U.S. DOE's Hg Control Technology RD&D Program—Significant Progress, But More Work to be Done!

3rd International Experts' Workshop – Mercury Emissions from Coal

June 5-7, 2006
Katowice, Poland

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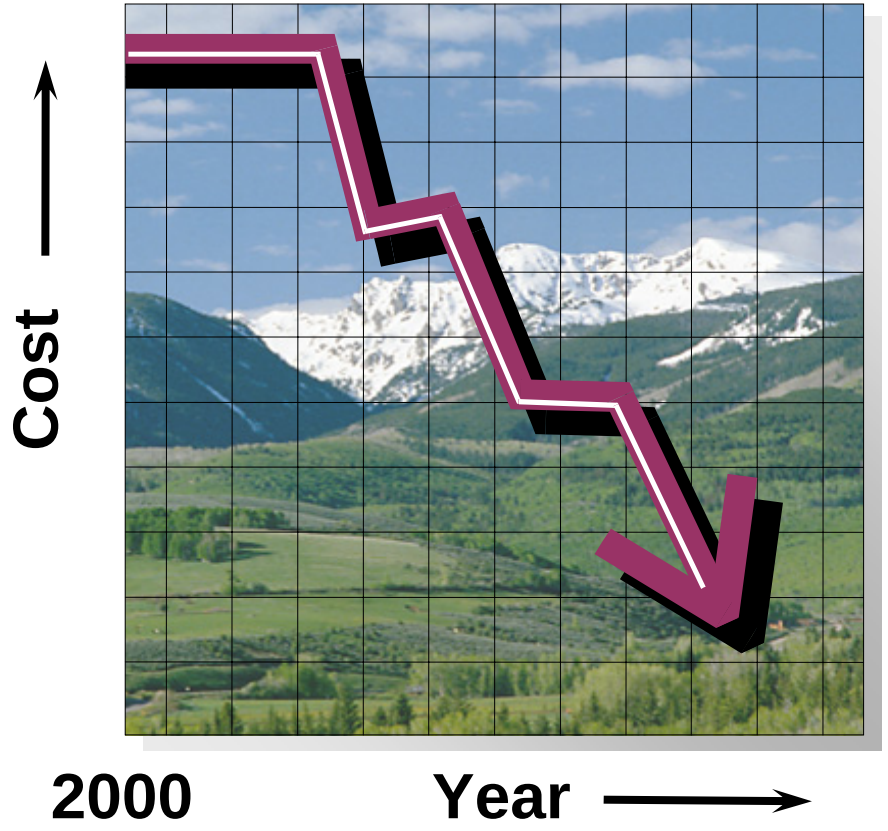
Outline

- Background
- Phase II project update/Phase III project descriptions
- BOP and related technical issues
- Preliminary economic assessment
- Byproduct-Hg issues/potential economic impacts
- Conclusion

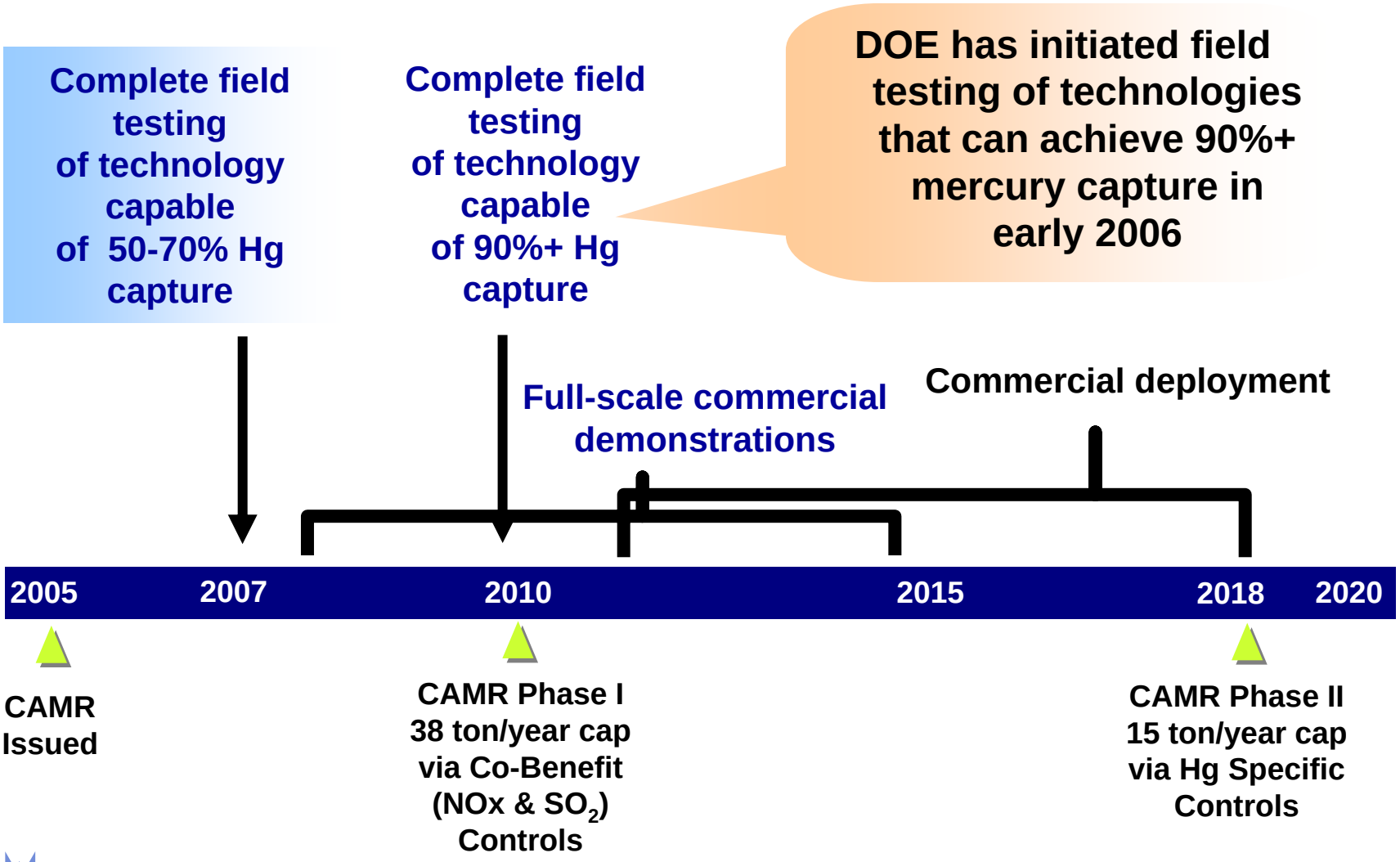
Mercury Control Technology Program
Performance/Cost Objectives

- Have technologies ready for commercial demonstration by:
  - 2007 that can reduce "uncontrolled" Hg emissions by 50-70%
  - 2010 for all coals that can reduce "uncontrolled" Hg emissions by +90%
- Reduce cost by 25-50% compared to baseline cost estimates



Baseline (1999) Costs: $60,000 / lb Hg Removed

DOE Hg Control RD&D Timeline in Sync with the Clean Air Mercury Rule (CAMR)



States Proposing Hg Regulations More Stringent than CAMR

- Connecticut
- Massachusetts
- New Hampshire
- New Jersey
- New York
- Delaware
- Maryland
- North Carolina
- Pennsylvania
- Georgia
- Illinois
- Michigan
- Minnesota
- Montana
- Washington
- Wisconsin

Source: John A. Paul, Ohio Regional Air Pollution Control Agency, April 27, 2006, Baltimore, MD

DOE/NETL Phase II Long-Term Field Testing Results
Technical Goal – 50%-70% Removal

Site Name	Coal Rank	APCD Configuration	Mercury Control Technology	Average Total Mercury Removal (%)	Date Completed
Leland Olds Unit 1	**ND Lignite**	**CS-ESP**	**DARCO® Hg,** 3 lb/MMacf **& $CaCl_2$ solution,** 500 ppm Cl in wet coal	**63%**	**May 2004**
Stanton Unit 10	**ND Lignite**	**SDA/FF**	**DARCO® Hg-LH,** 0.7 lb/MMacf	**60%**	**July 2004**
Holcomb Unit 1	**PRB**	**SDA/FF**	**DARCO® Hg-LH,** 1.2 lb/MMacf	**93%**	**August 2004**
St. Clair Unit 1	**85% PRB / 15% Bit.**	**CS-ESP**	**B-PAC™,** 3 lb/MMacf	**94%**	**October 2004**
Meramec Unit 2	**PRB**	**CS-ESP**	**DARCO® Hg-LH,** 3.3 lb/MMacf	**93%**	**November 2004**
Plant Yates Unit 1	**Bituminous**	**CS-ESP & wet FGD**	**Super HOK,** 4.5 – 9.5 lb/MMacf	**50-86%**	**December 2004**
Antelope Valley Unit 1	**ND Lignite**	**SDA/FF**	**DARCO® Hg,** 1 lb/MMacf **& SEA-2,** 0.033 lb/MMacf	**~ 90%**	**March 2005**
Milton R. Young Unit 2	**ND Lignite**	**CS-ESP & wet FGD**	**DARCO® Hg,** 0.15 lb/MMacf **& SEA-2,** 60-100 ppm (dry coal basis)	**40-60%**	**May 2005**
Monroe Unit 4	**60% PRB / 40% Bit.**	**SCR & CS-ESP**	**DARCO® Hg,** 4.9 lb/MMacf	**78%**	**July 2005**

DOE/NETL Phase II Long-Term Field Testing Results
Technical Goal: 50%-70% Removal

Site Name	Coal Rank	APCD Configuration	Mercury Control Technology	Average Total Mercury Removal (%)	Date Completed
Dave Johnston Unit 3	**PRB**	**CS-ESP**	**Mer-Clean™ 8,** 0.63 lb/MMacf	**90%**	**September 2005**
Stanton Unit 1	**PRB**	**CS-ESP**	**B-PAC™,** 2 lb/MMacf	**70–95%**	**October 2005**
Independence Unit 1	**PRB**	**TOXECON II™**	**DARCO® Hg-LH,** 4-5 lb/MMacf	**50-80%**	**November 2005**
Lee Unit 1	**Bituminous**	**CS-ESP**	**B-PAC™,** 8 lb/MMacf	**85%**	**April 2006**

DOE/NETL Phase II Long-Term Field Testing Results
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Dave Johnston Unit 3	PRB	CS-ESP	**Mer-Clean™ 8,** 0.63 lb/MMacf	90%	September 2005
Stanton Unit 1	PRB	CS-ESP	**B-PAC™,** 2 lb/MMacf	70–95%	October 2005
Independence Unit 1	PRB	TOXECON II™	**DARCO® Hg-LH,** 4-5 lb/MMacf	50-80%	November 2005
Monticello Unit 3	TX Lignite	CS-ESP & wet FGD			December 2005
Leland Olds Unit 1	ND Lignite	CS-ESP			December 2005
Miami Fort Unit 6	Bituminous	CS-ESP			March 2006
Big Brown Unit 1	TX Lignite	TOXECON™			March 2006
Lee Unit 1	Bituminous	CS-ESP	**B-PAC™,** 8 lb/MMacf	85%	April 2006

Phase III Hg Solicitation Awards

Long-Term Carbon Injection Field Test for >90% Hg Removal for PRB Unit w/ Spray Dryer and FF	ADA-ES
Long-Term Demonstration of Sorbent Enhancement Additive Technology for Hg Control	UNDEERC
Demonstration of Mer-Cure Technology for Enhanced Hg Control	ALSTOM
Full-Scale Field Trial of Low Temperature Hg Capture Process	CONSOL
Mercury Control for Plants Firing Texas Lignite and Equipped w/ ESP and Wet FGD	URS
Evaluation of Control Strategies to Effectively Meet 70-90% Mercury Reduction on an Eastern Bituminous Coal Cyclone Boiler	ADA-ES
Full-Scale Testing of Hg Oxidation Catalyst Upstream of Wet FGD	URS
Utilization of Partially Gasified Coal for Hg Removal	GE-EERC
Advanced Hg Sorbents with Low Impact on Power Plant Operations	Apogee
On-Site Production of Hg Sorbent with Low Concrete Impact	Praxair
Enhanced High Temperature Hg Oxidation and In-Situ Activated Carbon Generation for Low Cost Mercury Capture	Breen
Pilot Testing of WRI's Novel Hg Control Technology by Pre-Combustion Thermal Treatment of Coal	WRI

- 90%+ capture field testing

- 50-70% capture field testing

-Combustion/post combustion novel concepts

- Pre-combustion novel concepts

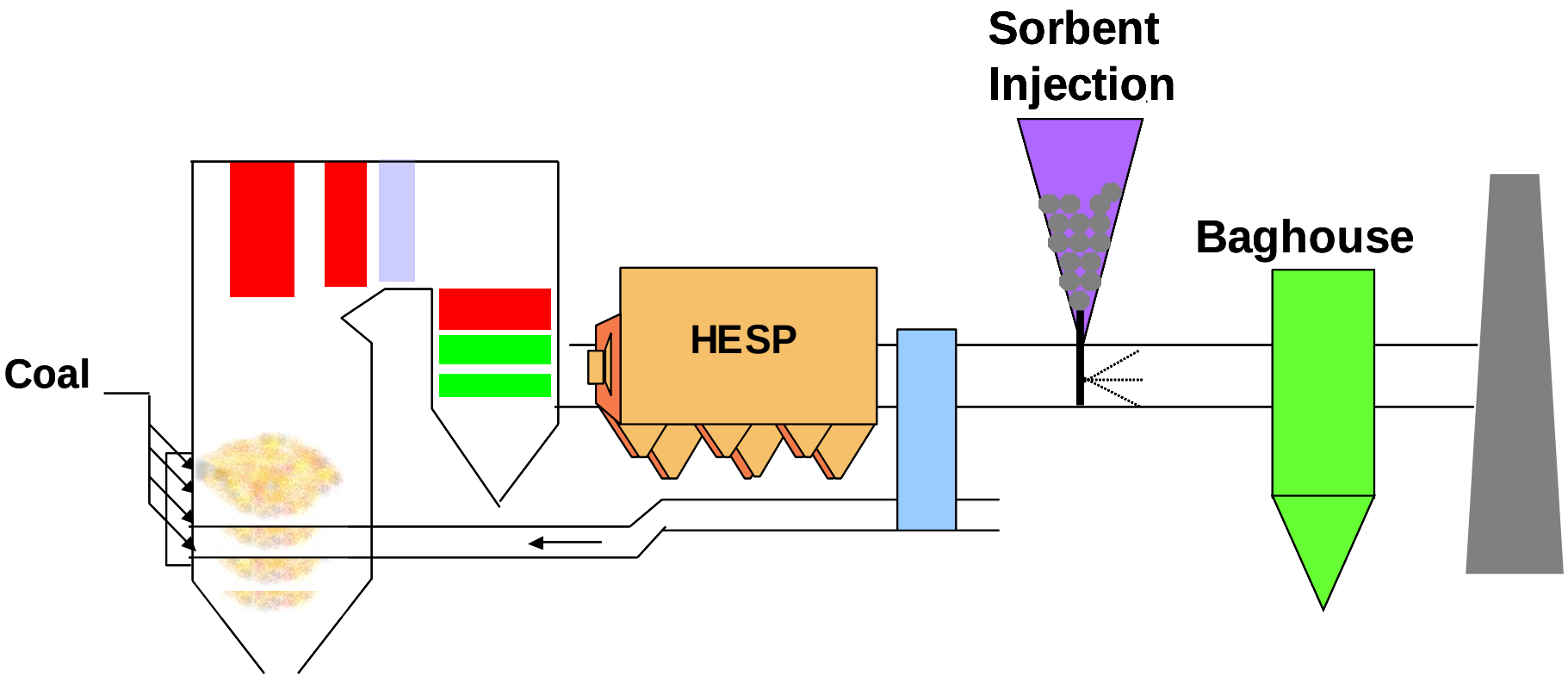
Balance-of-Plant Issues/Lessons Learned

TOXECON Retrofit for Hg and Multi-Pollutant Control
U.S. DOE Clean Coal Power Initiative, Round 1

Presque Isle Power Plant, Marquette, MI

- **Plant was built in early 1950's and expanded over the years to 9 coal fired Units**
- **Nine units total 625 MW representing approximately 50% of the power generation in Michigan Upper Peninsula**
- **Units 7,8 & 9 are 90 MW units burning western bituminous, PRB coal**
- **PIPP currently sells fly ash for concrete**

TOXECON™



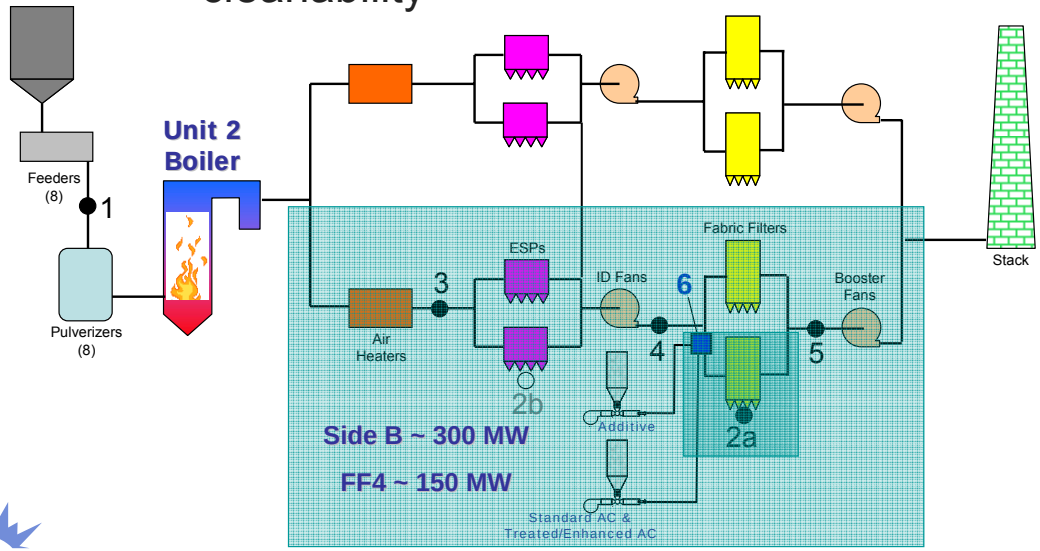
TOXECON™ is an Electric Power Research Institute (EPRI) patented process in which sorbents including powder activated carbon for mercury control and others for NOx and SOX control are injected into the combustion gases downstream of an existing particulate control device and collected by a new particulate control device, typically a pulse jet fabric filter (baghouse).

Problem with Overheating Powdered Activated Carbon at Presque Isle

- Hot burning embers found on February 27, by March 2 all hoppers had embers
- System bypassed and opened to atmosphere, worsened situation, causing flames that damaged 200 bags in 2 (of 10) compartments
- Likely cause is excessive temperatures from hopper heaters
- PAC can ignite at temperature greater than 700 ^{o}F. (welding, cutting, hopper heaters)
- Investigation is ongoing

Mercury Control Options for TXU's Big Brown

- **Project Objective: Evaluate long term feasibility of activated carbon (AC), treated carbon, and additive injection for mercury control**
  - ≥ 55% mercury removal
  - Evaluate balance-of-plant (BOP) impacts
    - Increase in ΔP across FF4 over time
    - Increased difficulty in bag cleanability



- **Possible sources of BOP impacts:**
  - Injection of sorbent/additive material causing filter blockage.
  - Changes in flue gas or ash chemistry due to addition of sorbent/additive materials.
  - Changes in operating conditions during test period:
    - Flow rate variations (rebalancing of flow, increased flow)
    - Frequent flow bypass (when ΔP exceeded 10" H_2O)
    - Temperature fluctuations
    - Use of ash conditioning
    - Variation in fuel blend
    - Load variation
    - Unplanned outages, chemical and morphology analysis is ongoing

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

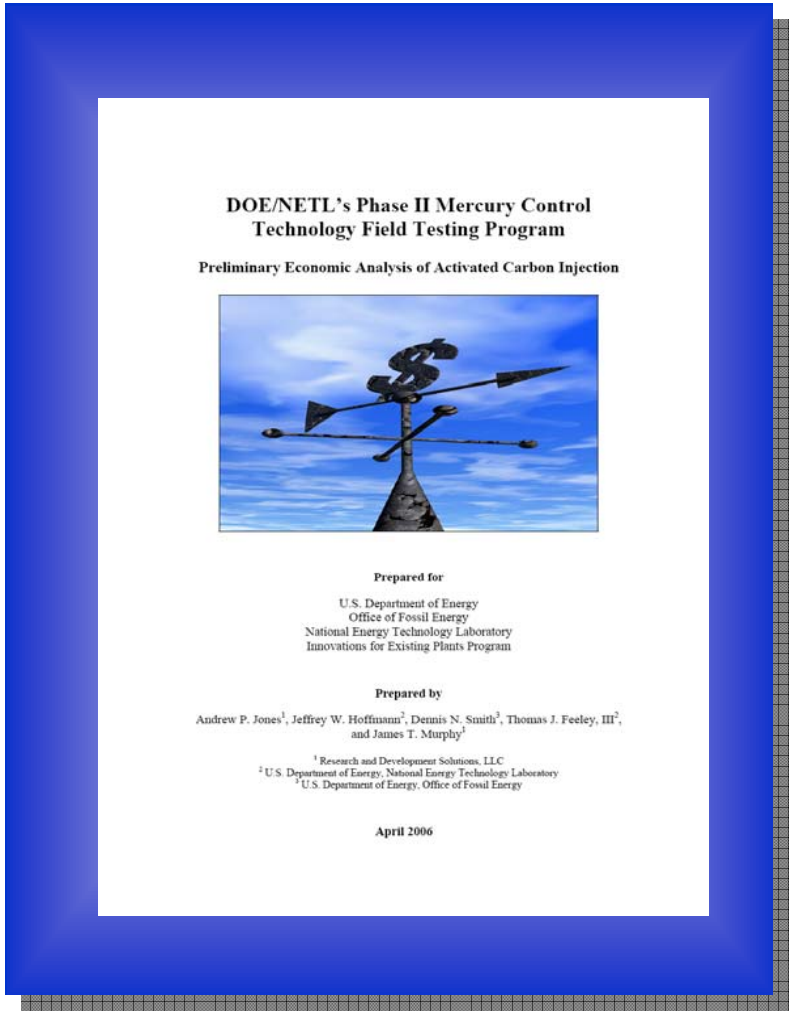
Preliminary Results of Field Testing at Conesville Power Plant – Impact of High-S Coal

- 400 MW T-fired PC burning high-S (3.5-4%) bituminous coal equipped with ESP and wet FGD
- Very little baseline Hg removal
- Initial tests w/ treated and untreated activated C yielded only 5-31% Hg removal @ 9-18 lb/MMacf

Conesville Power Plant, Coshocton, OH

- 2nd round of parametric testing with "improved" sorbents yielded worst results (3-13% removal), even with improved AC distribution
- High sulfur trioxide (SO_3) suspected to compete with sorbtion sites on AC or otherwise compromise AC Hg removal capabilities

Phase II Field Testing Economic Analysis



DOE/NETL's Phase II Mercury Control Technology Field Testing Program

Preliminary Economic Analysis of Activated Carbon Injection

Prepared for

U.S. Department of Energy
Office of Fossil Energy
National Energy Technology Laboratory
Innovations for Existing Plants Program

Prepared by

Andrew P. Jones[1], Jeffrey W. Hoffmann[2], Dennis N. Smith[3], Thomas J. Feeley, III[2], and James T. Murphy[1]

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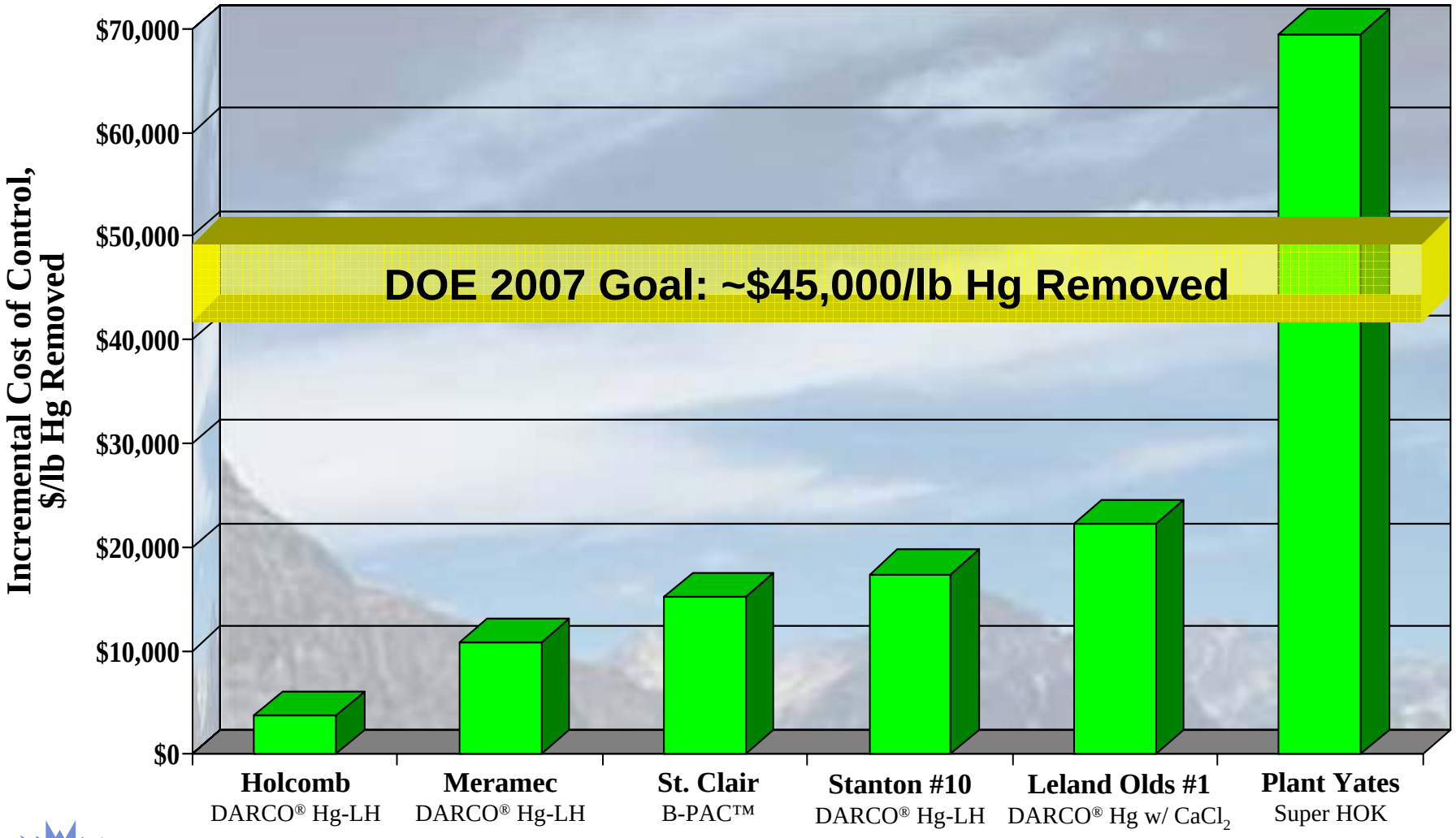
[2] U.S. Department of Energy, National Energy Technology Laboratory
[3] U.S. Department of Energy, Office of Fossil Energy

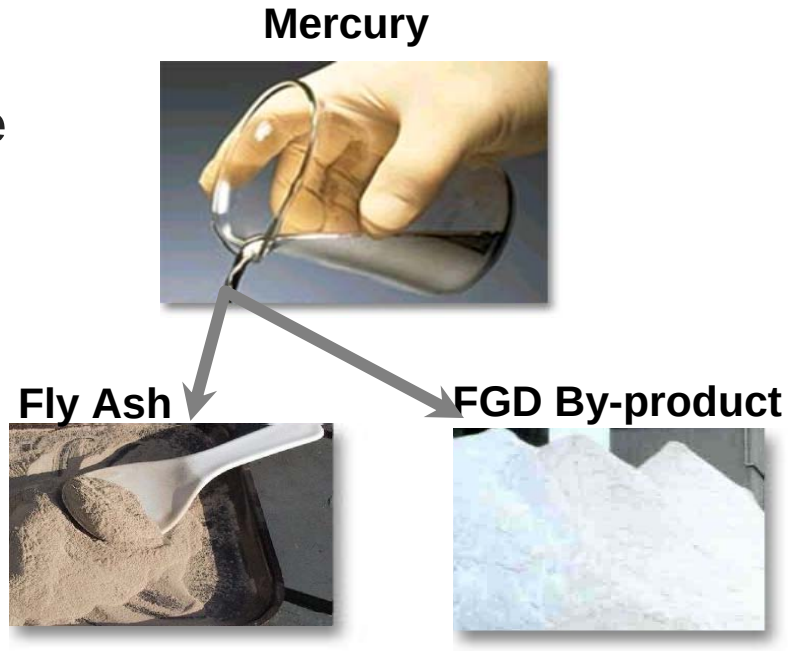
April 2006

Incremental Cost of 70% ACI Mercury Control



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

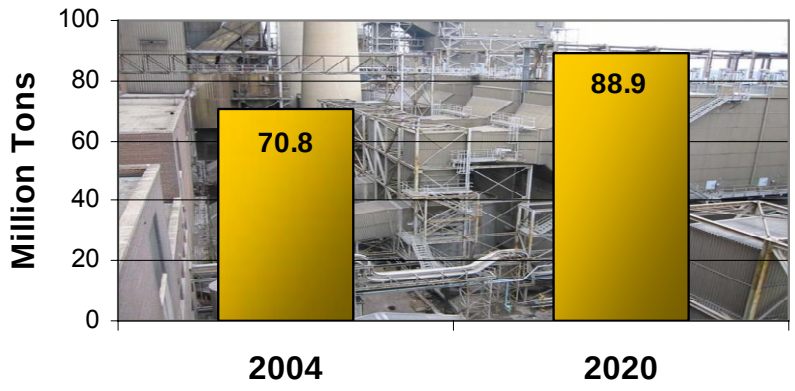


- Increased public scrutiny of CUBs due to transfer of Hg from flue gas to fly ash and scrubber solids

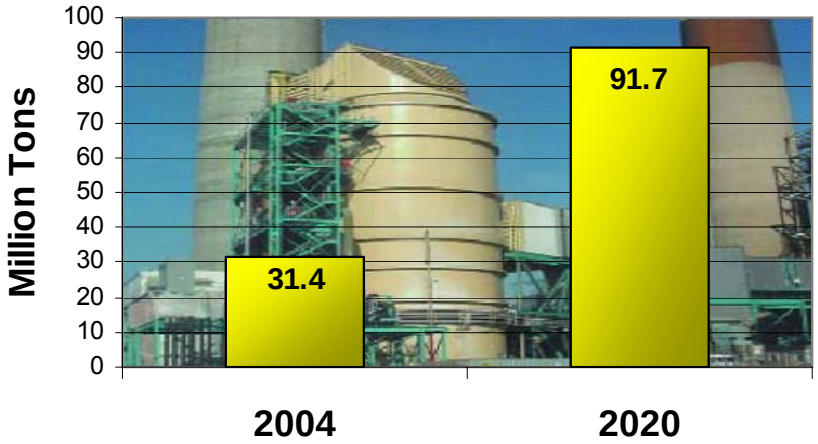
Projection of U.S. Coal-Fired Power Plant CUB Production

Coal-fired power generation projected to increase from 1,916 to 2,405 billion kWh from 2004 to 2020

Flyash Production



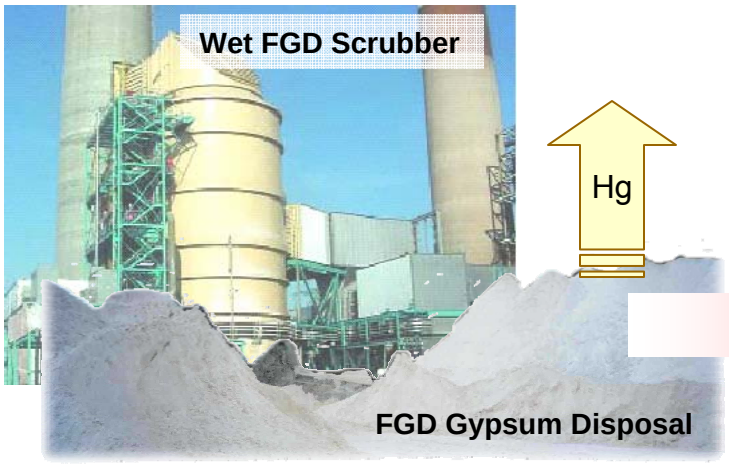
FGD Solids Production

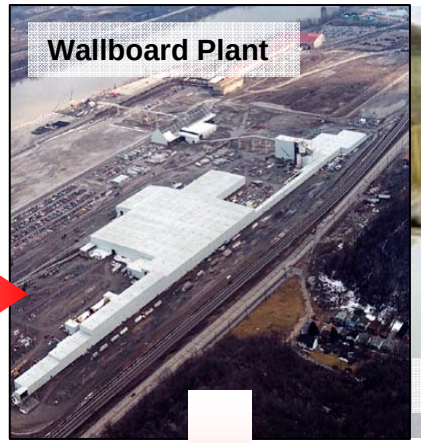


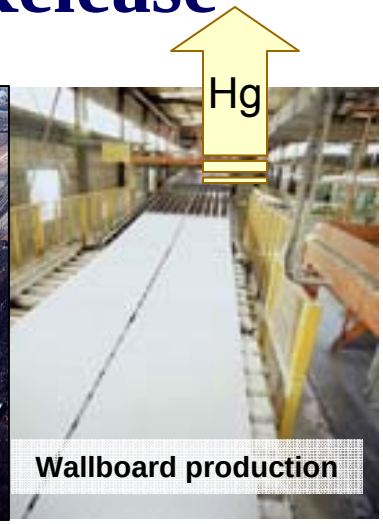
FGD capacity projected to increase from 100 to 231 GW from 2004 to 2020

Sources: ACAA, EIA AEO 2006, and EPA IPM Analysis for CAMR/CAIR

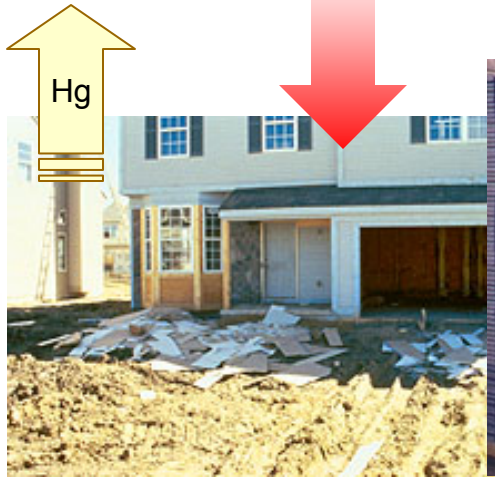
FGD Gypsum:
Pathways for Potential Mercury Release





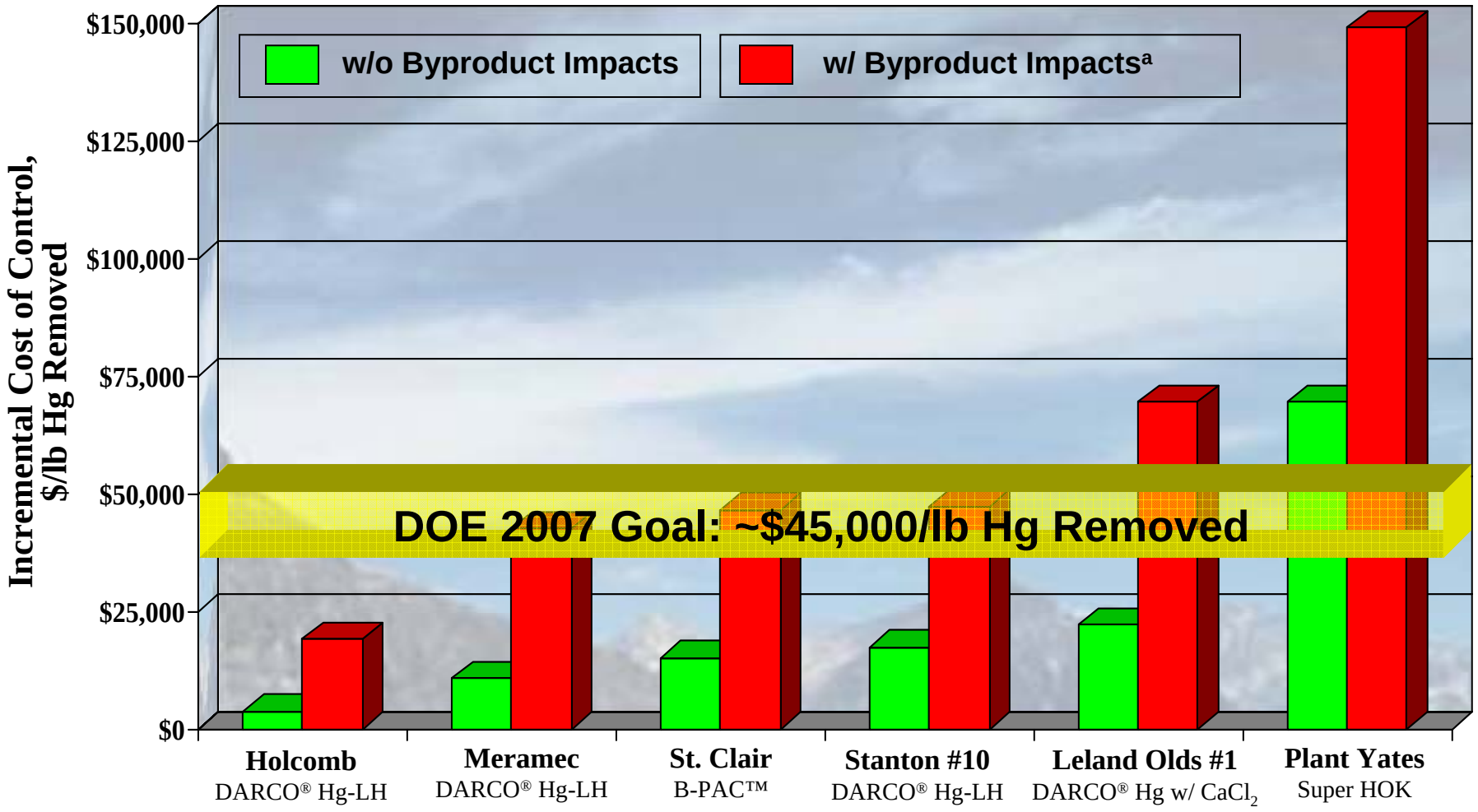


Wallboard disposal



Home Construction

Incremental Cost of 70% ACI Mercury Control

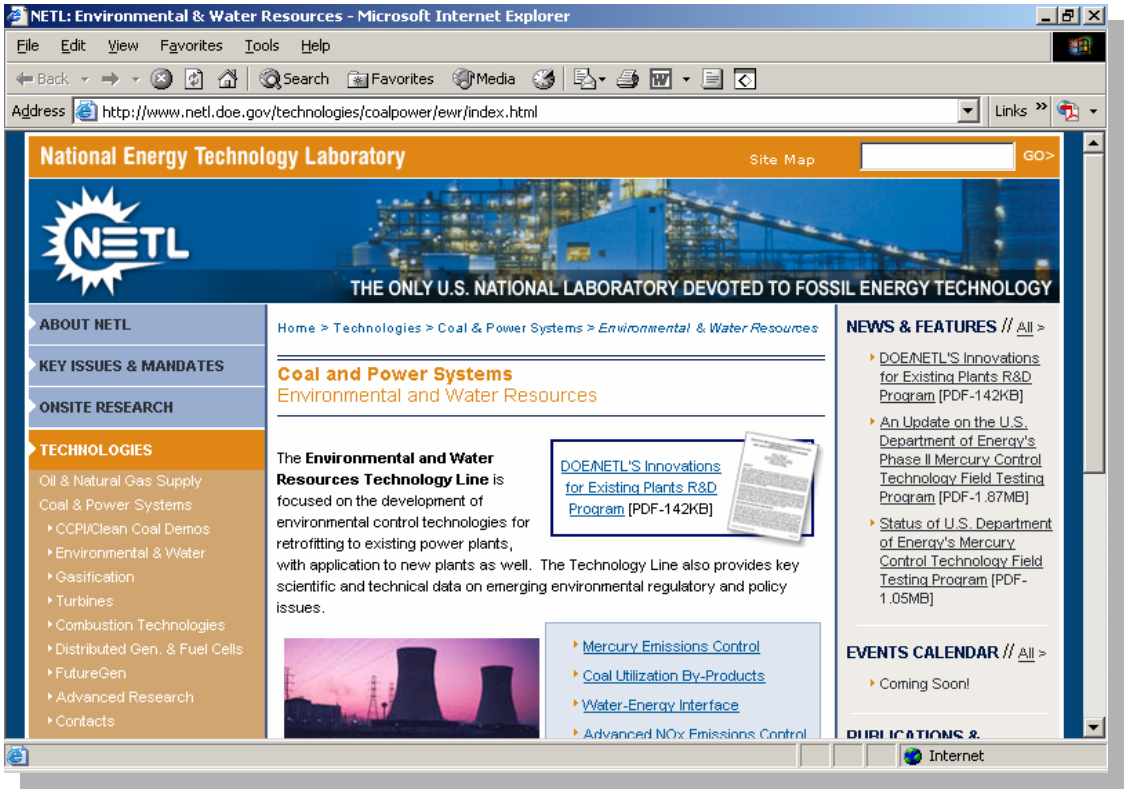


[a] For units equipped with CS-ESP, byproduct impacts include the fly ash disposal cost ($17/ton) and lost revenue from fly ash sales ($18/ton) assuming 100% utilization. For the SDA/FF configuration, only the cost of SDA byproduct disposal is included.

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 BOP issues and impacts of sulfur/SO_3 and small SCA ESP on ACI effectiveness**
- **Potential coal combustion byproduct impacts on cost of mercury control remain a “wild card”**
- **DOE’s RD&D model projects broad commercial availability in 2012-2015**

DOE/NETL Environmental and Water Resources (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/technologies/coalpower/ewr/index.html