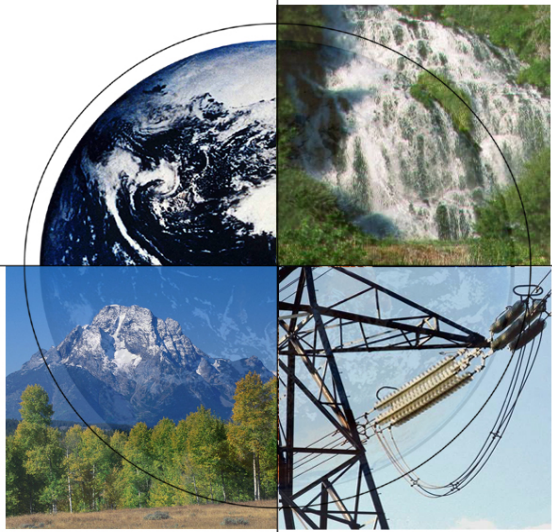
# Department of Energy/National Energy Technology Laboratory's Mercury Control Technology R&D Program



***PADEP Mercury Stakeholder Meeting***

**November 18, 2005**
**Harrisburg, PA**

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**National Energy Technology Laboratory**

# Outline

- **Background**
- **Advanced mercury control technology**
  - Focus on bituminous coal
- **Co-benefit control**
- **Coal combustion byproduct issues**
- **Key takeaways**

# DOE's Office of Fossil Energy
# Innovations for Existing Plants Program

- **Goal**
  - Enhance environmental performance of existing fleet of coal power plants and advanced power systems

- **Objectives**
  - Develop low-cost, integrated, non-complex technology to control emissions/releases (air, water, and solids) to the environment
  - Provide high-quality scientific and technical information on environmental issues for use in future regulatory and policy decision making

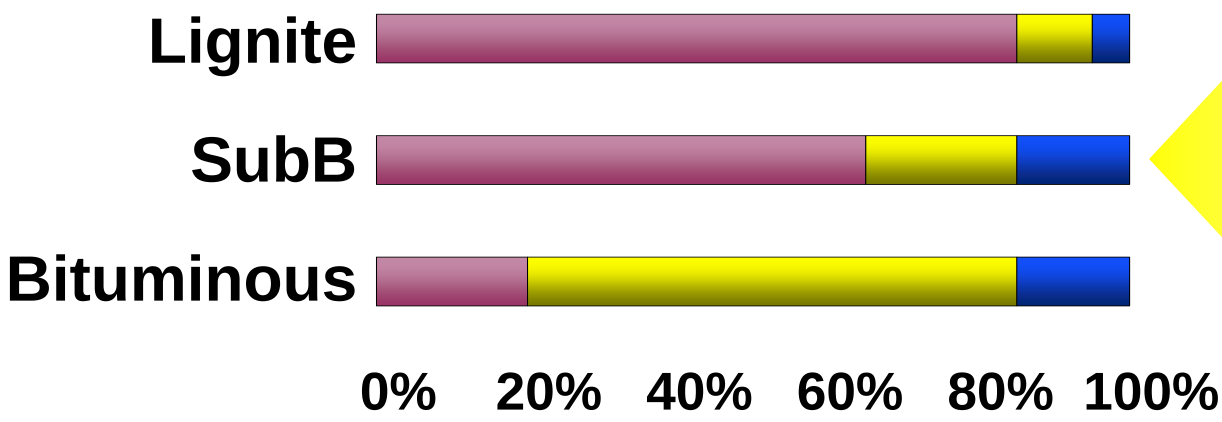
# PA Coal Production & Consumption

- **PA coal production in 2003**
  - 62 million tons bituminous
  - 1 million tons anthracite

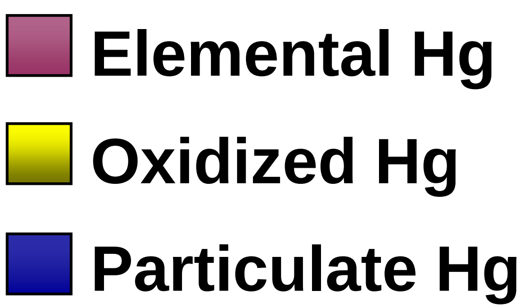
- **PA coal-fired power plant consumption in 2003**
  - 44 million tons bituminous
  - 8 million tons waste coal

**Source: NETL 2005 Power Plant Database and EIA Annual Coal Report, 2004**

# Hg Chemistry Directly Impacted by Coal Rank




% Hg Species in Flue Gas



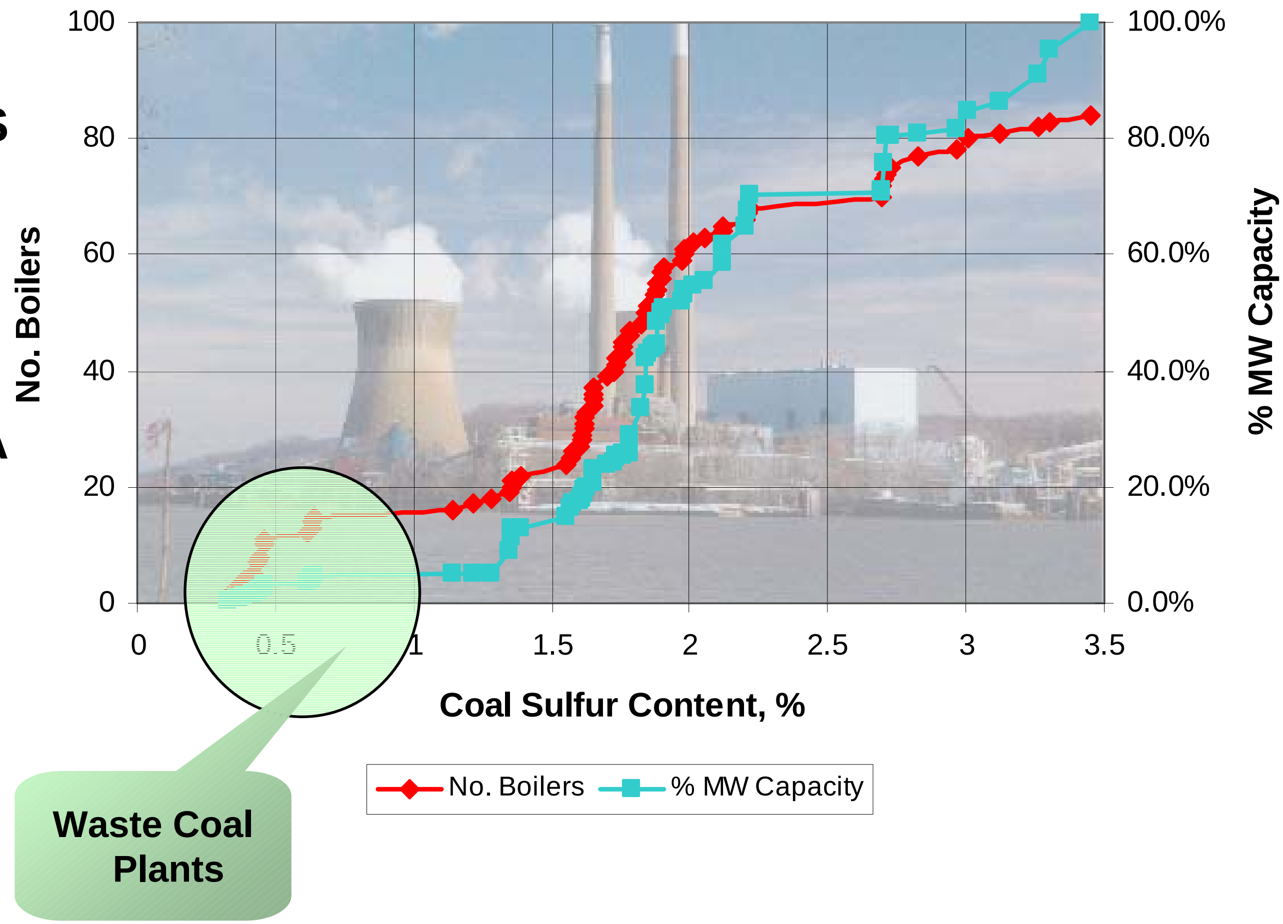

**Other Influences**

- Time
- Temperature
- Gas composition
- Catalysts

# PA Power Plant Coal Sulfur Content

**Weighted average coal sulfur content was 2.14% in 2003**

- **What impact does S content have on ACI performance?**
- **Will S content of PA coals limit use of fabric filters?**



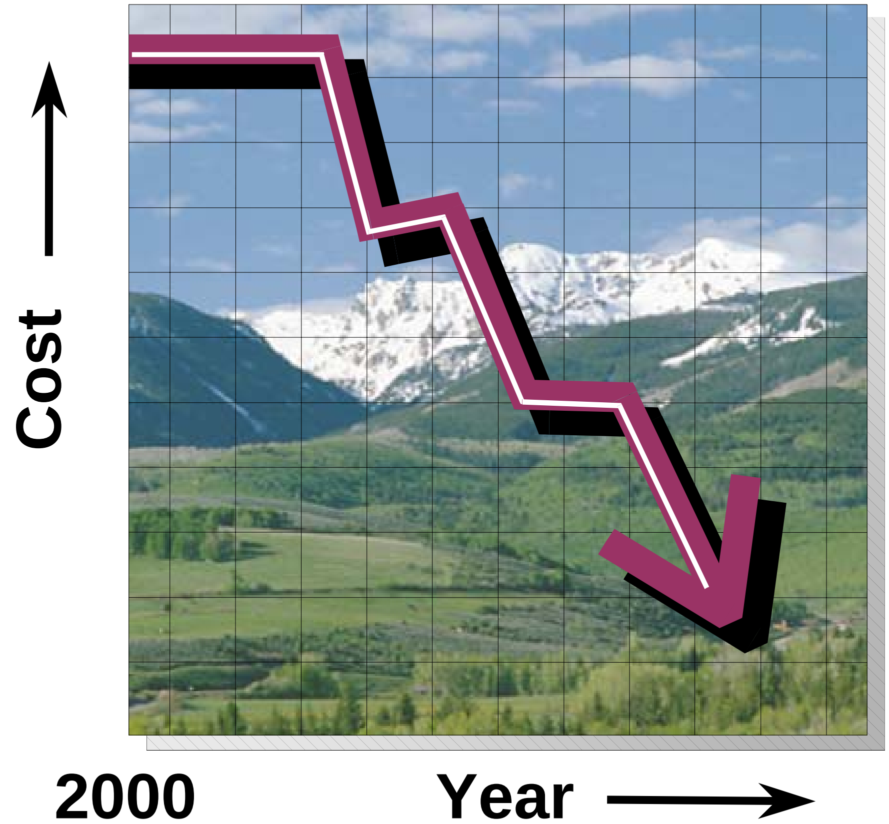

**Source: NETL 2005 Power Plant Database**

# Innovations for Existing Plants
## *Program Components*

- **R&D Activities**
  - **Mercury control**
  - $NO_x$ control
  - Particulate matter control
  - Air quality research
  - Coal utilization by-products
  - Water management

# Mercury Control Technology Field Testing Program
## *Performance/Cost Objectives*

- **Have technologies ready for <u>commercial demonstration</u> by 2007 for all coals**
- **Reduce "uncontrolled" Hg emissions by 50-70%**
- **Reduce cost by 25-50% compared to baseline cost estimates**




**Baseline (1999) Costs: $50,000 - $70,000 / lb Hg Removed**

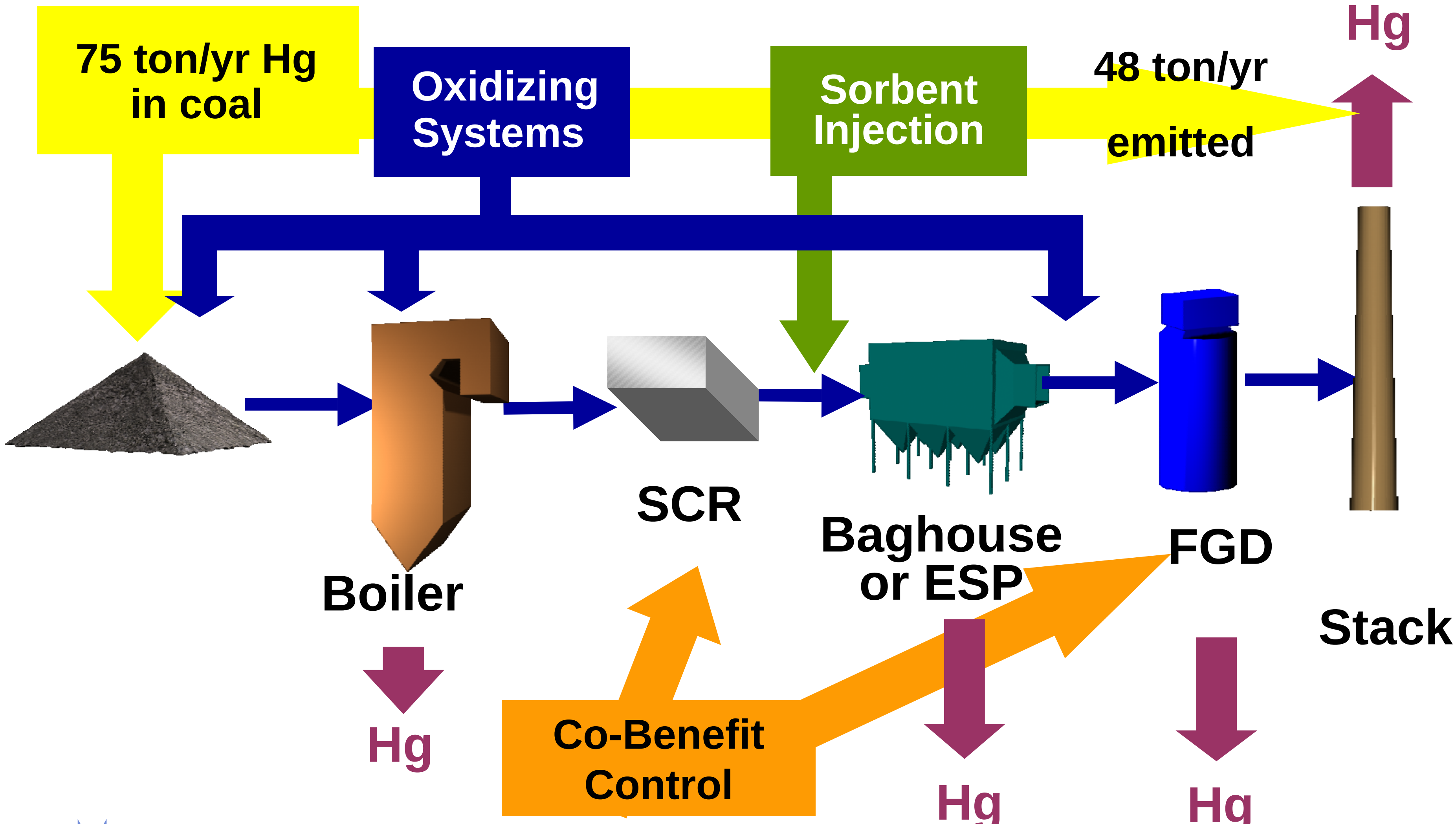
# Capturing Mercury Is Challenging

*Houston Astrodome*

*A Hypothetical Example*

- **Dome filled with 30 billion ping-pong balls**
- **30 black mercury balls**
- **Find and remove 27 balls for 90% Hg capture**

# Mercury Control Technology Options



# Phase II Mercury Control Field Testing
# *An R&D Program*

- **Fourteen projects (2004-2006)**
- **Long-term (30 days or more @ optimum conditions) full-scale and slip-stream testing at operating power plants**
- **Research & development effort**
- **Broad range of coal-rank and air pollution control device configurations; focus on low-rank coals**
- **Sorbent injection & mercury oxidation control technologies**

***Field testing at 28 different coal-fired units --representing approximately 2.3% of 1,165 existing coal-fired generating units.***

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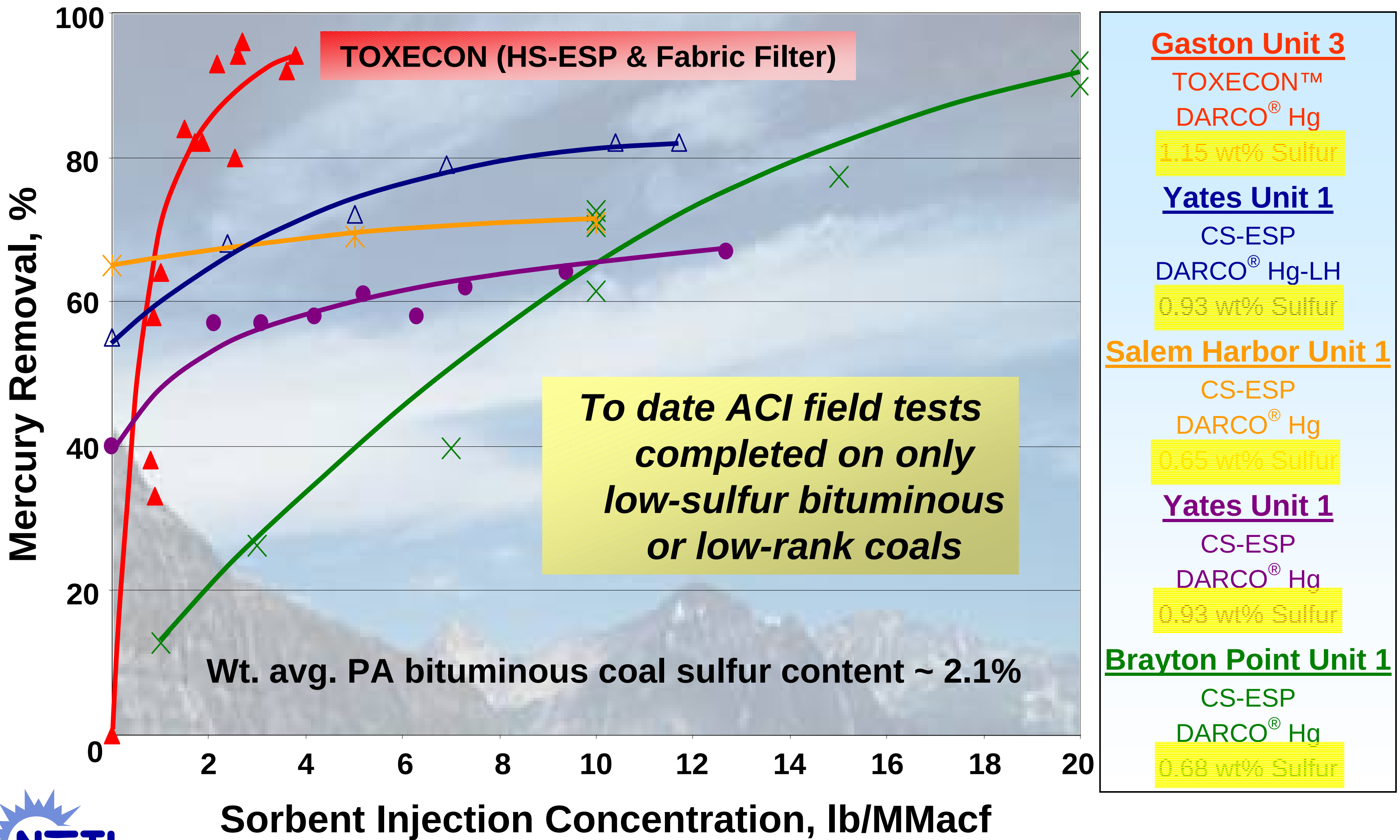
# Sorbent Injection Field Test Results for Bituminous-Fired Units

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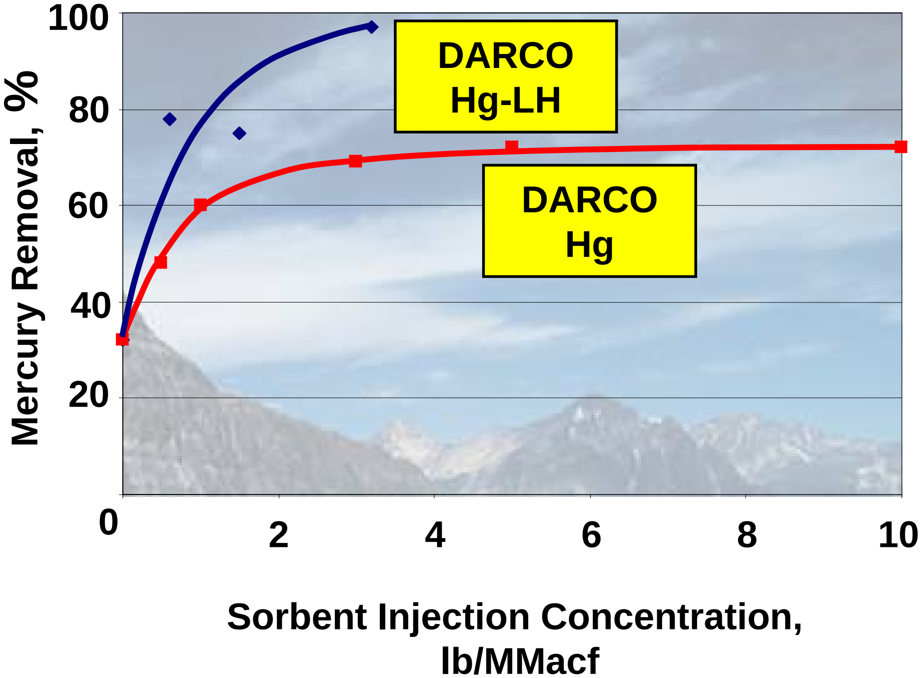
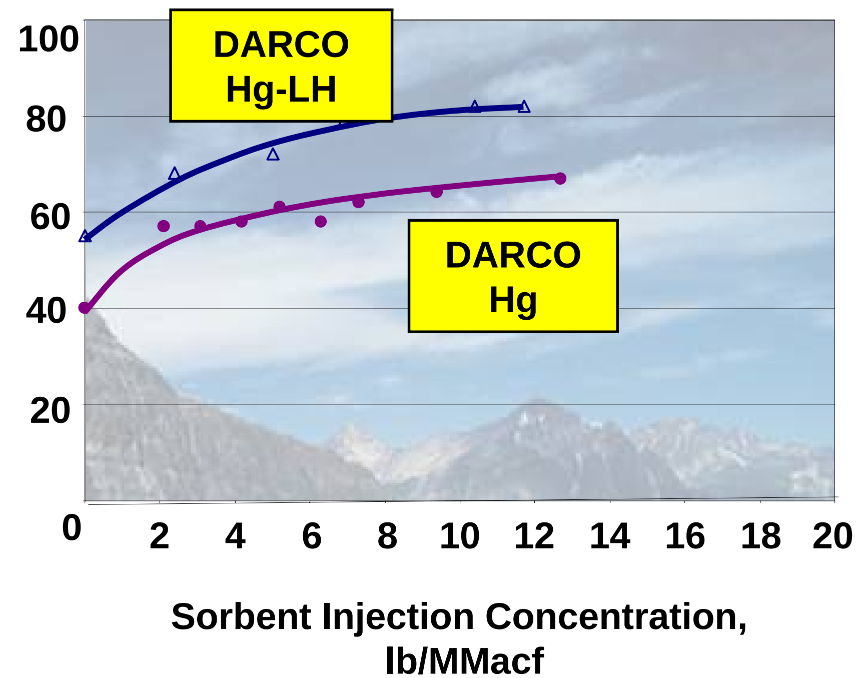
# Conventional vs. Brominated PAC Performance

## *Subbituminous Coal*
*Meramec Station*




## *Bituminous Coal*
*Yates Station*




**Performance improvement with brominated PAC greater for LRC than for bituminous coal – can we improve performance, is coal sulfur content a factor?**

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# Potential Effect of Flue Gas Sulfur on Carbon-Based Sorbents

- **Bench-scale investigation of physiochemical surface characteristics of sorbents exposed to flue gas conducted by UNDEERC**

- **Study objectives:**
  - Determine role of HCl in promoting oxidation of elemental mercury
  - Determine role of carbon structure in providing active sites for oxidation of mercury and $SO_2$
  - Evaluate various sorbents

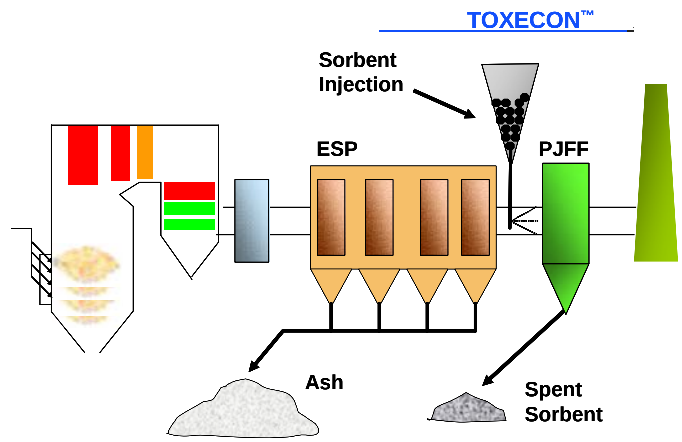
- **Preliminary results:**
  - Observed build-up of sulfur on carbon surface
  - Possible interference between sulfur and binding oxidized mercury on the carbon surface

**Source: UNDEERC Technical Progress Report dated April 2005 for Project No. DE-FC26-98FT40321 JV Task 78**

# Potential for TOXECON with Bituminous Coal?

- **May be limited to low-sulfur coal applications**

- **Power generation industry has avoided use of fabric filters for particulate control in mid- to high-sulfur coal applications due to concern with sulfuric acid deterioration of filter bags**



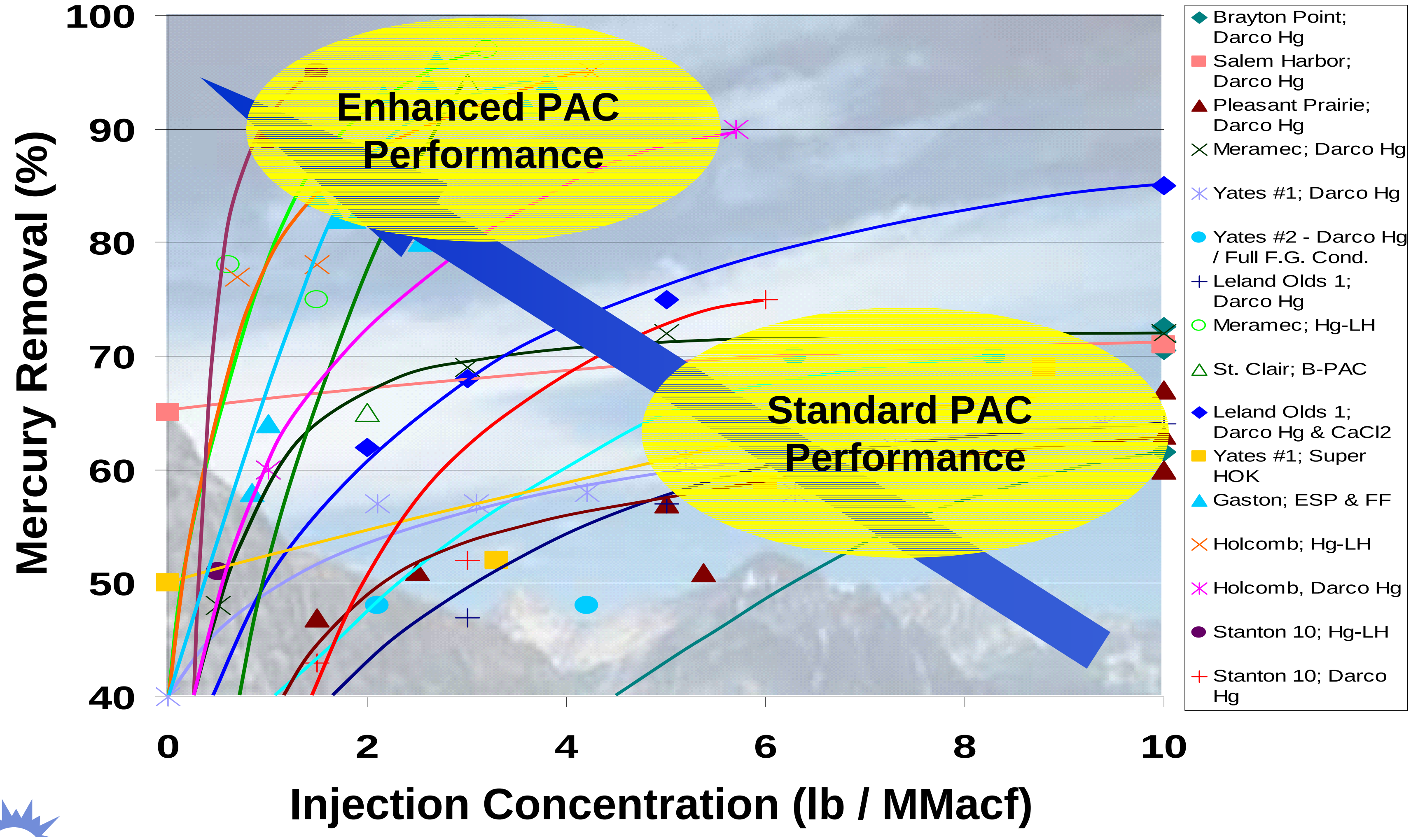

| | All Boilers | | Boilers w/ Fabric Filters | |
|---|---|---|---|---|
| | **All Coal** | **Bituminous** | **All Coal** | **Bituminous** |
| No. Boilers | 1075 | 662 | 116 | 55 |
| Total Capacity, MW | 325,412 | 184,633 | 31,984 | 11,028 |
| Avg. Capacity, MW | 303 | 279 | 276 | 201 |
| Average age, years | 40 | 43 | 33 | 38 |
| Avg. Coal Sulfur, % | 1.09 | 1.46 | 0.66 | 0.83 |
| Avg. Coal Ash, % | 9.05 | 9.72 | 10.78 | 9.92 |

** Average S content of PA coals was ~2.1% in 2003*

**Source: NETL 2005 Power Plant Database**

# ACI Field Testing Results (2001 – 2005)

## *Continuing Improvement in Performance and Cost*

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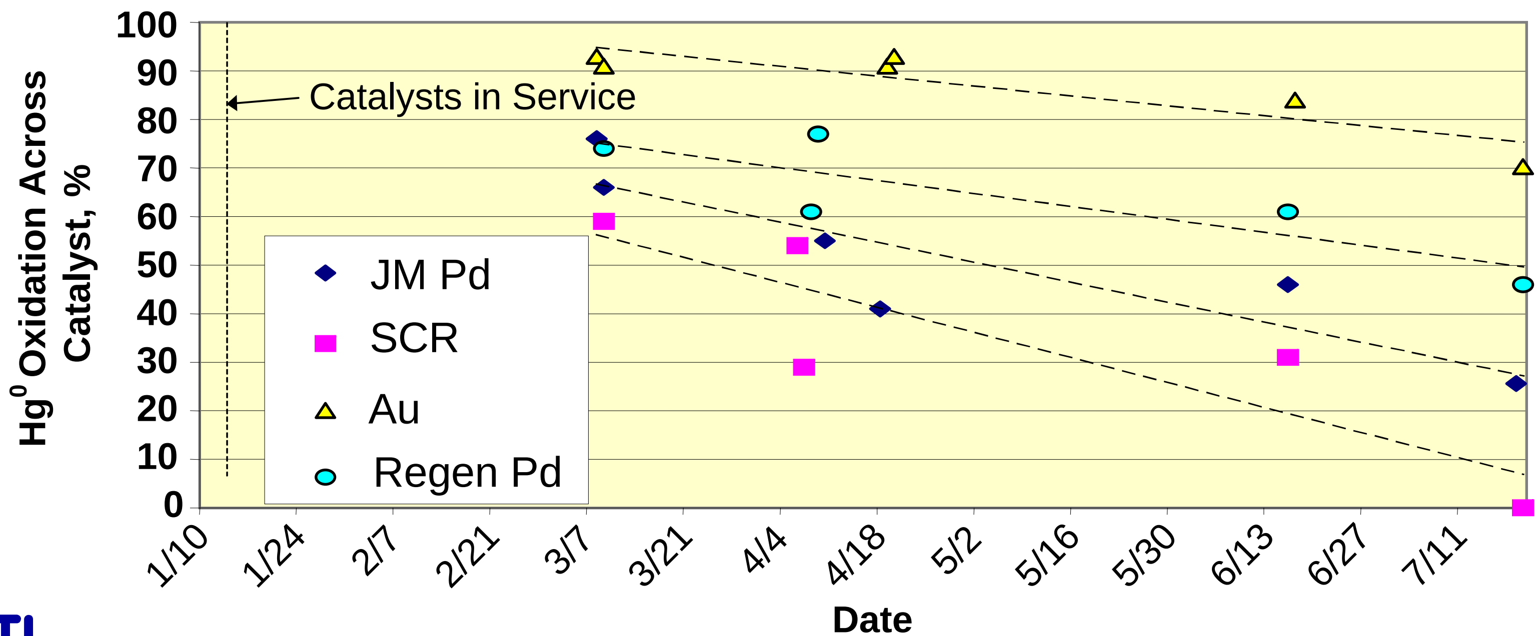
# Other Mercury Control Technologies

- **Oxidation catalysts to improve FGD mercury capture**
- **Chemical additives to improve FGD mercury capture**
- **Low temperature mercury capture with an ESP**

# Honeycomb Catalyst System for Oxidizing Hg
## *Preliminary Results*

### *TXU's Monticello Station Unit 3 (TX lignite/PRB)*

- After 8 months, oxidation of elemental mercury decreased to:
  - 70% across Gold (Au) catalyst
  - 25% across palladium (Pd) catalyst
  - 0% across SCR catalyst
  - 47% across regenerated Pd catalyst (from Coal Creek)



# Low Temperature Mercury Capture with an ESP
## *CONSOL Energy*

- Mercury capture with native fly ash at reduced flue gas temperatures (300° to 220°F**)**
- Alkaline sorbent ($Mg(OH)_2$) injection to remove corrosive $SO_3$ upstream of air preheater
- Six month long-term pilot-scale testing at ***Allegheny Energy's Mitchell Power Station***
  - High sulfur (>3%) bituminous coal
  - Cold-side ESP and wet FGD


***Allegheny Energy's Mitchell Station***

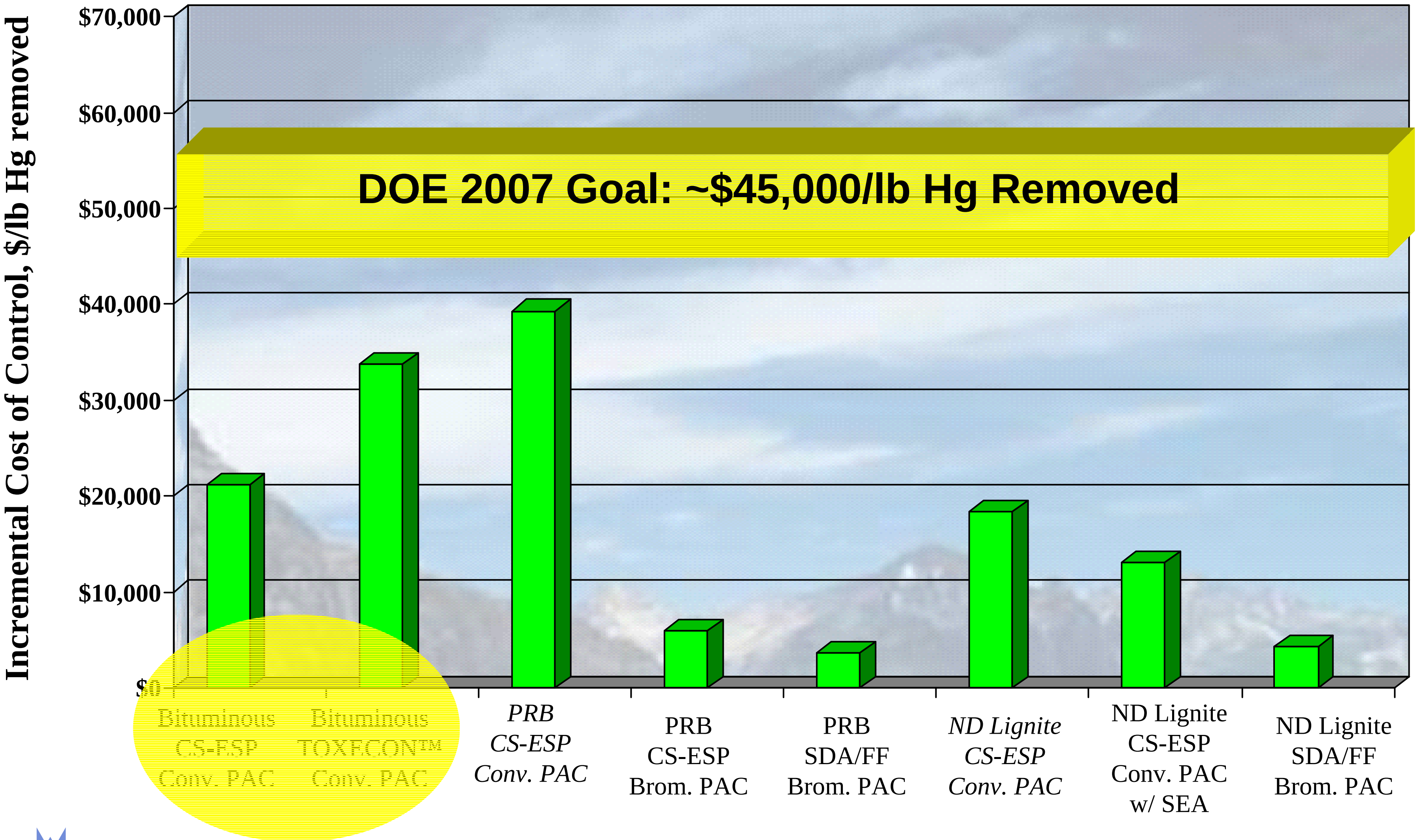
# Low Temperature Mercury Capture with an ESP
## *Test Results*

- **Parametric test results**
  - Baseline mercury capture ~25% across ESP at 290ºF
  - ~50% mercury capture across ESP at 240°F
- **Long-term test results**
  - ~80% (61 to 96%) mercury capture across ESP at 205ºF

# Upcoming NETL Field-Testing at Bituminous Units

| Bituminous Unit | APCD Configuration | Start Date | Mercury Control | Coal Sulfur Content (wt%) |
|---|---|---|---|---|
| Yates Unit 1 | CS-ESP / Wet FGD | September 2005 | Oxidation Catalysts | 0.93 |
| Yates Unit 1 | CS-ESP / Wet FGD | November 2005 | MerCAP™ | 0.93 |
| Yates Unit 1 | CS-ESP / Wet FGD | Fall 2005 | Wet FGD additive | 0.93 |
| Lee Unit 1 | CS-ESP | November 2005 | Enhanced ACI | 0.77 |
| Lee Unit 3 | CS-ESP / $SO_3$ conditioning | 1st Quarter 2006 | Integrated Approach | 0.82 |
| Miami Fort Unit 6 | CS-ESP | 1st Quarter 2006 | Amended Silicates™ | 2.21 |
| Conesville Unit 6 | CS-ESP / Wet FGD | March 2006 | Enhanced ACI | 3.00 |
| Portland Unit 1 | CS-ESP | March 2006 | Mer-Cure™ | 2.01 |
| Gavin Station | CS-ESP / Wet FGD | Unknown | TOXECON™ II | 3.76 |

# Incremental Cost of 70% Mercury Control[a]




[a] 60% mercury removal for italicized data labels.

# Effectiveness of SCR-FGD Systems in Capturing Hg

- Evaluate the mercury removal co-benefits achieved by the SCR-FGD combination

- 10 SCR / FGD equipped units:
  - **2 SCR-SDA-baghouse units**
  - **5 SCR-ESP-wet limestone FGD units**
  - **3 SCR-ESP-wet lime FGD units**

- Units fire bituminous coal

- 7 ozone-season and 3 year-round units

- Four units without SCR for comparison

# Effectiveness of SCR-FGD Systems

| Plant No. | FGD Type | Mercury Flow Rate, mg/sec | | | Mercury Emissions, lb/$10^{12}$ Btu | % Hg Removal, Coal to Stack | Mercury Balances | |
|---|---|---|---|---|---|---|---|---|
| | | Coal Feed | AH Outlet | Stack | | | AH Out vs. Coal Feed | Total Mass Balance |
| 1 | Lime Spray Dryer | 1.8 | 2.0 | 0.22 | 0.84 | 87 | 116% | 100% |
| 2 | Lime Spray Dryer | 1.8 | 1.6 | 0.09 | 0.44 | 95 | 90% | 99% |
| 5 | Limestone, In-Situ Ox. | 10.7 | 12.2 | 1.52 | 0.93 | 86 | 114% | 105% |
| 6 | Limestone, Ex-Situ Ox. | 6.5 | 6.8 | 0.76 | 1.11 | 88 | 104% | 96% |
| 7 | Limestone, Ex-Situ Ox. | 7.0 | 7.0 | 1.15 | 1.77 | 84 | 100% | 99% |
| 8 | Mg-Lime, Ex-Situ Ox. | 5.7 | 6.0 | 1.61 | 1.96 (1.11) | 72 (84) | 104% | 110% |
| 9 | Mg-Lime, Inhibited Ox. | 6.6 | 7.4 | 0.88 | 1.13 | 87 | 111% | 99% |
| 10 | Mg-Lime, Inhibited Ox. | 16.9 | 14.2 | 1.81 | 1.01 | 89 | 84% | 88% |

# Effectiveness of SCR-FGD Systems
## *What About Re-emissions?*

***Based on data from tests conducted at 8 sites with SCR/FGD***

- The SCR/air heater combination effectively oxidized Hg
  - **At all units with SCR, flue gas exiting the air heater contained only 2% to 6% $Hg^0$**
  - **Same or similar units without SCR, 7% to 34% $Hg^0$**

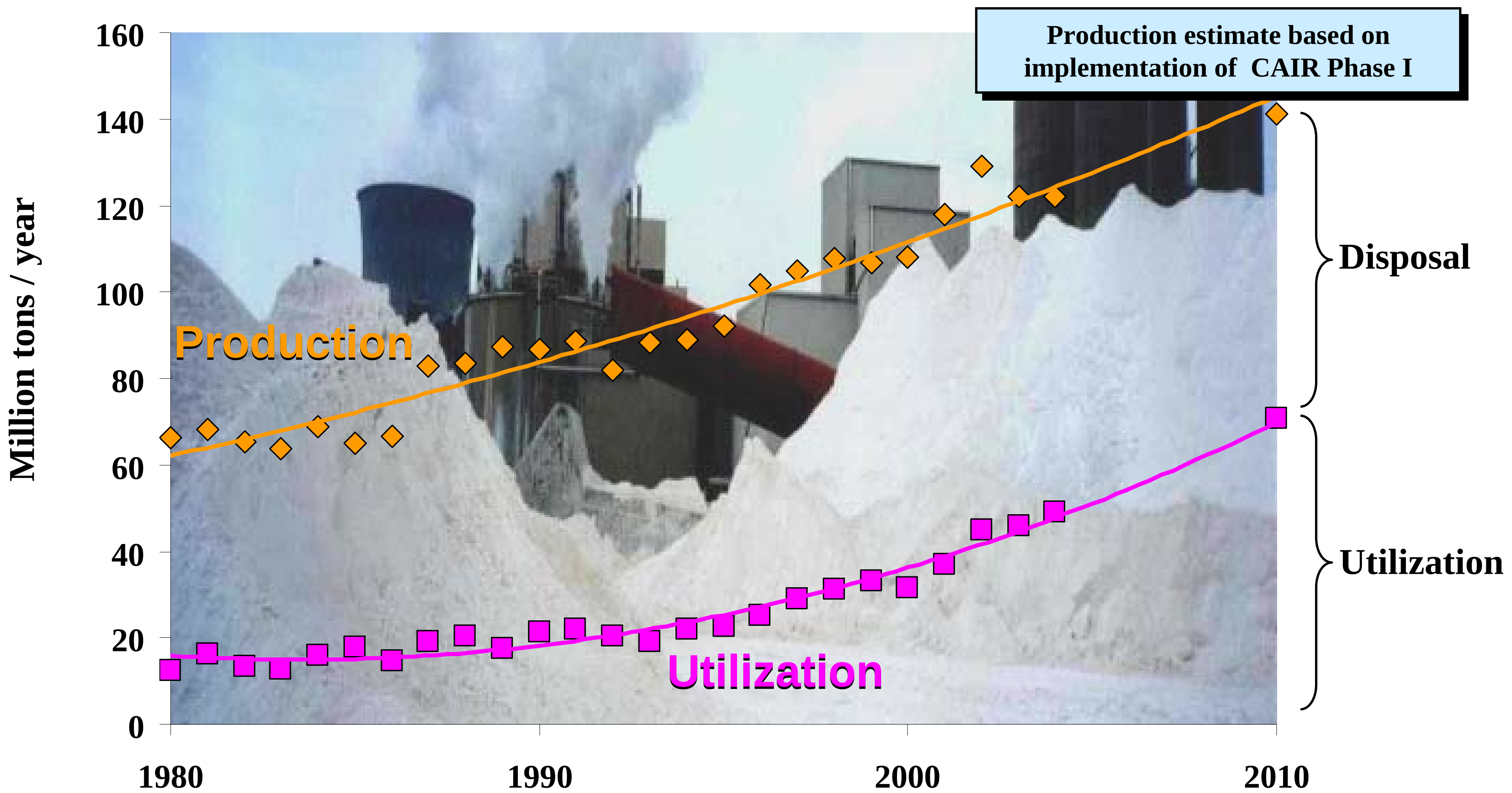
- On a coal-feed basis, Hg removals were:
  - **87% and 95% for the lime spray dryer units**
  - **84% to 89% for the lime and limestone wet scrubber units.**
  - **51% to 75% for the wet scrubbed units without SCR**

- How significant an issue is “re-emission?”
  - **It has been observed that some oxidized Hg captured in scrubbers is reduced to elemental Hg and is emitted**

# Innovations for Existing Plants
## *Program Components*

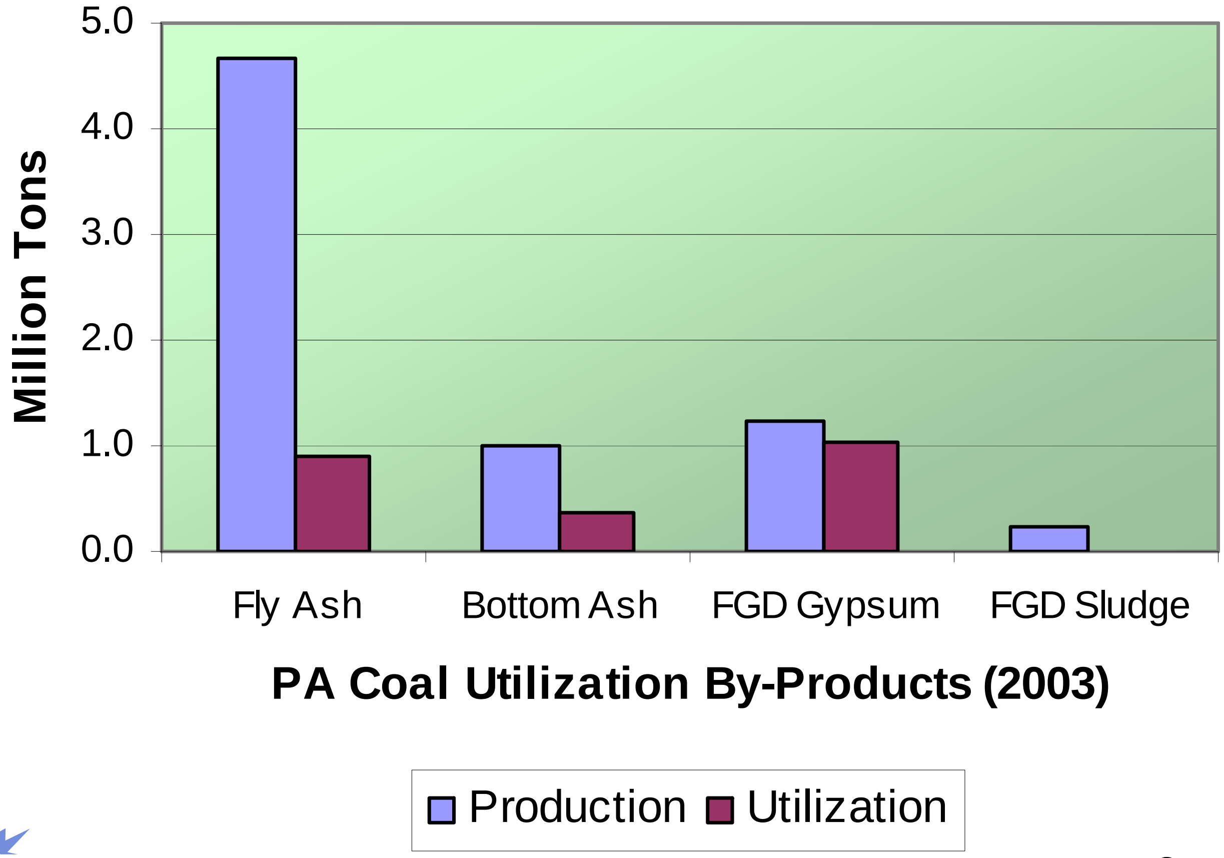
- **R&D Activities**
  - Mercury control
  - $NO_x$ control
  - Particulate matter control
  - Air quality research
  - **Coal utilization by-products**
  - Water management

# DOE-NETL CUB Program Goal:
## *50% Utilization by 2010*



# PA By-Product Production and Utilization

**Approx. 33% Overall CUB Utilization in 2003**

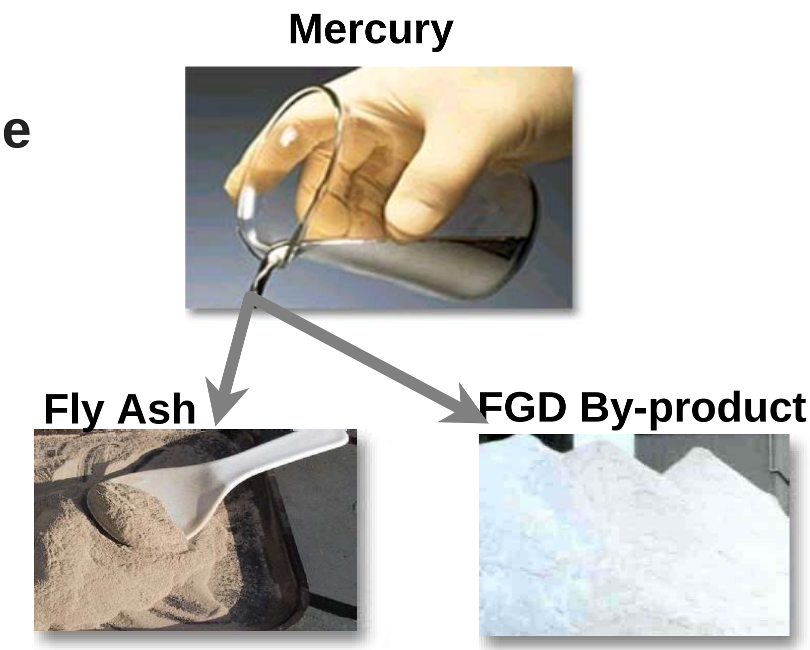



- **~ 7.1 mtpy production**
- **~2.3 mtpy utilization**

**Source: NETL 2005 Power Plant Database**

# Key Challenges to Continued/Increased By-Product Use

- **Installation of additional FGD to meet CAIR ($SO_2$) will increase volume of scrubber solids**
- **Installation of additional advanced combustion technology and SCR to meet CAIR (NOx) will increase UBC and $NH_3$ in fly ash**
- **Use of PAC injection for Hg control could negatively impact fly ash utilization due to increased carbon content**




- **Increased public scrutiny of CUBs due to transfer of Hg from flue gas to fly ash and scrubber solids**

# Summary of Hg Release from Fly Ash after ACI
## *Phase I Field Testing Program*

*Activated carbon silo*

- Hg in solids increased slightly after ACI
- Most leachates below 0.01 µg/L
- Max. leachate 0.07 µg/L (Brayton Point)
- ***Below all EPA water quality/drinking water criterion:***
  - *CCC = 0.77 µg/L*
  - *CMC = 1.4 µg/L*
  - *MCL = 2.0 µg/L*

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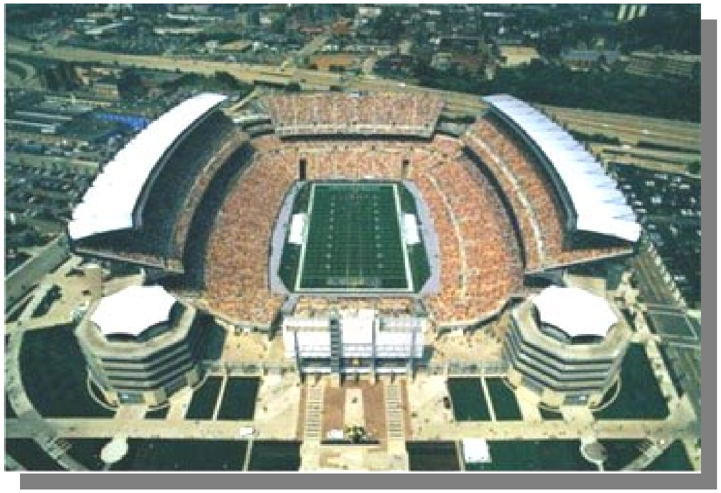
# What if FGD By-Products Can't Be Used Commercially?

- **FGD solids production***
  - 163,000 tpy
  - Require 3.8 million cubic feet of landfill volume for 100% disposal
  - Equivalent volume to filling a football field to depth of 80 feet



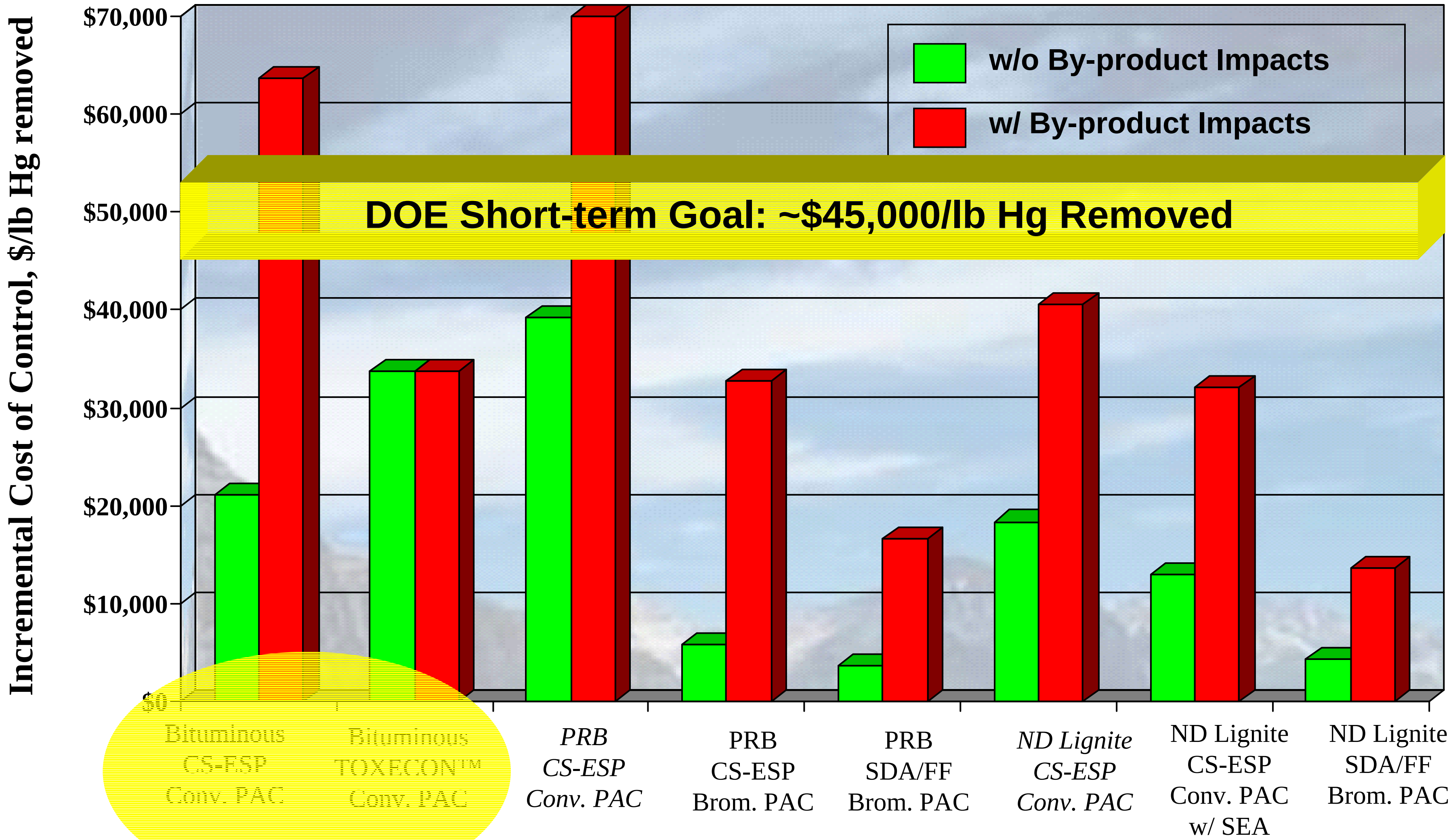
***Heinz Field - Pittsburgh***

**** Based on a 500 MW coal-fired power plant equipped with a wet FGD system***

**Total by-product production in 2003 for PA coal-fired power plants equivalent to filling 31 football fields to a depth of 100 feet.**

**Source: NETL estimates**

# By-product Impacts on Cost of 70% Hg Control[a]




[a] 60% mercury removal for italicized data labels.

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# DOE Hg Control RD&D Timeline

Complete field testing of technology capable of 50-70% Hg capture

Complete field testing of technology capable of 90%+ Hg capture

DOE will initiate field testing of technologies that can achieve 90%+ mercury capture in early 2006

Full-scale commercial demonstrations

Commercial deployment

2005 2007 2010 2015 2018 2020

CAMR Issued

CAMR Phase I
38 ton/year cap
via Co-Benefit
(NOx & $SO_2$)
Controls

CAMR Phase II
15 ton/year cap
via Hg Specific
Controls

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*RD&D – Research, Development and Demonstration*

*T. Feeley Nov. 2005*

# Key Takeaways from Field Testing

- Halogenated activated carbon and halogen-based additives have shown to be effective in capturing elemental Hg from low-rank coals with both ESP and fabric filters
- Estimated cost of Hg control on a $/lb removed basis continues to decline under "no by-product impact" scenario
- SCR combined with wet- or dry-scrubbing systems can provide high (~80%-95%) Hg removal with bituminous coals – re-emissions may decrease total Hg capture; uncertainty remains with low-rank coals
- Further long-term field testing is needed to bring technologies to commercial-demonstration readiness, particularly related to potential impacts of sulfur/$SO_3$ and small SCA ESP on ACI effectiveness
- Potential coal combustion byproduct impacts remain a "wild card"
- DOE's RD&D model projects broad commercial availability in 2012-2015

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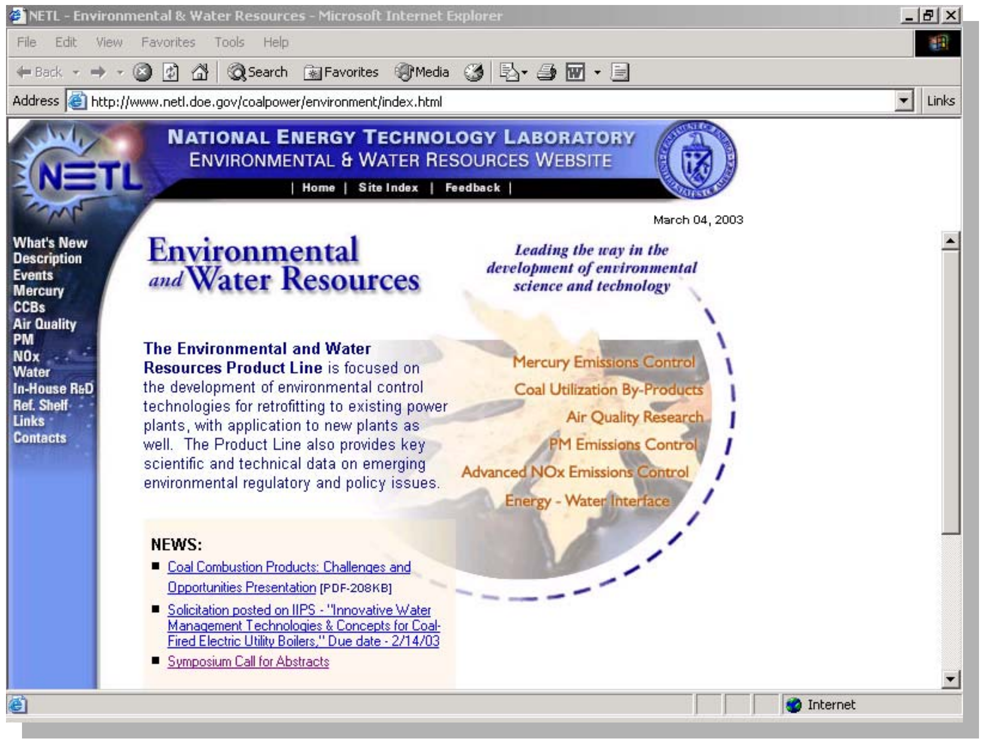
# DOE/NETL Innovations for Existing Plants Program




*To find out more about DOE-NETL's Hg R&D activities visit us at:*

***http://www.netl.doe.gov/coal/E&WR/index.html***

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