical for FF because most capture is on the bags
- Injecting upstream of the air preheater can improve residence time
- Duct transitions can improve distribution
- CFD Modeling can improve likelihood of good distribution (*modeling often conducted for commercial systems*)

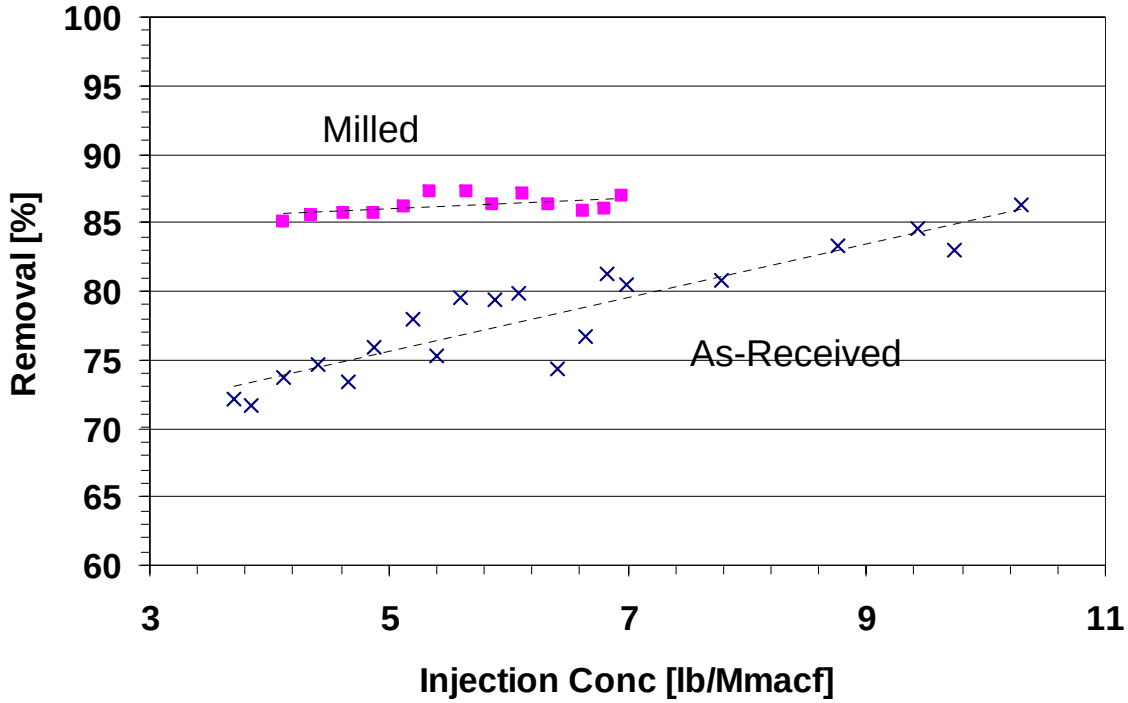


APH Inlet Injection – Questions

- Is it safe?
  - Most activated carbon has very low or no volatile content
  - Lab tests indicate no fire hazard at APH inlet temperatures and projected PAC injection concentrations
- Does material build up on the air preheater?
  - No evidence of increased APH pressure drop during short-term tests (extended tests scheduled)
- Are alternate lance materials required?
  - Standard stainless recommended for all installations
- What is the mercury removal performance improvement?
  - Promising results compared to APH outlet injection

Advanced ACI: Reduce Particle Size

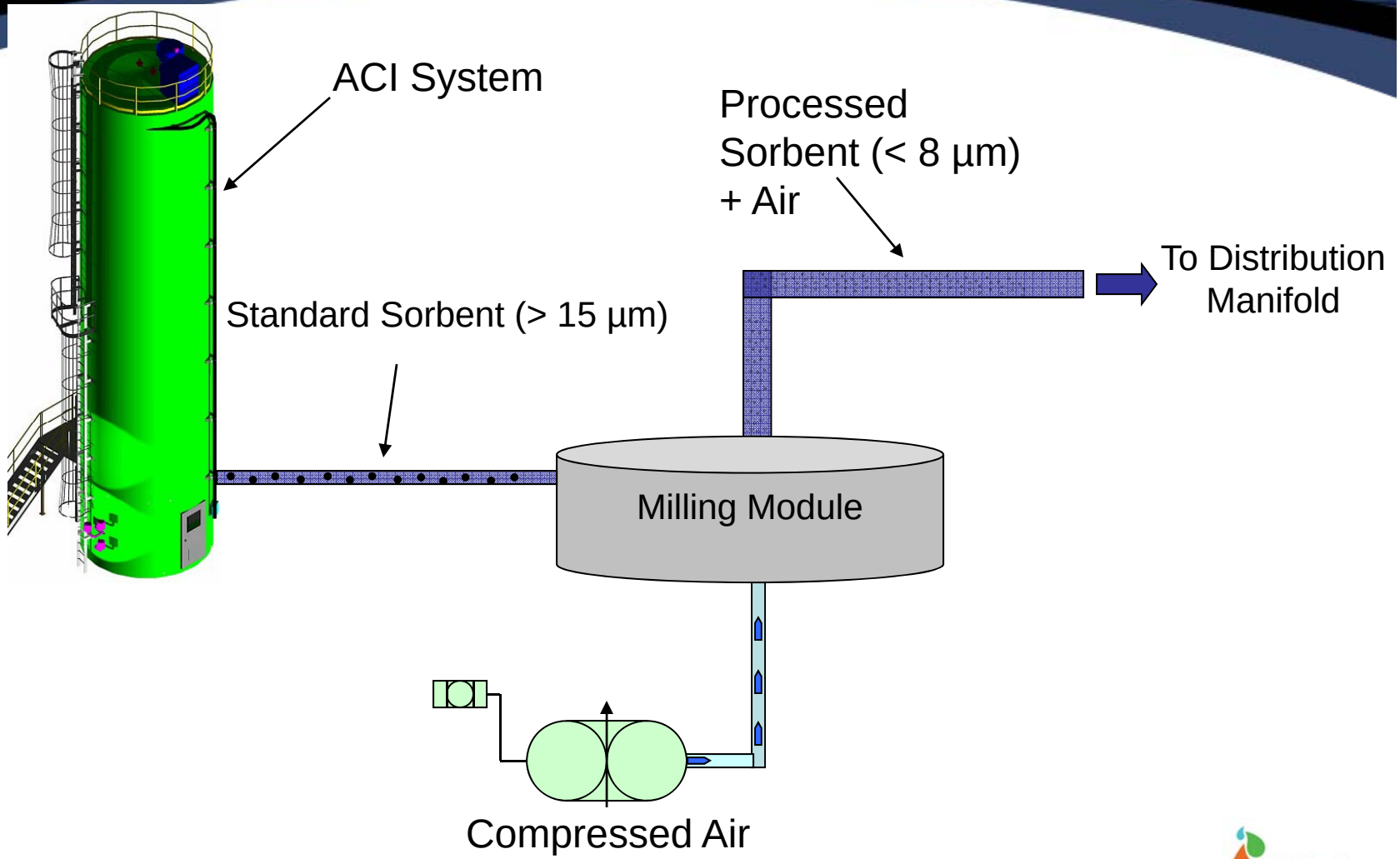
- More particles and surface area available for mercury removal. *Not as critical for fabric filter applications*
- Mill in-line to mitigate agglomeration



U.S. Patent 7361209

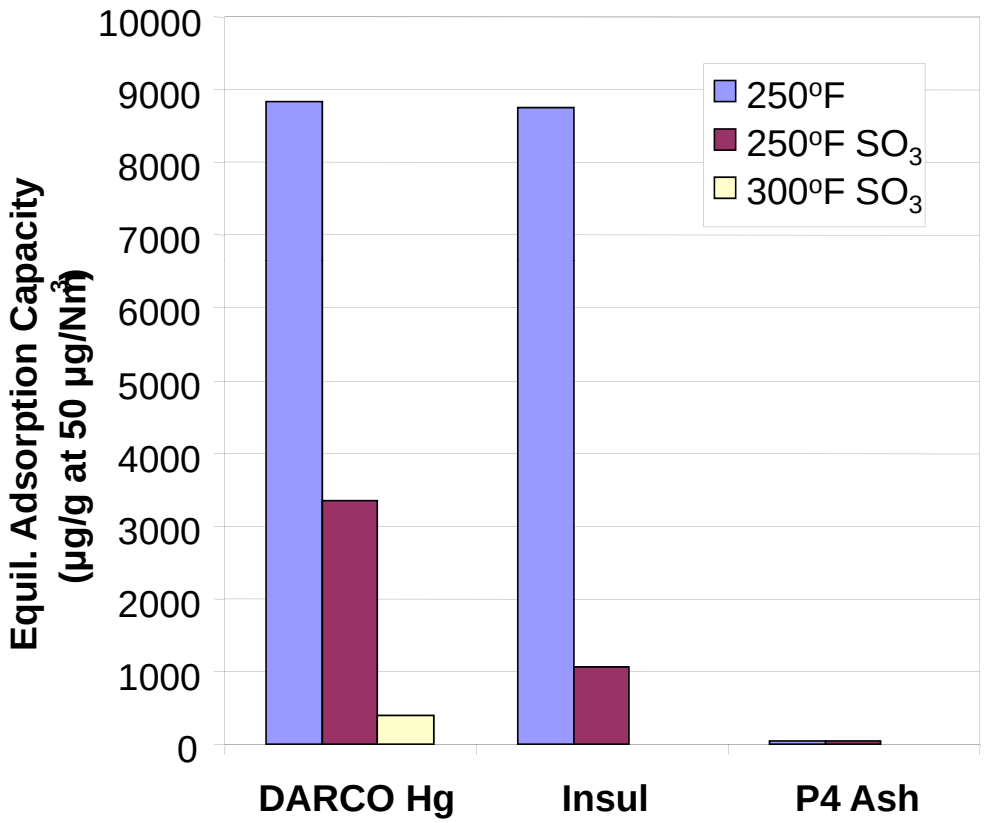
Labadie Data: DOE Cooperative Agreement DE-FC26-03NT41986 and EPRI

Advanced ACI Options: In-Line Milling



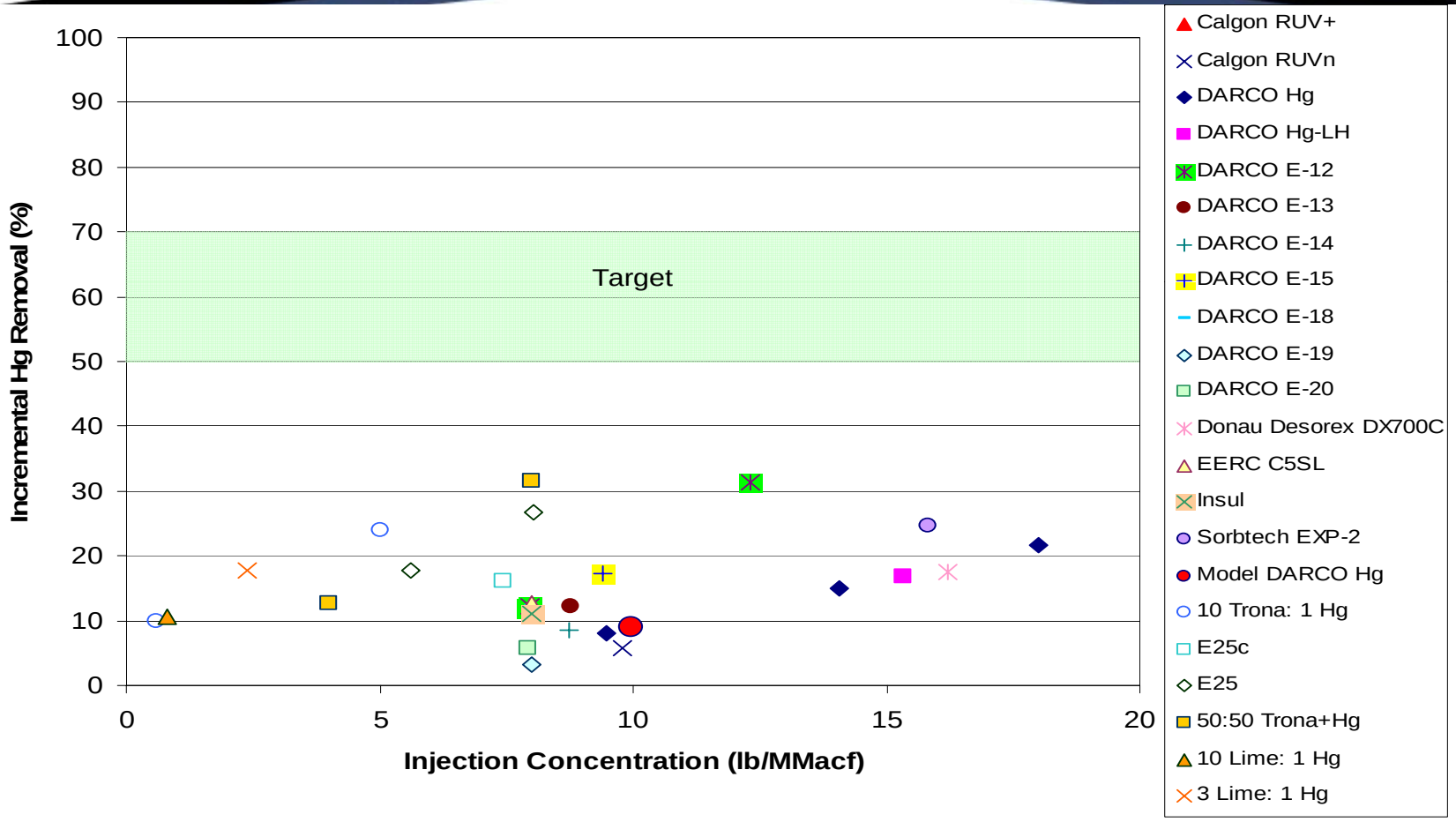
U.S. Patent 7361209, ADA-ES

Effect of SO_3 on Sorbent Capacity – Fixed-Bed Results



Equilibrium Adsorption Capacities Upstream and Downstream of SO_3 Injection for FGC

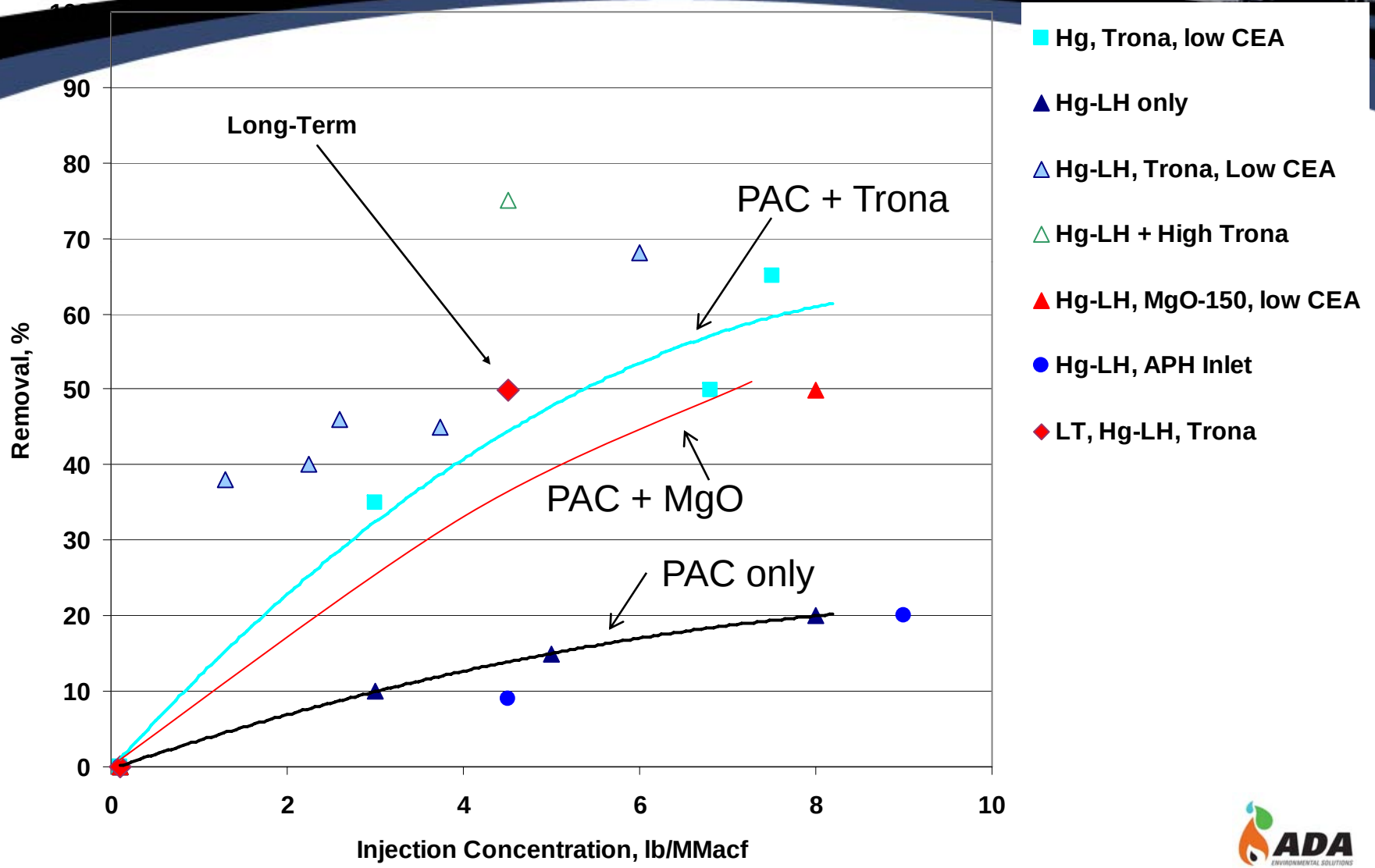
Impact of High Sulfur Coal



High Sulfur Coal

Conesville Data: DOE Cooperative Agreement DE-FC26-03NT41986

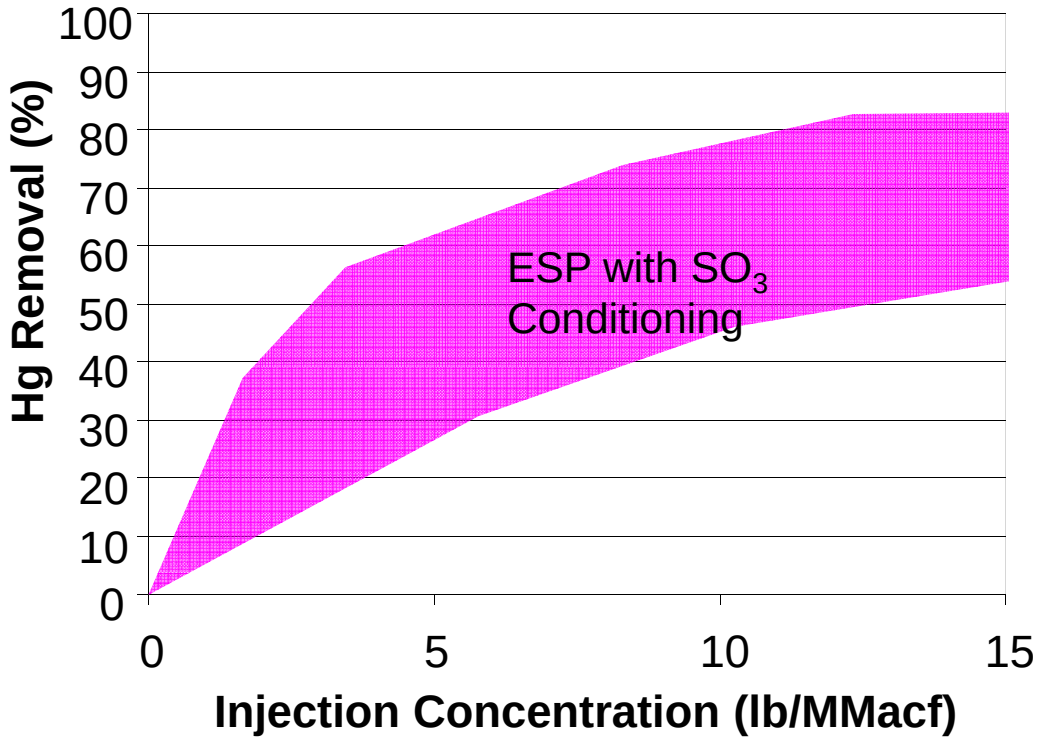
Improved Mercury Removal with Co-Injection of Trona and Magnesium Oxide Sorbents



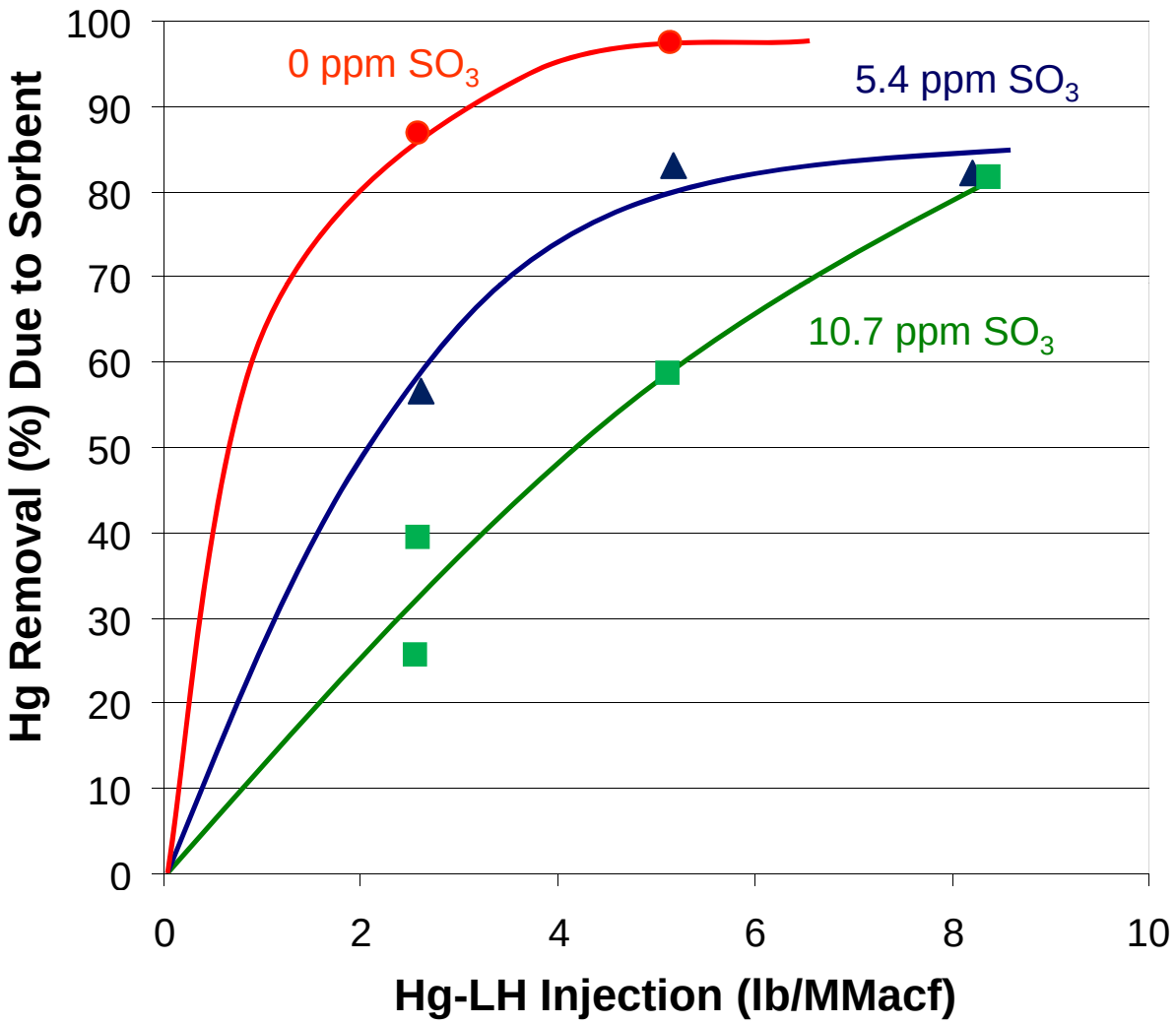
Merrimack Data: DOE Cooperative Agreement DE-FC26-06NT42780

Significance of SO_3 Injection

Approximately 25 GW of power is produced by units that fire PRB or low-sulfur bituminous coals and inject SO_3 to improve ESP performance.



Impact of Injected SO_3

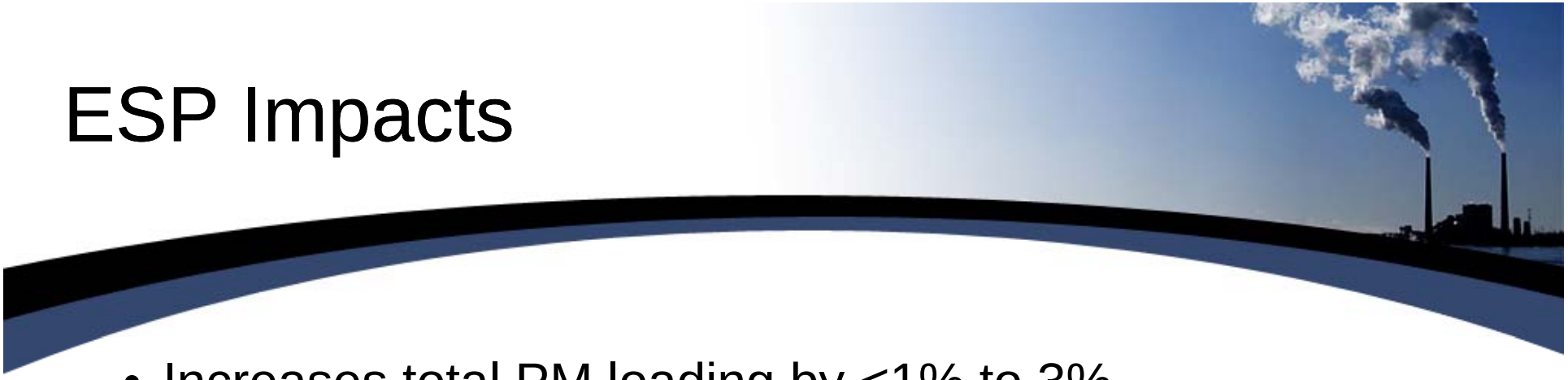


Labadie Data: DOE Cooperative Agreement DE-FC26-03NT41986 and EPRI

Balance of Plant Impacts

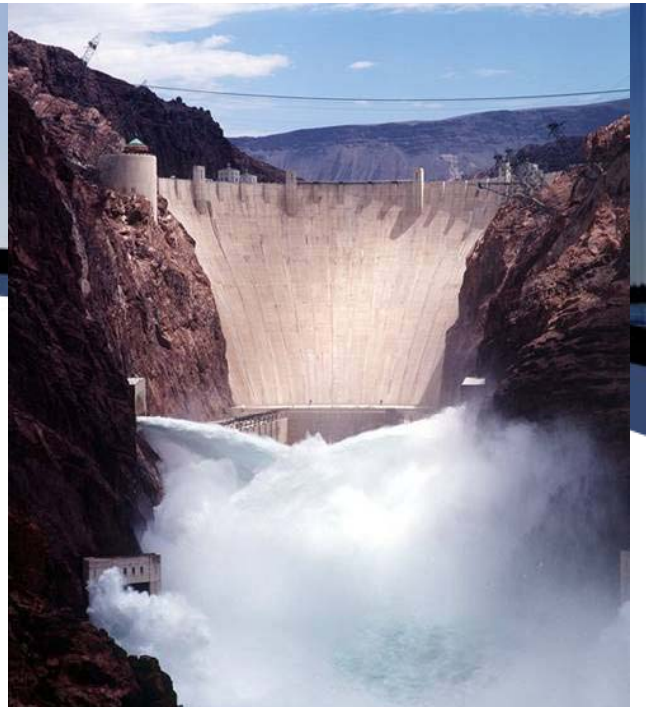
- Impacts to particulate control
- Impacts on ash
  - Mercury on PAC is stable
  - Flyash utilization
    - Ash-compatible sorbents
    - Flyash treatment
    - TOXECON
- Fate of halogens introduced into flue gas
  - Stack or with ash, leachable?
- Fire & Explosion Risks

ESP Impacts



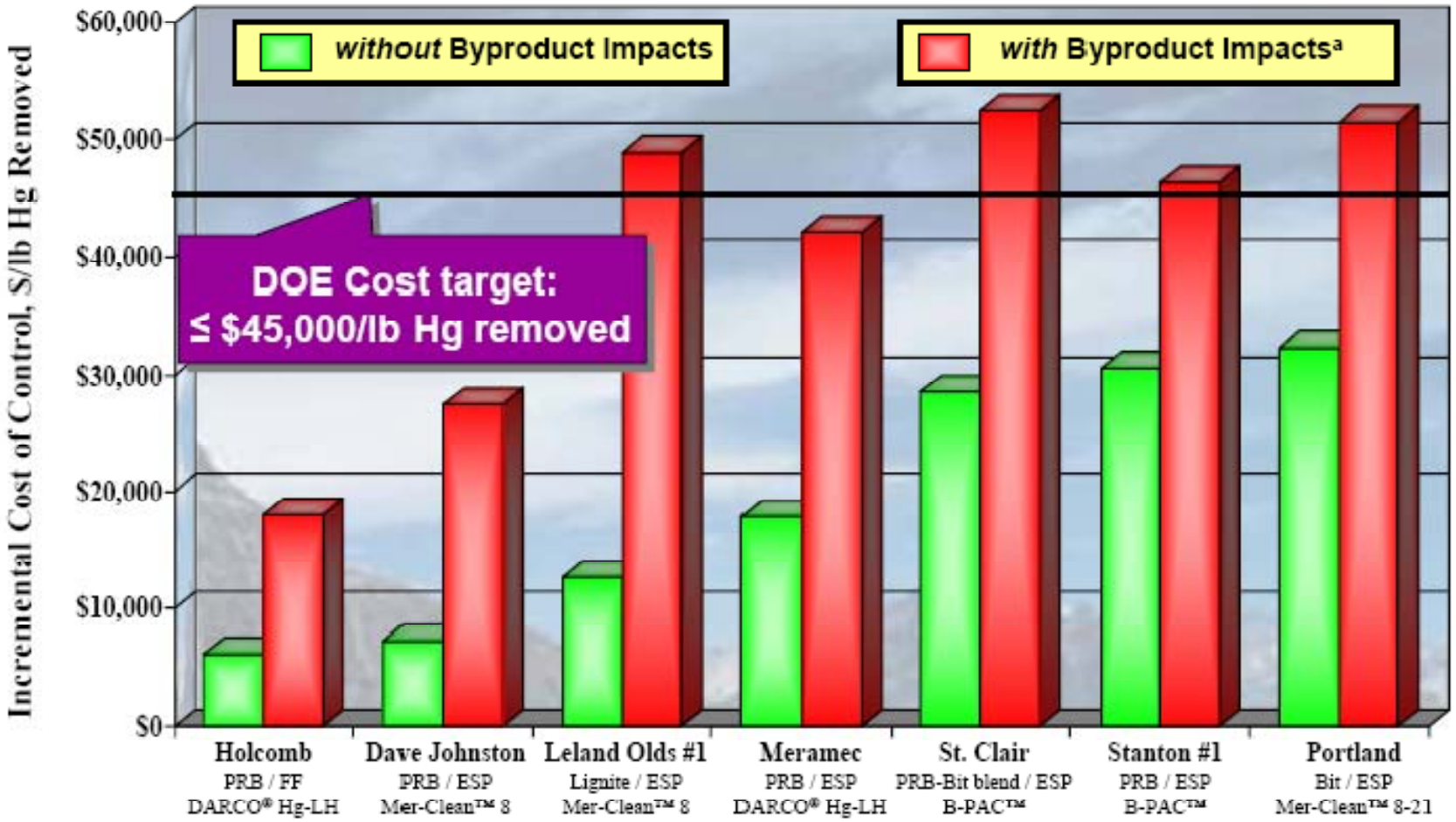
- Increases total PM loading by <1% to 3% (worst case: high injection rate on PRB)
- Minimal impact observed on ESPs in full-scale applications and demonstrations
- Little or no increases in opacity or PM emissions where applied to date

Fly Ash Sales and PAC



- In 2006, over 72 million tons of fly ash were produced in the US
  - 21% was used in concrete, concrete products, and grout
- Activated carbon can absorb the organic air-entraining additives (AEA) required to improve freeze/thaw durability of concrete
- Fly ash land filling costs are significant
  - can become **one of the largest operating costs for plants after labor and fuel**

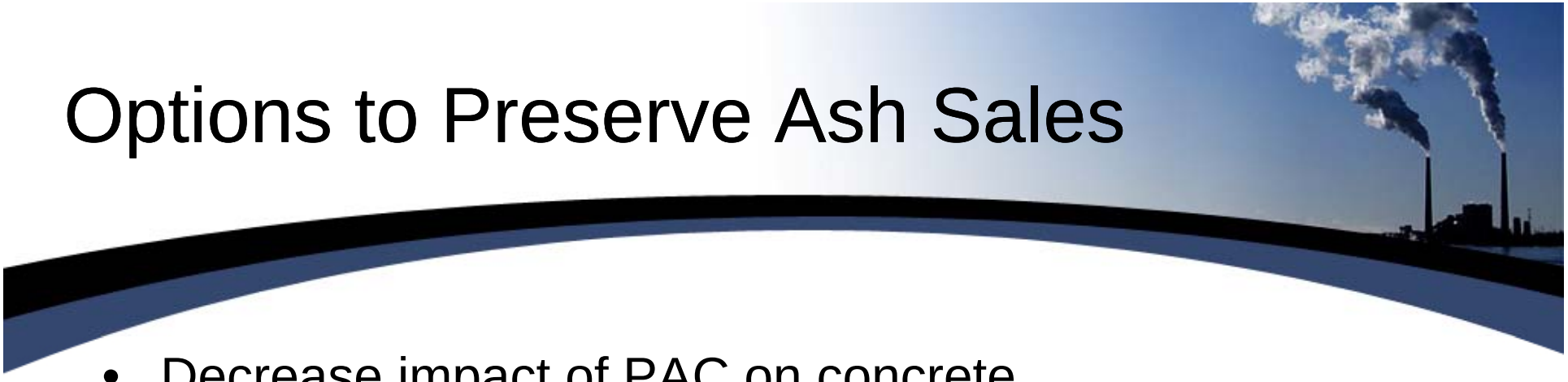
Incremental Cost of 90% ACI Mercury Control



[a] For units equipped with an ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton), assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal ($17/ton) is included.

Source: DOE/NETL's UPDATED Economic Analysis of Activated Carbon Injection, May 2007
http://www.netl.doe.gov/technologies/coalpower/ewr/mercury/pubs/Phase_II_UPDATED_Hg_Control_Economic_Analysis.pdf

Options to Preserve Ash Sales



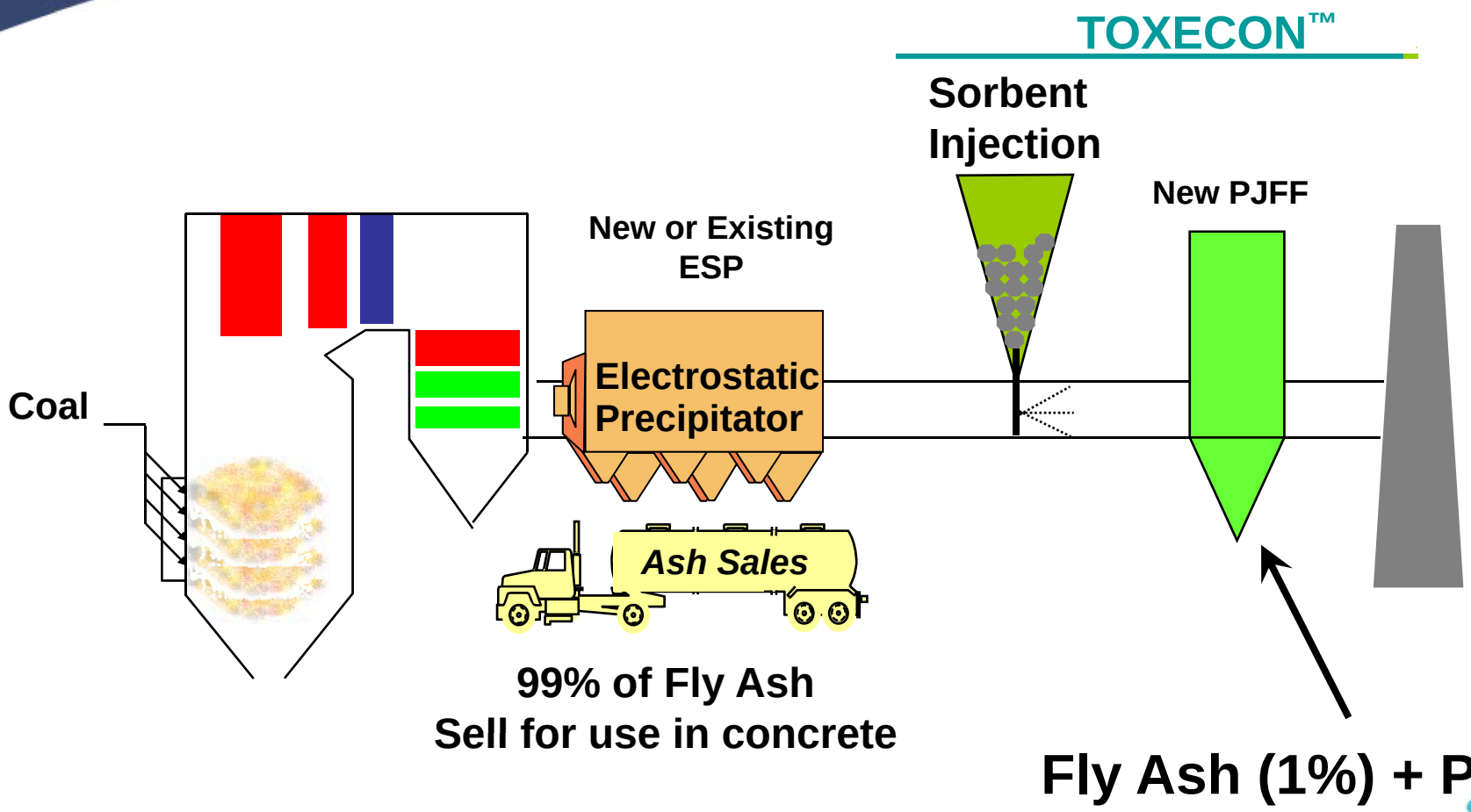
- Decrease impact of PAC on concrete
  - Improve effectiveness of PAC
  - Replace air entraining agents used for concrete
  - Ash Compatible Carbon (ACC)

    Foam Index Specification
    Specialized Air Retention Testing

    Strength and Freeze/Thaw Tests

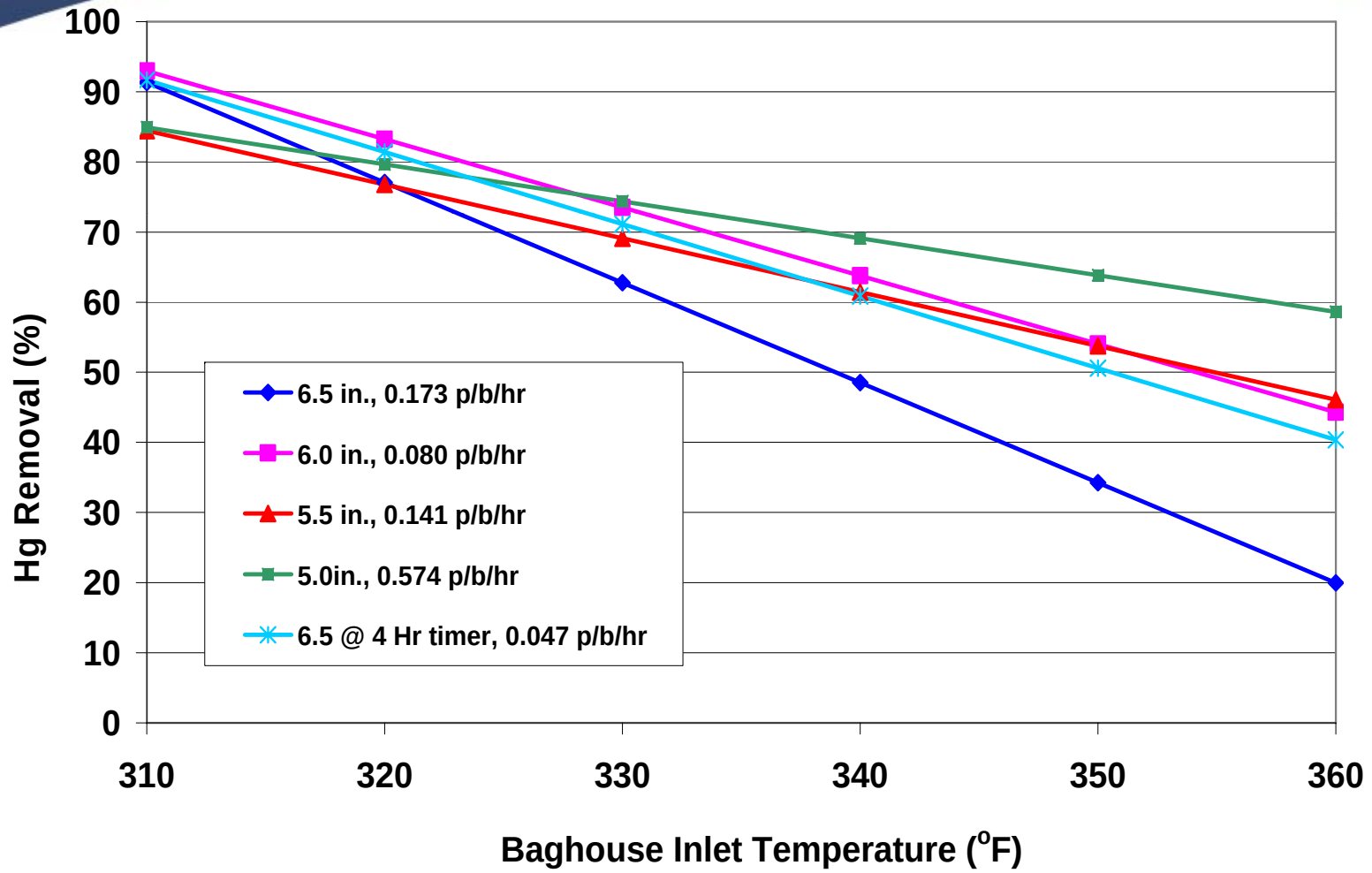
    Color Specification
- Separate PAC from ash
  - TOXECON™
  - TOXECON II™

Typical TOXECON™ Configuration

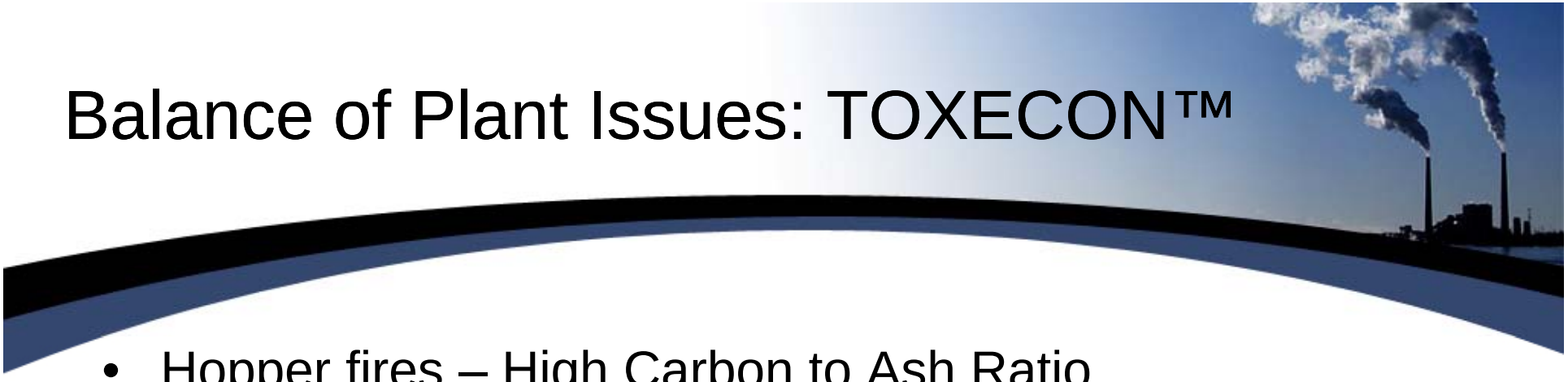


ADA ACI System at We Energies Presque Isle (270MW) TOXECON™

Effect of Cleaning Frequency and Temperature



Balance of Plant Issues: TOXECON™

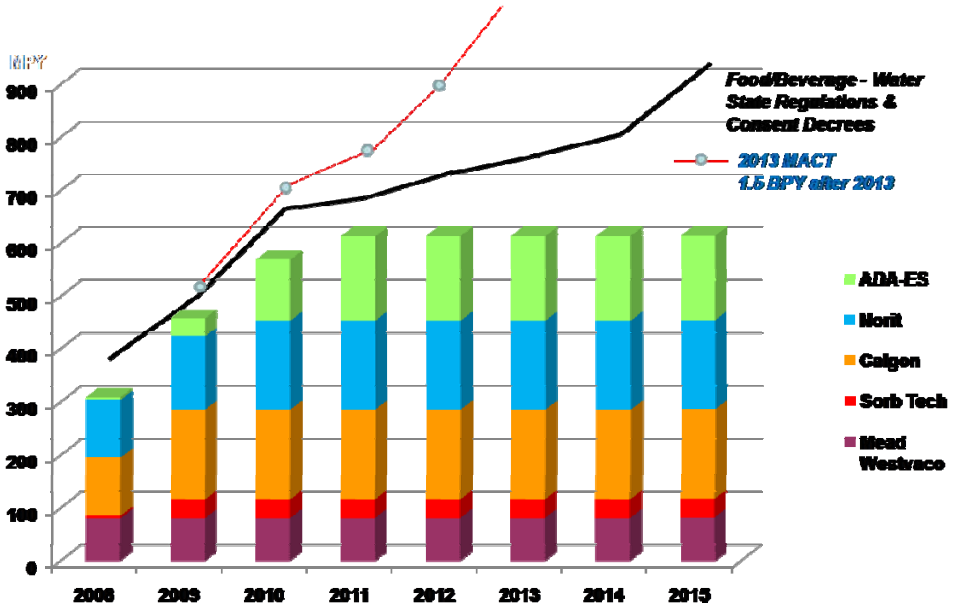


- Hopper fires – High Carbon to Ash Ratio
  - Hopper fires when hopper heaters were too hot
  - Can be operationally controlled
    - Frequent Hopper Evacuations
    - Careful application and operation of hopper heaters
- Ash handling
  - Ash/PAC mix (high fraction of PAC) can become “sticky”

Activated Carbon Near-Term Supply Capacity

- New AC production plants are necessary for emerging mercury control market
  - Total gap in 2010 could be 300-400 mpy
- Existing suppliers have announced plans to expand production by 225+ mpy by 2010

PAC Sorbent Supply and Demand



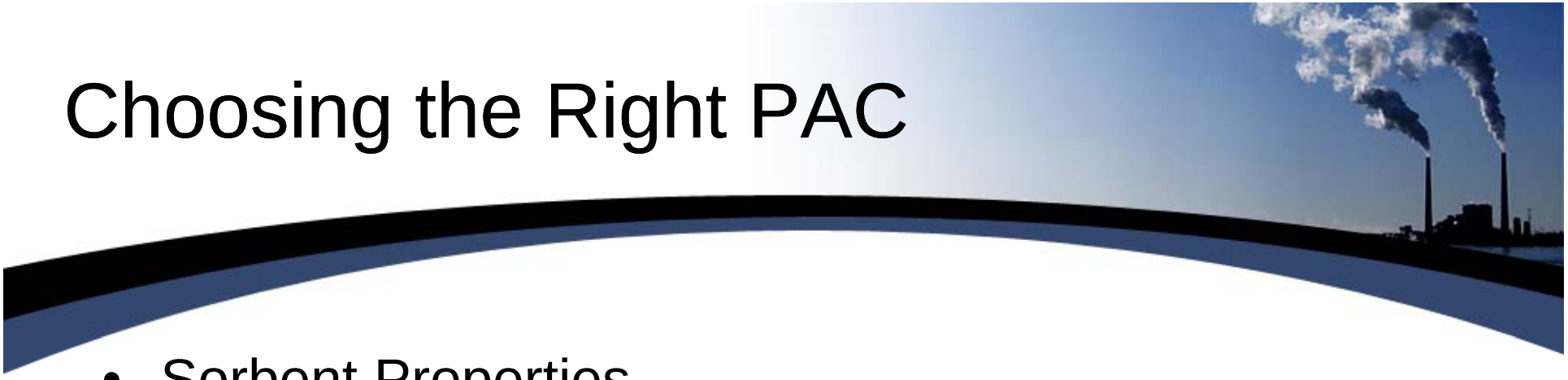
ADA-ES New Activated Carbon Production

- **Building largest AC plant(s) to date**
- **Each line will produce ~150 mm lbs/yr**
- **Capital cost: ~$360 mm**
- **On schedule to startup in Red River, LA mid-2010**

Potential for Up to Six Production Lines

Permitting near lignite mines in LA and ND to

Choosing the Right PAC



- Sorbent Properties
  - Bulk Density
  - Iodine Number
  - Surface area
  - Chemical addition, etc.

Mercury Removal

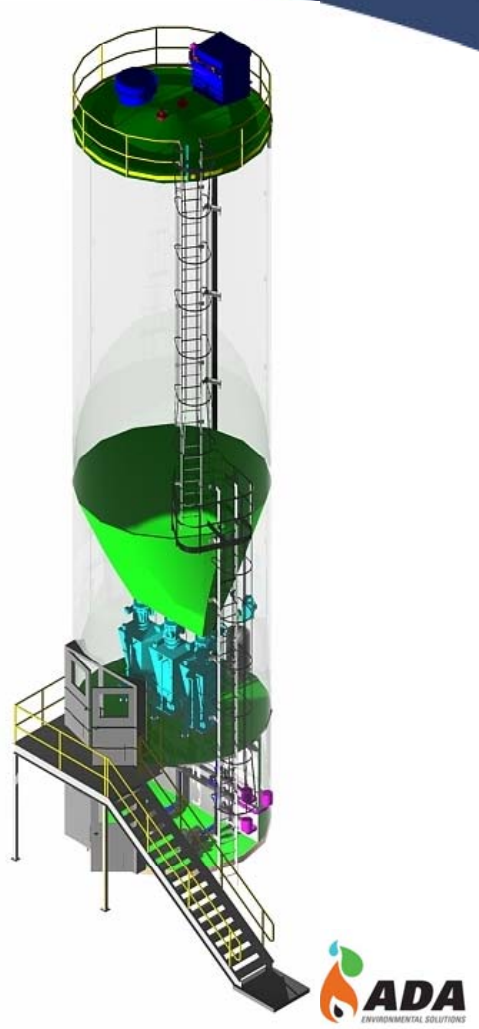
- Balance of Plant / ACI Equipment Performance
  - Abrasion
  - Corrosivity
- Performance Screening
  - Site-specific Sorbent Screening

Commercial ACI Systems

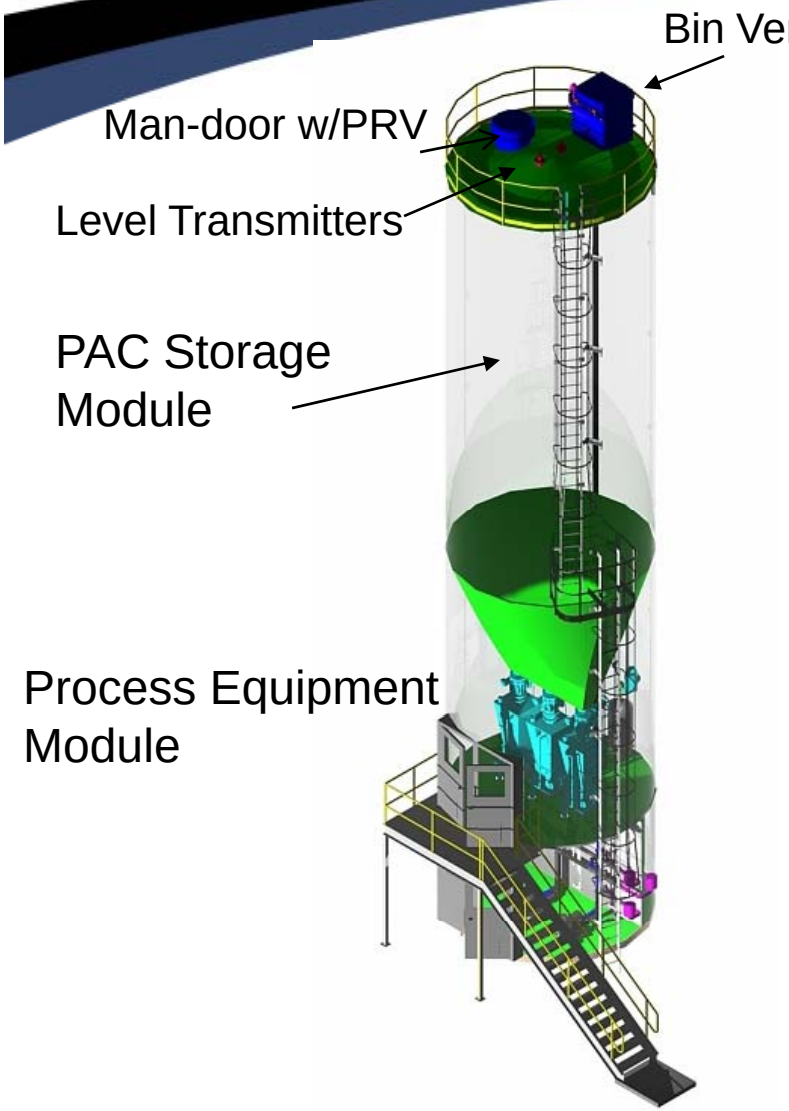
Activated Carbon Injection (ACI) Systems

Typical ACI System

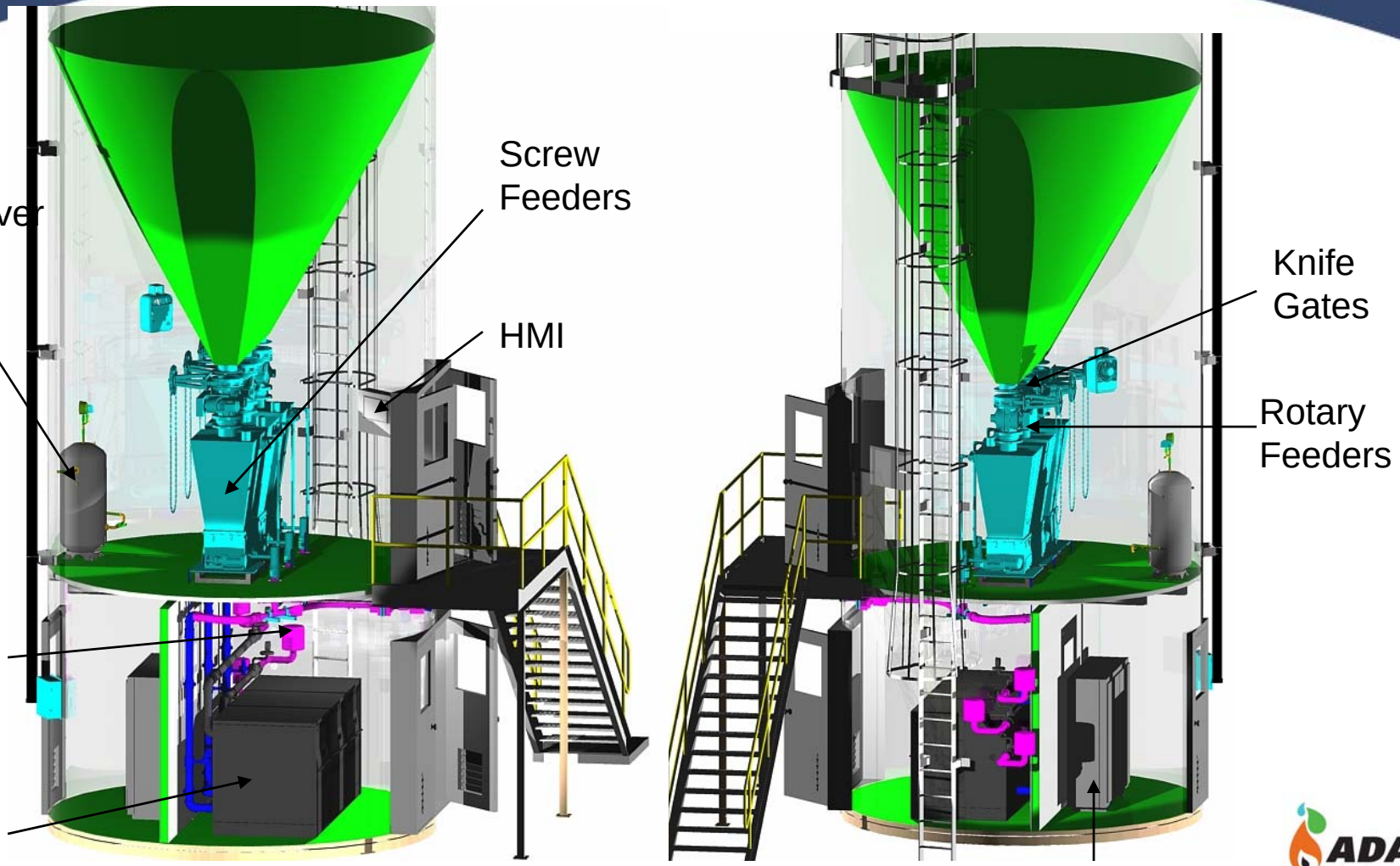
- Sorbent delivered in pneumatic trucks or rail cars
- Silo(s) with up to three product take-offs
  - 2 x 100% or 3 x 50% feed trains for spare capacity
- Dilute-phase pneumatic conveying
- Distribution manifolds
- Injection lances



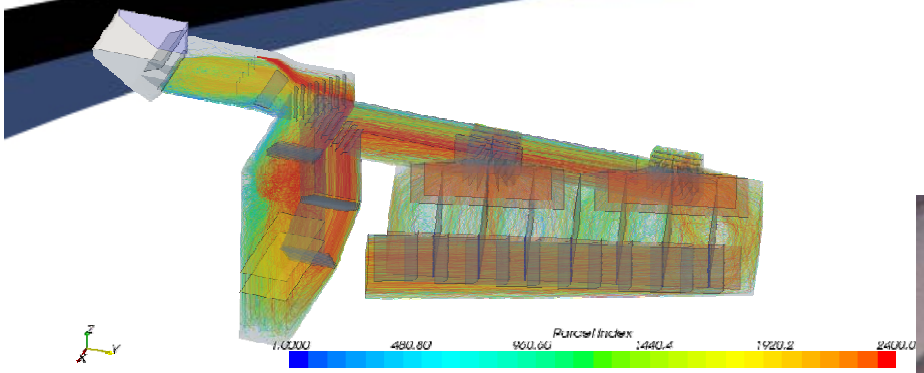
ADA Standard ACI System



Process Equipment Module

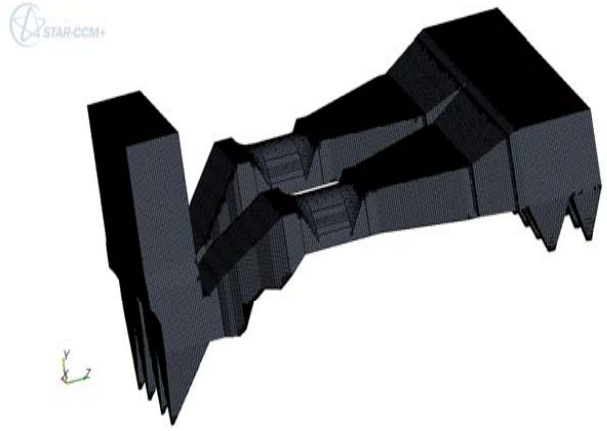


PAC Distribution

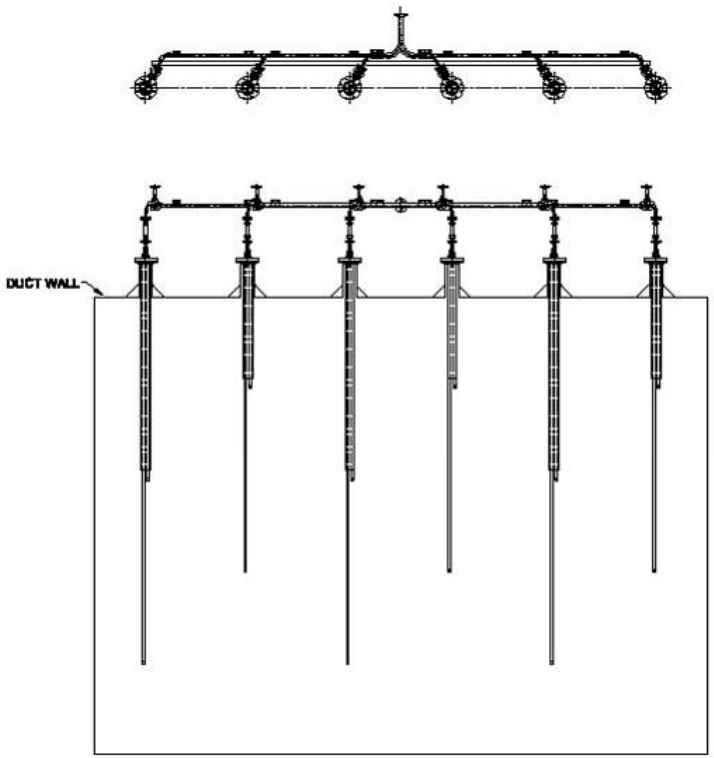


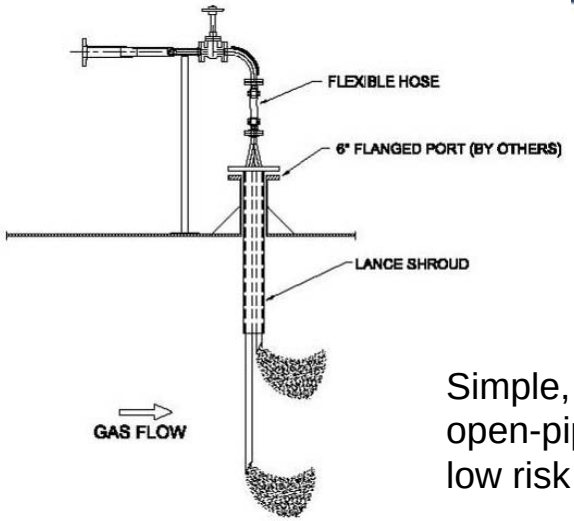
ADA PAC
Distribution Manifold

ADA In-House CFD Modeling



Typical Open-Pipe Lance Design





Simple, low-maintenance, open-pipe discharge design; low risk of pluggage

Plant Interface/Utility Requirements

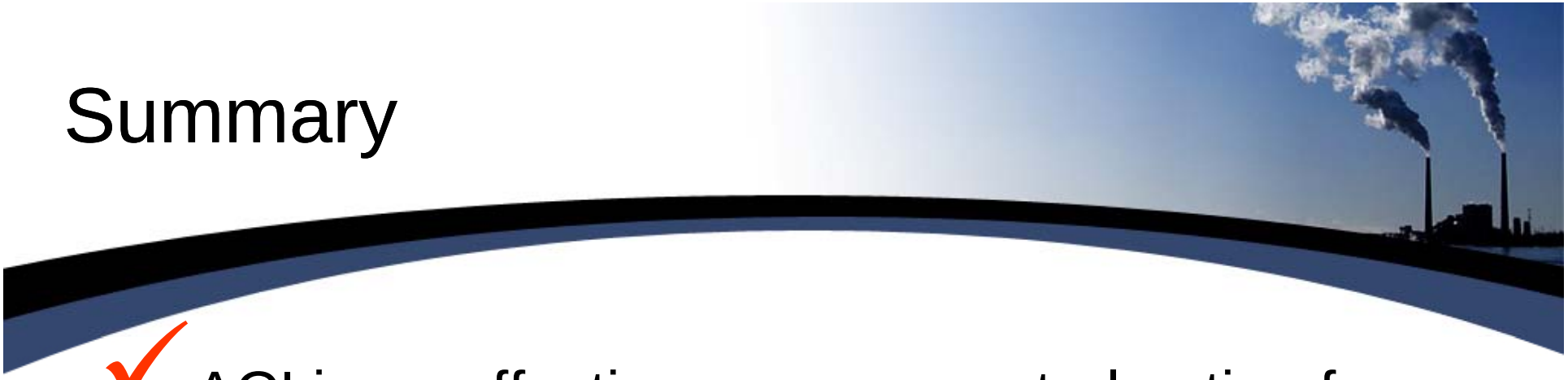
- Power: 30 to 50 kW per silo
- Clean dry (-40 ºF) compressed air, 20 scfm @ 100 psig for silo fluidizing and vent filter cleaning
- DCS interface (direct or via PLC communications link)
- Foundation: Silo is 14-ft diameter
- PAC conveying piping: 2.0- to 3.0-inch schedule 40 with ceramic-backed long-radius sweeps
- Duct penetrations for lances (4- to 6-inch NPT with 150-lb flange)
  - Quantity Varies Depending on Duct Geometry

Mercury Removal Performance Guarantees

Considerations:

- **Plant-specific and coal-specific**
- **Fabric filters: 80–90% depending on temperature, coal type & SO_3**
- **ESPs alone: fuel- and SO_3-specific (50–80% expected)**
- **SDA/FFs: 90% with halogenated sorbents**

Summary



- ACI is an effective mercury control option for many configurations

Remaining Challenges

- Minimize Interference from SO_3
- Minimize Impact of PAC on flyash sales
- Optimize performance to meet new regulation targets
- Develop sufficient activated carbon supply to meet needs of industry
- Develop PAC quality standards specific for this industry

Questions?