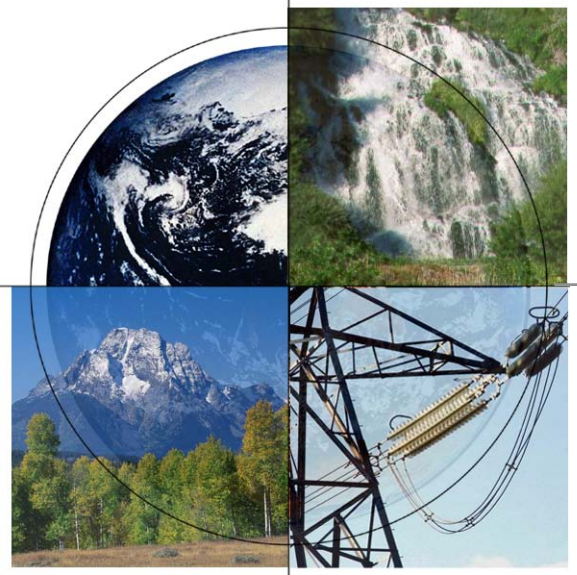
DOE-NETL's Mercury Control Technology R&D Program for Coal-Fired Power Plants



Mercury Emissions from Coal 1st International Experts' Workshop

May 12-13, 2004
Glasgow, Scotland

Thomas J. Feeley, III
thomas.feeley@netl.doe.gov
National Energy Technology Laboratory

Presentation Outline

- **Who is NETL**
- Why mercury control?
- NETL mercury control R&D
- NETL coal utilization by-products R&D

National Energy Technology Laboratory

- **One of DOE's 17 national labs**
- **Government owned / operated**
- **Sites in:**
  - Pennsylvania
  - West Virginia
  - Oklahoma
  - Alaska
- **More than 1,100 federal and support contractor employees**

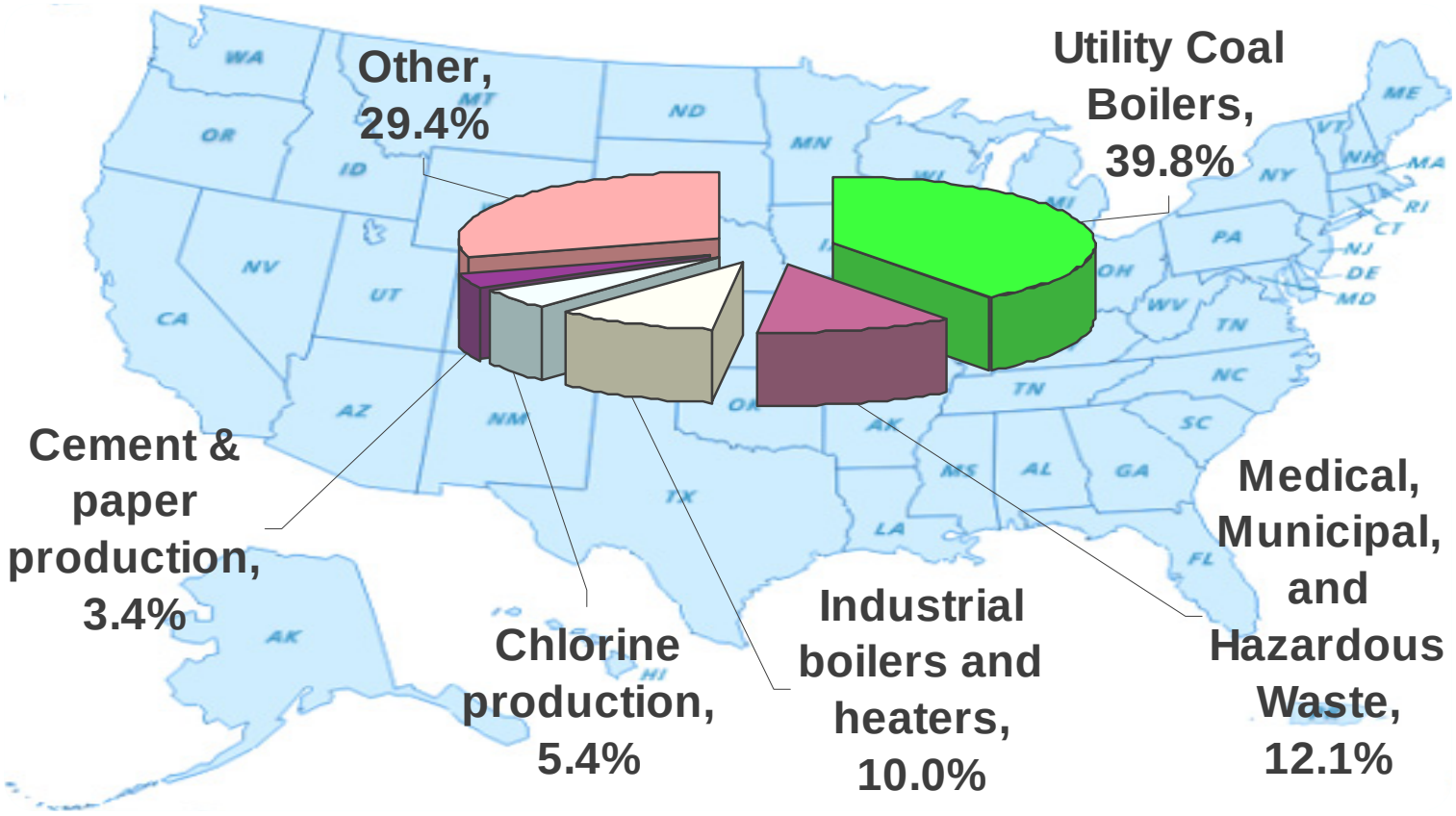
Innovations for Existing Plants
Program Components

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

Presentation Outline

- Overview of NETL
- **Why mercury control?**
- NETL mercury control R&D
- NETL coal utilization by-products R&D

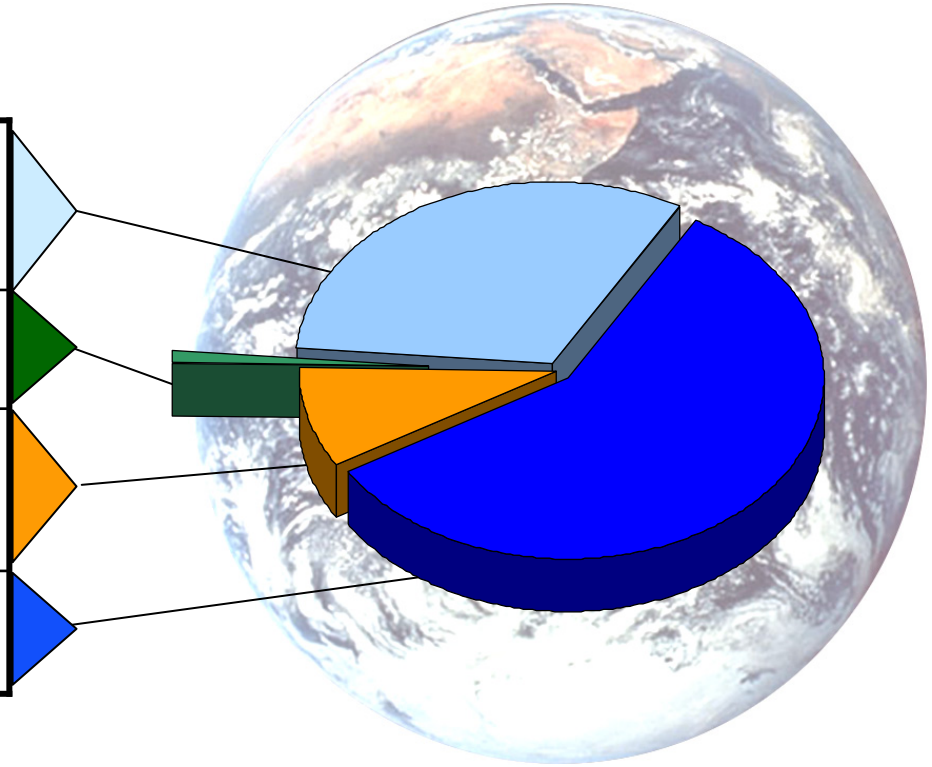
Estimated U.S. Anthropogenic Mercury Emissions in 1999



Source: Personal communication with U.S. EPA 7/16/03 1999 NEI Version 3.0

Global Mercury Emissions

Emissions from Natural Sources (Volcanoes, Forest Fires, etc.)	**1540 tons**
U.S. Coal-Fired Power Plants	**48 tons**
Re-Emission of Prior Anthropogenic Emissions	**440 tons**
New Anthropogenic Emissions*	**2820 tons**



*Note: Does not include U.S. Coal-Fired Power Plant Emissions

FACT: It is estimated that U.S. coal-fired power plants emit approximately 1% of annual global mercury emissions

Source: UNEP Global Mercury Assessment, December 2002

Presentation Outline

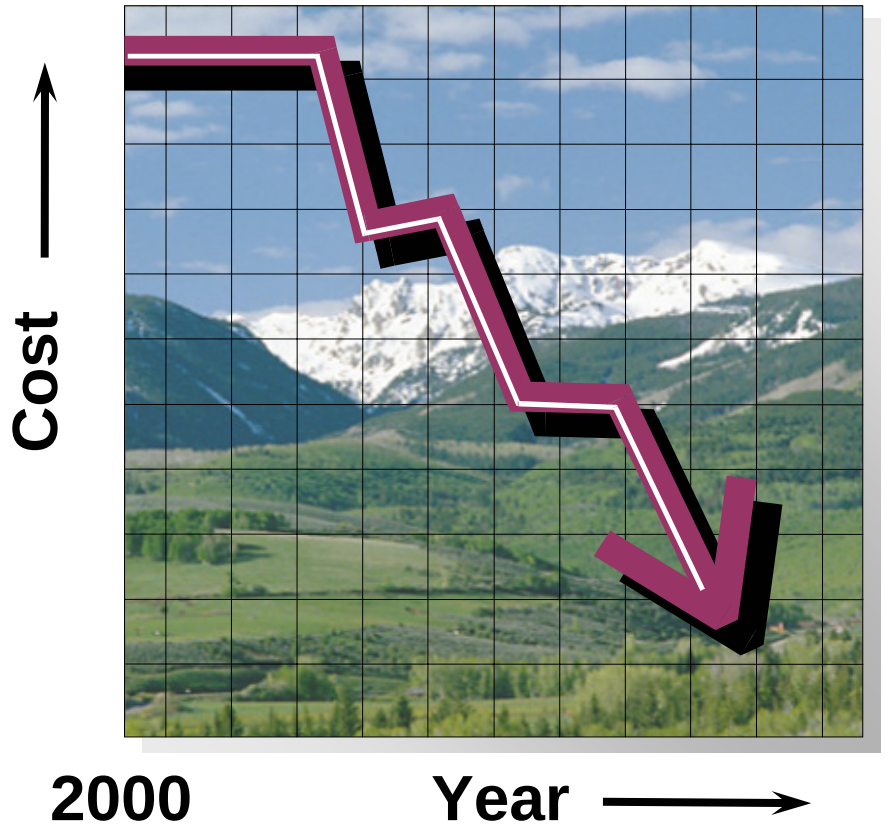
- Overview of NETL
- Why mercury control?
- **NETL mercury control R&D**
- NETL coal utilization by-products R&D

DOE-NETL Mercury Control Program

R&D Goals

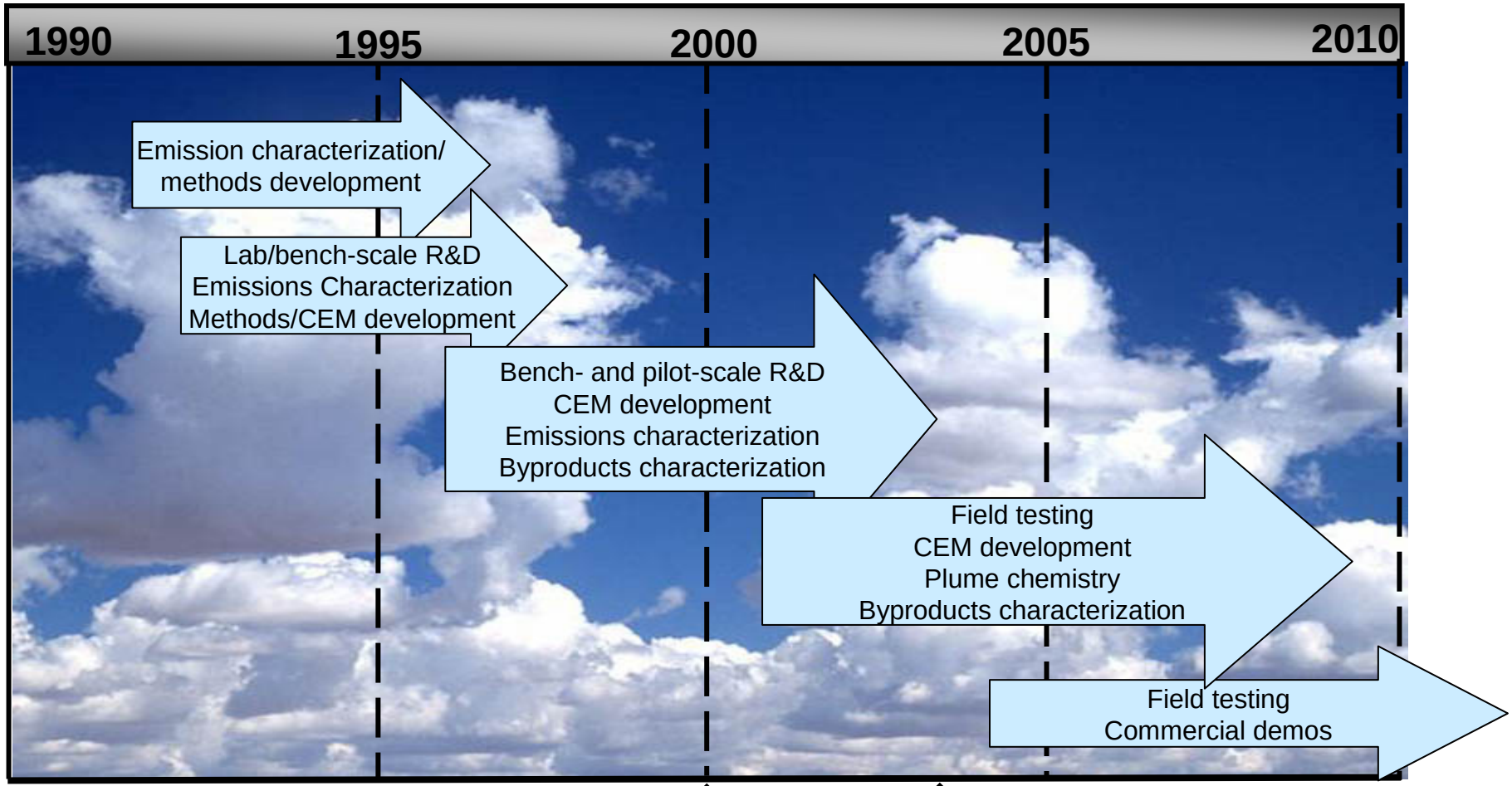
Have control technologies ready for commercial demonstration:

- **Near-term, reduce emissions 50-70%**
  - By 2005 for bituminous coal
  - By 2007 for low-rank coal
- **Long-term, reduce emissions 90% by 2010**
- **Cost 25-50% less than current estimates**

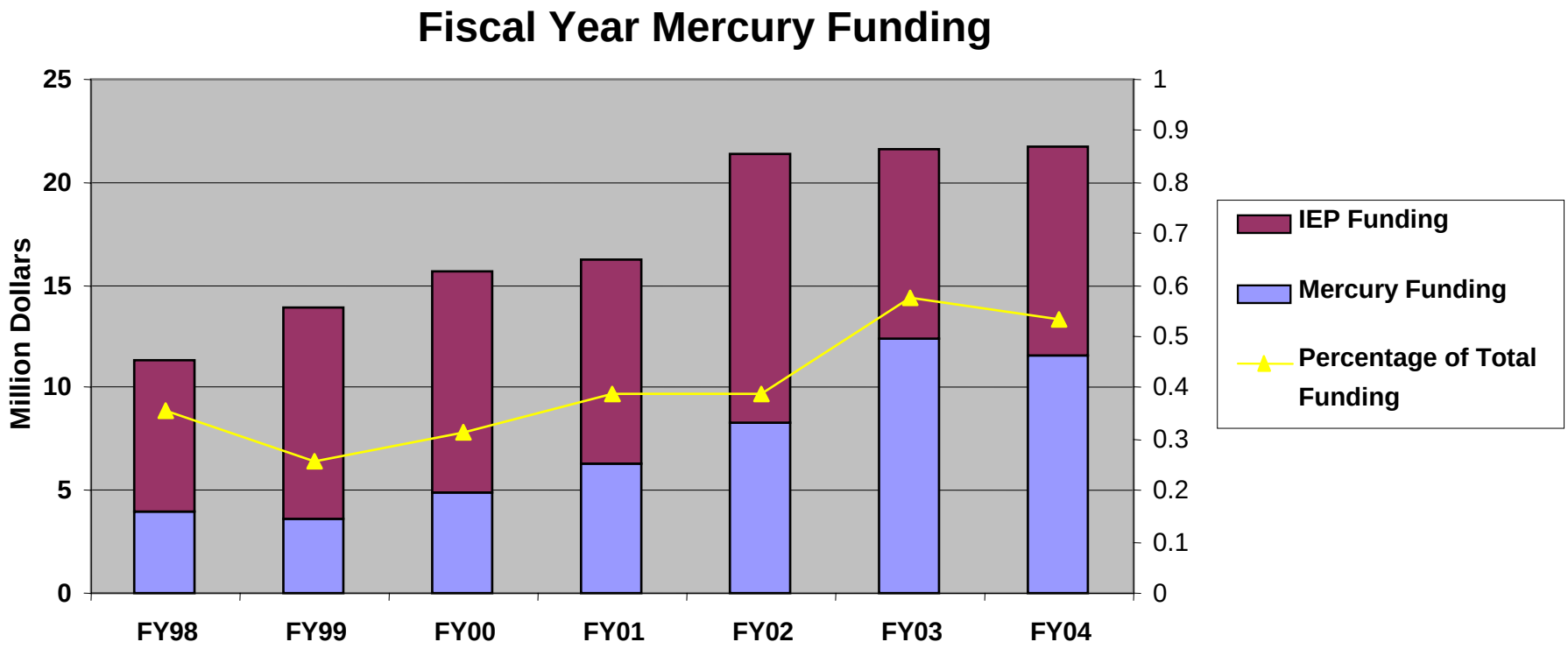


Baseline Costs: $50,000 - $70,000 / lb Hg Removed

Over a Decade of DOE/NETL Hg R&D

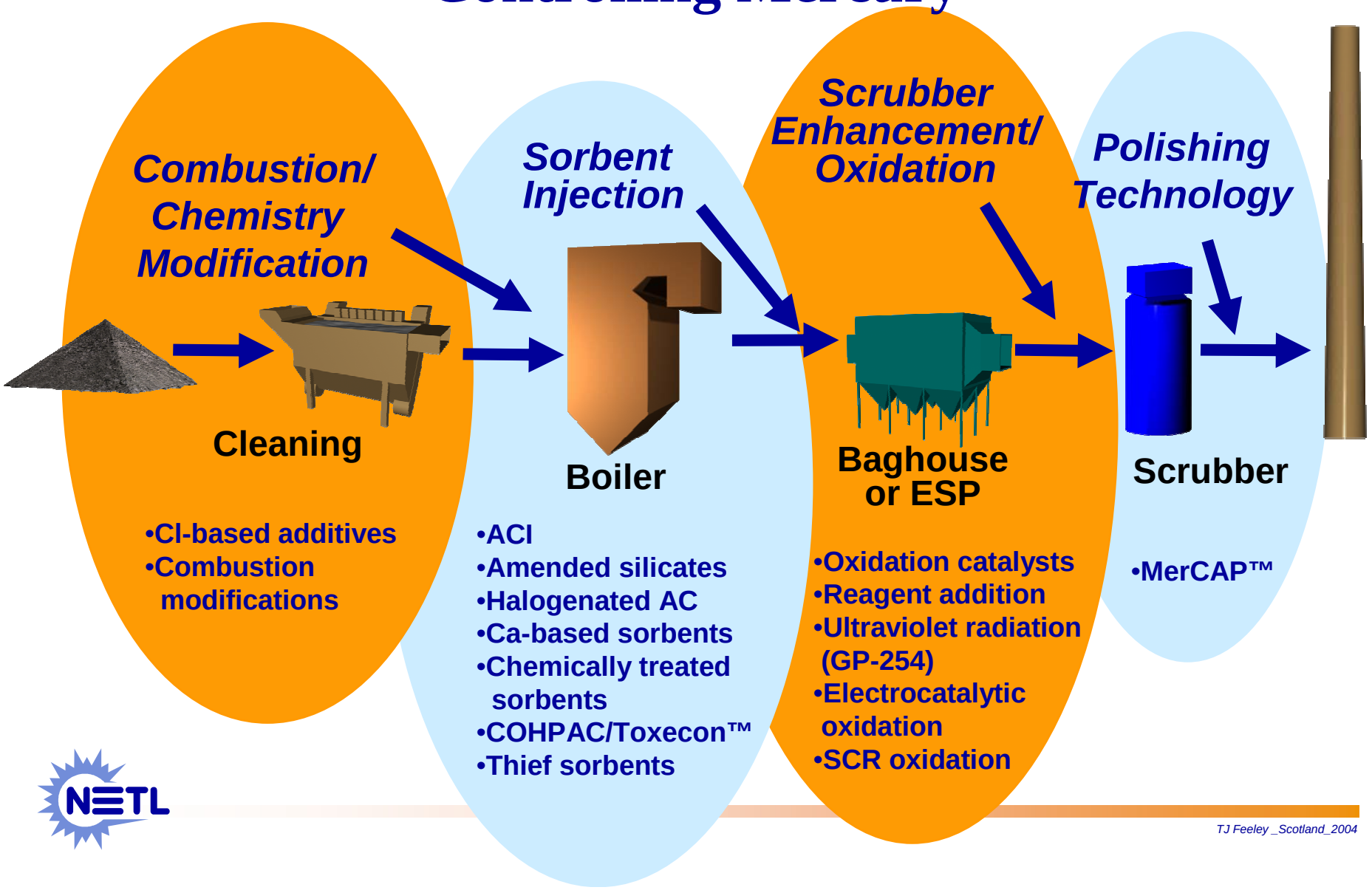


DOE/NETL Funding for Hg R&D



Over $52.5 million spent on mercury R&D over the past seven years!

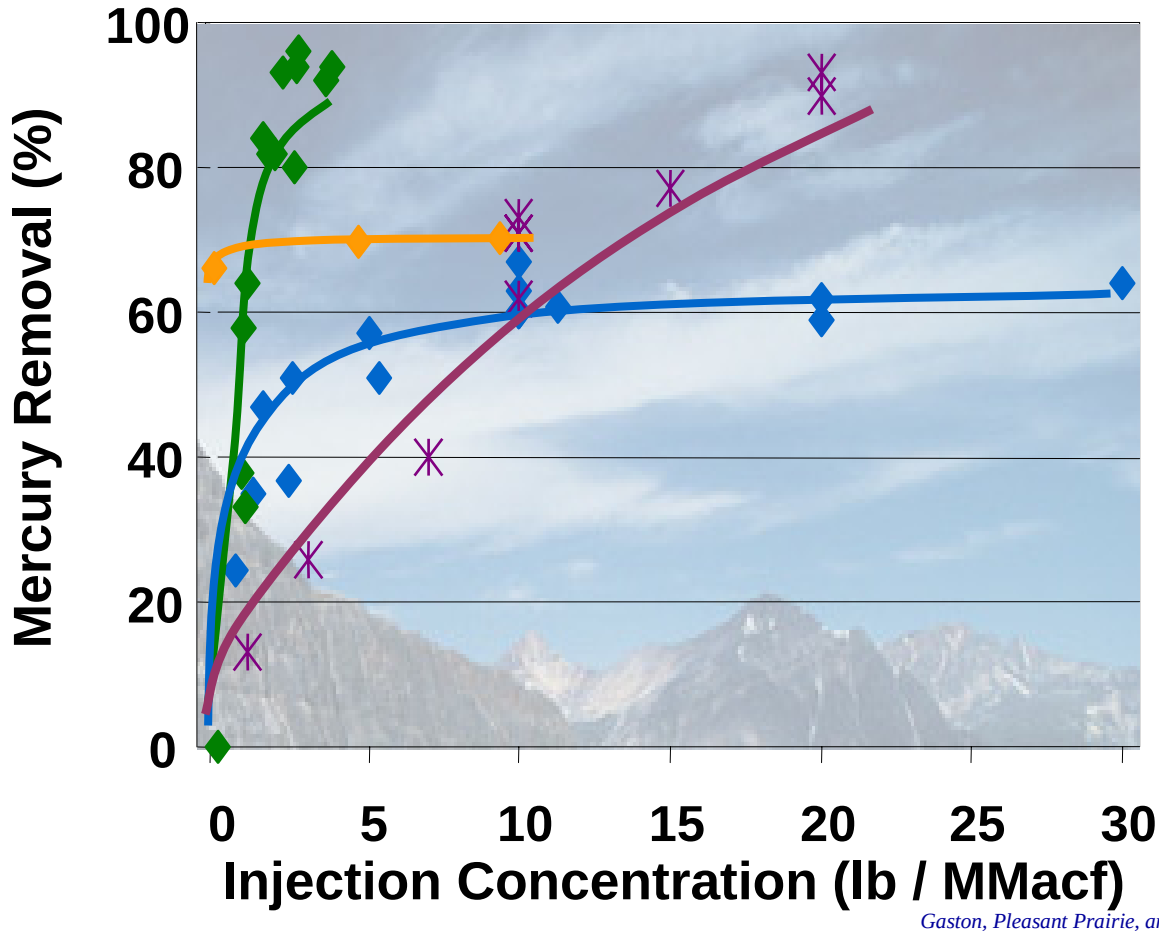
DOE/NETL Funded Approaches for Controlling Mercury



Mercury Field Testing 2001-02

Technology / Utility Plant	Test Completion
ADA-ES – Sorbent Injection	
Alabama Power – Gaston	April 2001
We Energies – Pleasant Prairie	November 2001
PG&E – Brayton Point	August 2002
PG&E – Salem Harbor	November 2002
McDermott-B&W – Enhanced Scrubbing	
Michigan South Central Power – Endicott	October 2001
Cinergy – Zimmer	November 2001

ADA-ES Phase I Field Test Results
Activated Carbon Injection



Gaston:
Bituminous coal,
ESP + fabric filter

Salem Harbor:
Bituminous coal, ESP
(gas temp. at 280-290 °F)

Pleasant Prairie:
Subbituminous coal, ESP

Brayton Point:
Bituminous coal, ESP

Gaston, Pleasant Prairie, and Brayton Point test data from ADA-ES presentation at August 2002 EPA Utility MACT Working Group meeting.
Salem Harbor test data from ADA-ES technical paper "Results of Activated Carbon Injection Upstream of ESP for Mercury Control" presented at May 2003 Mega Symposium.

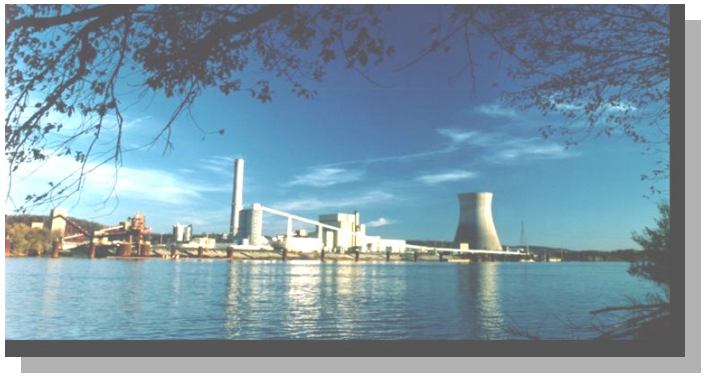
McDermott Technology and B&W
Enhanced Mercury Control in Wet FGD

Michigan South Central Power's Endicott Plant

- 60 MW
- High-sulfur bituminous coal
- ESP
- Limestone wet FGD

Cinergy's Zimmer Plant

- 1300 MW
- High-sulfur bituminous coal
- ESP
- Magnesium-enhanced wet FGD



McDermott Technology and B&W

Phase I Enhanced Mercury Control in Wet FGD

Wet FGD Mercury Removal,%

MSCP's Endicott Plant		
Mercury Species	Baseline	Reagent*
Total	~ 60%	76%
Oxidized	~ 90%	93%
Elemental	~ (40%)	20%

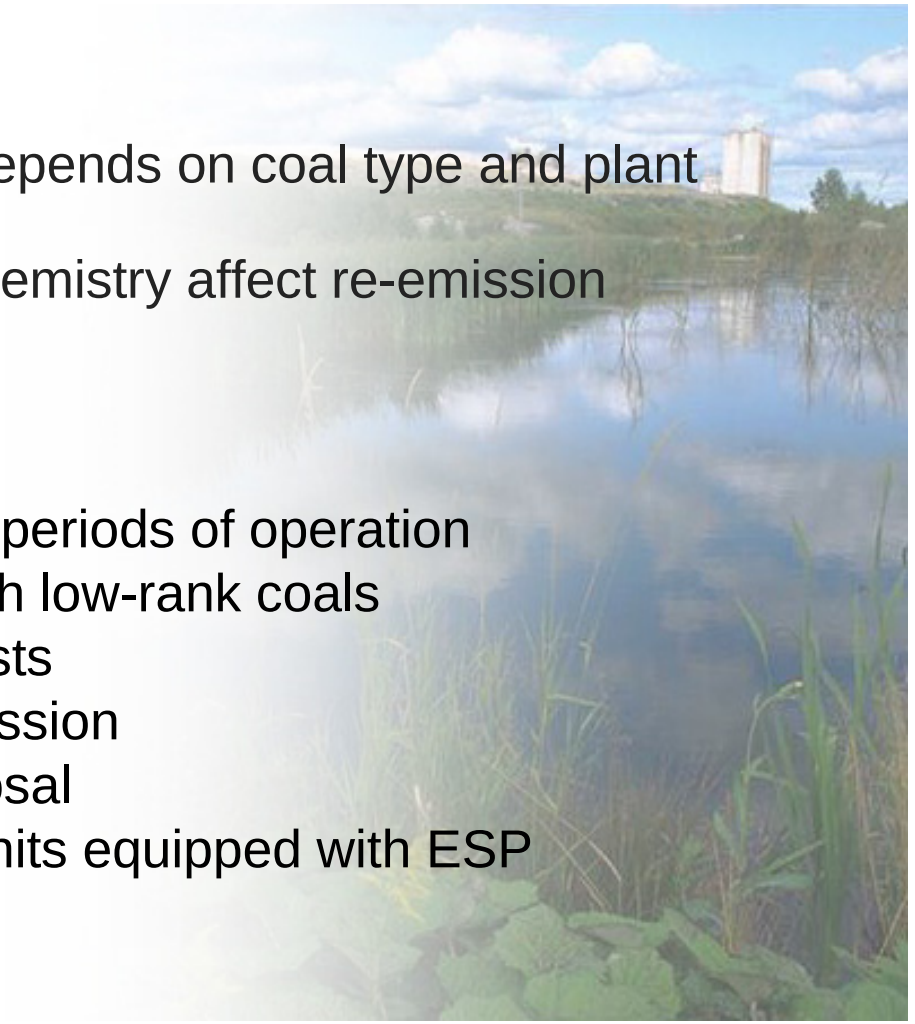
Cinergy's Zimmer Plant		
Mercury Species	Baseline	Reagent*
Total	~ 45%	51%
Oxidized	~ 90%	87%
Elemental	~ (20%)	(41%)

***Reagent feed results during two-week verification testing.**

Observations From Phase I Field Tests

- **Hg capture performance**
  - ACI works, however…
    - Effectiveness of ACI depends on coal type and plant configuration
  - Wet scrubber size and chemistry affect re-emission

- **Uncertainties remain**
  - Performance over longer periods of operation
  - Capture effectiveness with low-rank coals
  - Sorbent feed rate and costs
  - FGD Hg reduction/re-emission
  - By-product use and disposal
  - Need for fabric filter for units equipped with ESP
  - Balance-of-plant impacts



Mercury Control Using ACI
Preliminary Cost Estimate

	Activated Carbon Injection System for 500 MW Bituminous Coal-Fired Plant*		
Mercury Removal,%	50%	70%	90% w/ COHPAC
Levelized Cost	Without lost ash sales penalty		
Mills/kWh	0.37	1.27	2.15
$/lb mercury removed**	32,700	46,100	49,000
	With lost ash sales penalty***		
Mills/kWh	2.79	3.69	2.15
$/lb mercury removed**	245,700	133,800	49,000

*Plant equipped with cold-side ESP

**Incremental cost excluding co-benefit ESP mercury capture (36%)

***Penalty includes lost sales revenue ($18/ton) and ash disposal cost ($17/ton).

Note: mills equal to one tenth of a cent.

Mercury Pilot-Scale Testing
Projects Conducted in 2001-03

- **Apogee Scientific**
  - Advanced novel sorbent testing at Midwest Generation's Powerton Plant and We Energies' Valley Plant
- **CONSOL**
  - Evaluate effect of lowering flue gas temperature on Hg capture with ESP at Allegheny Energy's Mitchell Power Station
- **UNDEERC**
  - Sorbent injection testing with Advanced Hybrid Particulate Collector (AHPC) at Otter Tail Power's Big Stone Plant
- **Powerspan**
  - Multi-pollutant control for Hg, SO2, NOx, particulates, and acid gases using electro-catalytic oxidation (ECO) at FirstEnergy's R.E. Burger Plant
- **Southern Research Institute**
  - Evaluate calcium-based sorbents, oxidation additives, and coal blending
- **URS Group**
  - Evaluate fixed-bed oxidation catalysts at Great River Energy's Coal Creek Station and City Public Service of San Antonio's J.K. Spruce Plant

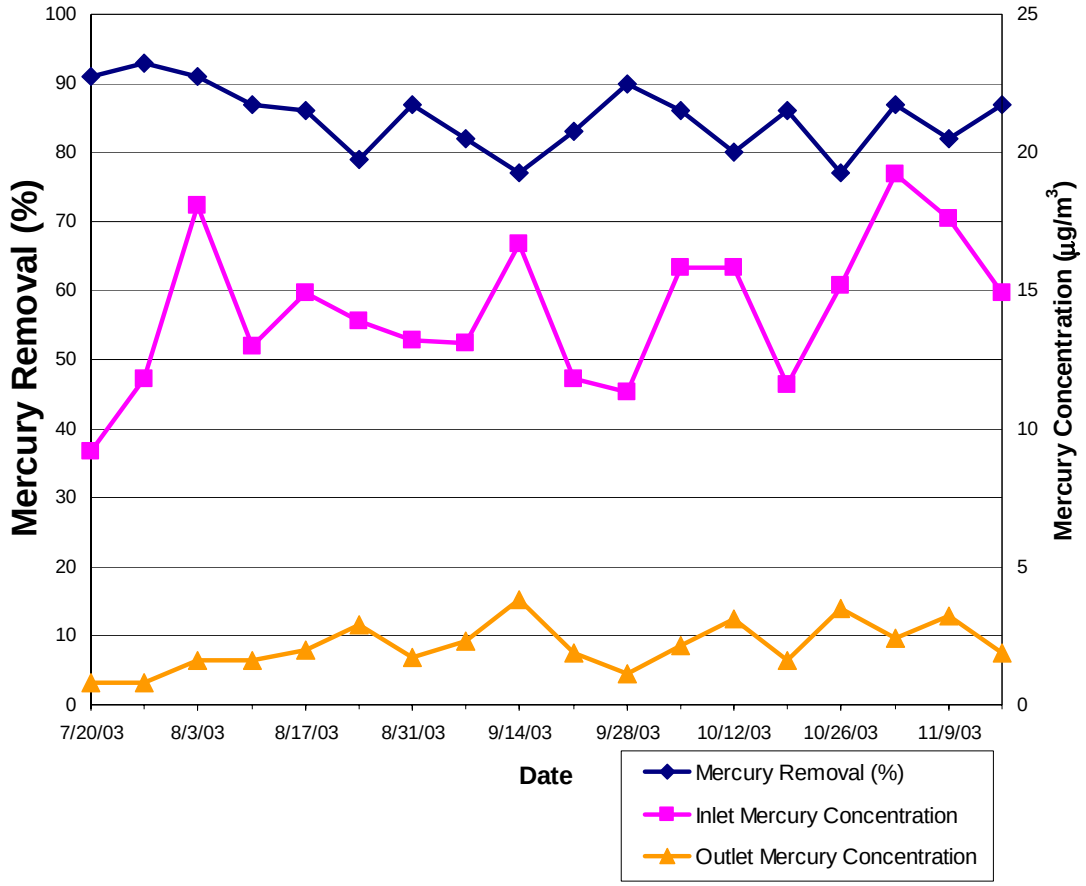
Designed to Achieve ≥ 90% Hg Removal

Additional Field- and Pilot-Scale Testing

Projects Initiated in 2003

- **ADA-ES**
  - Long-term, full-scale sorbent injection test on the COHPAC at Southern's E.C. Gaston Plant
- **General Electric Energy and Environmental Research Corp**
  - Evaluate OFA and coal reburn to optimize mercury removal with an ESP at Western Kentucky Energy's Green Power Station
- **CONSOL**
  - Mercury speciation field testing at several plants equipped with both SCR and wet FGD
- **Reaction Engineering**
  - Pilot-scale mercury oxidation test for several NOx SCR catalysts at AEP's Rockport Power Plant which burns PRB coal
- **UNDEERC**
  - Laboratory and field testing of the potential release of mercury and other air toxics from coal utilization by-products

Long-term Testing at Gaston Station



- **Average Hg Removal**
  - 86 %
- **Average Inlet Concentration**
  - 14 µg/m³
- **Average Outlet Concentration**
  - 2 µg/m³

Average Weekly Data from S-CEM Measurements

DOE/NETL New Phase II, Round 1 Mercury Control Field Test Projects

- Eight new projects selected in September 2003
- Focus on longer-term, large-scale field testing
- Broad range of coal-rank and air pollution control device configurations
- Sorbent injection & mercury oxidation control technologies

DOE/NETL New Phase II, Round 1 Mercury Control Field Test Projects

Project Title	Lead Company	Preliminary Test Schedule*	Host Utility	Test Location	Coal Rank	PM	FGD
Evaluation of Sorbent Injection for Mercury Control	ADA-ES	3/04 - 6/04	Sunflower Electric	Holcomb	PRB/Bit. Blend	FF	SDA
		8/05 - 11/05	Ontario Power	Nanticoke	PRB/Bit. Blend	ESP	---
		8/04 - 11/04	AmerenUE	Meramec	PRB	ESP	---
		3/05 - 6/05	AEP	Conesville	Bit.	ESP	Wet FGD
Amended Silicates for Mercury Control	Amended Silicates	9/04 - 10/04	Cinergy	Miami Fort 6	Bit.	ESP	---
Sorbent Injection for Small ESP Mercury Control	URS Group	3/04 & 9/04 - 10/04	Southern	Yates 1	Bit.	ESP	Wet FGD
			Southern	Yates 2	Bit.	ESP w/ NH_3/SO_3	---
Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems	URS Group	6/04 - 7/05	TXU	Monticello 3	TX Lignite	ESP	Wet FGD
		2/05 - 3/06	Duke	Marshall	Bit.	ESP	---
Evaluation of MerCAP for Power Plant Mercury Control	URS Group	2/04 - 8/04	Great River Energy	Stanton 10	ND Lignite	FF	SDA
		1/05 - 6/05	Southern	Yates 1	Bit.	ESP	Wet FGD
Enhancing Carbon Reactivity in Mercury Control in Lignite-Fired Systems	UNDEERC	4/04 - 6/04	Basin Electric	Leland Olds 1	ND Lignite	ESP	---
		9/04 - 10/04	Great River Energy	Stanton 10	ND Lignite	FF	SDA
		4/05 - 6/05	Basin Electric	Antelope Valley 1	ND Lignite	FF	SDA
		4/04 - 5/04	Great River Energy	Stanton 1	ND Lignite	ESP	---
Mercury Oxidation Upstream of an ESP and Wet FGD	UNDEERC	6/05 - 8/05	Minnkota Power	Milton R. Young 2	ND Lignite	ESP	Wet FGD
		8/05 - 9/05	TXU	Monticello 3	TX Lignite	ESP	Wet FGD
Advanced Utility Mercury-Sorbent Field-Testing Program	Sorbent Technolgies	1/05 - 4/05	Duke	Buck	Bit.	Hot ESP	---
		6/04 - 9/04	Detroit Edison	St. Clair	Bit./PRB blend	ESP	---

* These are preliminary test schedules subject to change based on plant availability.

Phase II Hg Field Testing Program

Hg Control Approach	Host Sites	Coal Types	Downstream Control Equipment
Activated carbon injection (ACI)	5	PRB, Bit., PRB/Bit. blend	FF, ESP, ESP w/ NH_3/SO_3 inj.
Amended silicates	1	Bituminous	ESP
Oxidation catalyst	2	TX lignite, bituminous	ESP, ESP/wet FGD
Chemical inject. w/ ACI, chem. mod. ACI	4	ND lignite	ESP, FF/SDA
Chlorine injection	2	ND lignite, TX lignite	ESP/wet FGD
Fixed structure gold sorbent	2	ND lignite, bituminous	FF/SDA, ESP/wet FGD
Halogenated ACI	2	Bit., bit/PRB blend	HSESP, ESP

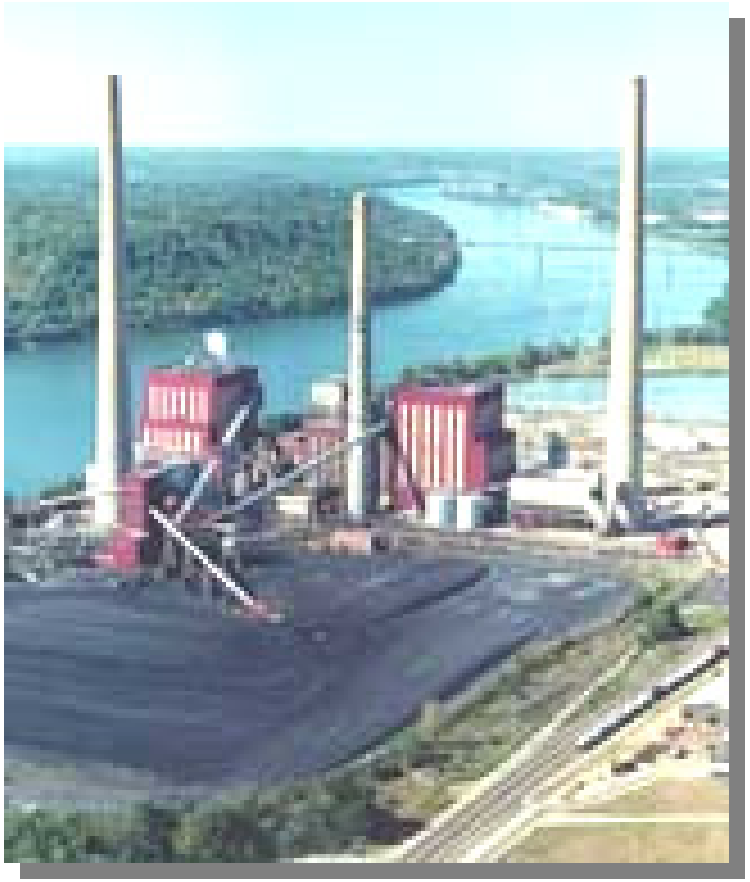
Evaluation of Sorbent Injection for Mercury Control - *ADA-ES*

- **Evaluate full scale sorbent injection with existing pollution-control equipment at four plants**

  - **Sunflower Electric's Holcomb Station**
    PRB/Bit coal blend and equipped with SDA/FF
  - **Ontario Power's Nanticoke Station**
    PRB/Bit coal blend and equipped with ESP
  - **AmerenUE's Meramec Station**
    PRB and equipped with ESP
  - **AEP's Conesville Station**
    Bituminous coal and equipped with ESP and wet FGD

Amended Silicates for Mercury Control - *Amended Silicates, LLC*

- **Joint venture of ADA Technologies and CH2M Hill**
- **Evaluate a new non-carbon sorbent - Amended Silicates™**
- **Avoid impact on fly ash sales**
- **Full-scale testing at Cinergy's Miami Fort Unit 6**
  - Burns bituminous coal and equipped with ESP



Sorbent Injection for Small ESP Mercury Control - *URS Group*

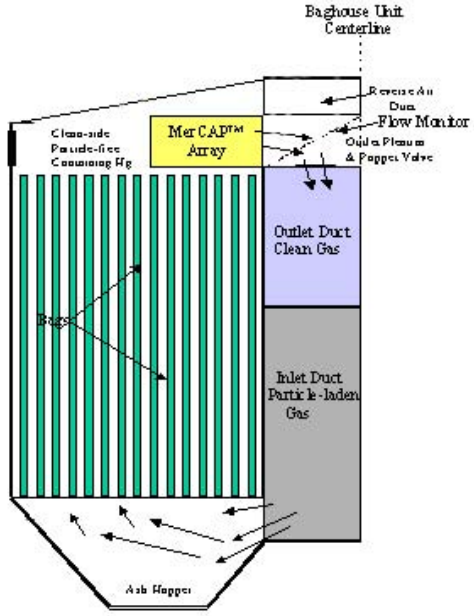
- **Evaluate sorbents injected upstream of ESP with small specific collection area (SCA)**
- **Full-scale testing at Southern Company Services' Plant Yates Unit 1 & 2**
  - Burns bituminous coal
  - Unit 1 equipped with ESP and wet FGD
  - Unit 2 equipped with ESP and NH_3/SO_3 conditioning

Pilot Testing of Mercury Oxidation Catalysts for Upstream of Wet FGD Systems - *URS Group*

- **Evaluate honeycomb catalyst system for oxidizing elemental mercury to enhance Hg removal in downstream wet lime or limestone FGD systems**
- **Testing at two plants equipped with ESP and wet FGD**
- **TXU Monticello Unit 3**
  - Burns Texas lignite
- **Duke Energy's Marshall Station**
  - Burns low-sulfur bituminous coal

Evaluation of MerCAP for Power Plant Mercury Control - *URS Group*

- **Evaluate EPRI's Mercury Control via Adsorption Process (MerCAP™) technology**
- **Regenerable, gold-coated fixed-structure sorbent**
- **Great River Energy's Stanton Unit 10**
  - Burns ND lignite coal and equipped with SDA/FF (Full-scale at 6 MW equivalent)
- **Southern's Plant Yates Unit 1**
  - Burns bituminous coal and equipped with ESP and wet FGD (Pilot-scale at 1 MW)



Enhancing Carbon Reactivity in Mercury Control in Lignite-Fired Systems - *UNDEERC*

- **Enhance effectiveness of activated carbon injection at four plants burning low-rank North Dakota lignite**
  - Use of chlorine-based additive to coal and activated carbon sorbent
  - Use of chemically treated sorbents
- **Basin Electric's Leland Olds Station Unit 1**
  - Equipped with ESP
- **Basin Electric's Antelope Valley Station Unit 1**
  - Equipped with SDA/FF
- **Great River Energy's Stanton Station Unit 1**
  - Equipped with ESP
- **Great River Energy's Stanton Station Unit 10**
  - Equipped with SDA/FF

Mercury Oxidation Upstream of an ESP and Wet FGD - *UNDEERC*

- **Evaluate chloride-based additive to increase mercury oxidation upstream of ESP and wet scrubber**
- **Full-scale testing at two plants burning lignite coal and equipped with both ESP and wet FGD**
  - **Minnkota Power Cooperative's Milton R. Young Unit 2**
    - Burns ND lignite
  - **TXU Monticello Unit 3**
    - Burns TX lignite

Advanced Utility Mercury Sorbent Field-Testing - *Sorbent Technologies*

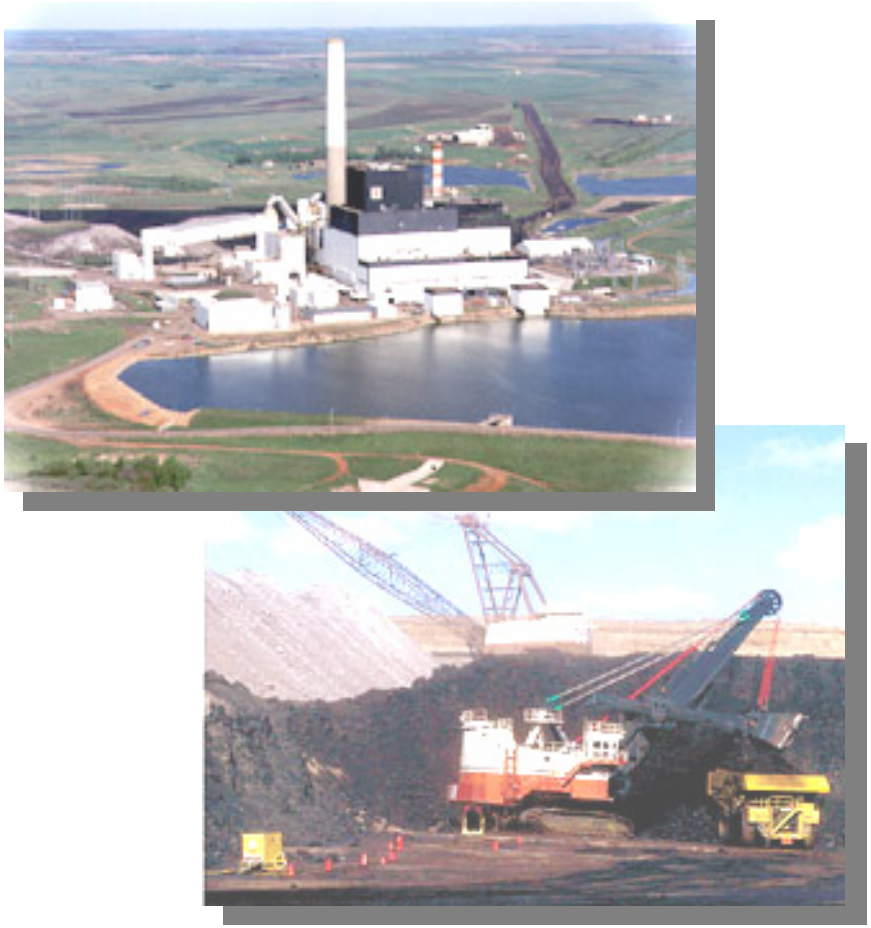
- **Evaluate new halogenated activated carbon sorbent in full-scale testing at two plants**

- **Duke Energy's Buck or Allen Station**
  - Burn bituminous coal
  - Hot-side ESP at Buck
  - Cold-side ESP at Allen

- **Detroit Edison's St. Clair Station**
  - Burns mixture of bituminous and subbituminous coal and equipped with cold-side ESP

DOE/NETL New Phase II, Round 2 Mercury Control Field Test Projects

- **Proposals due by end of April 2004**
- **Focus on technologies for plants that burn low-rank coal**
  - Powder River Basin
  - Texas Lignite
  - Coal blends

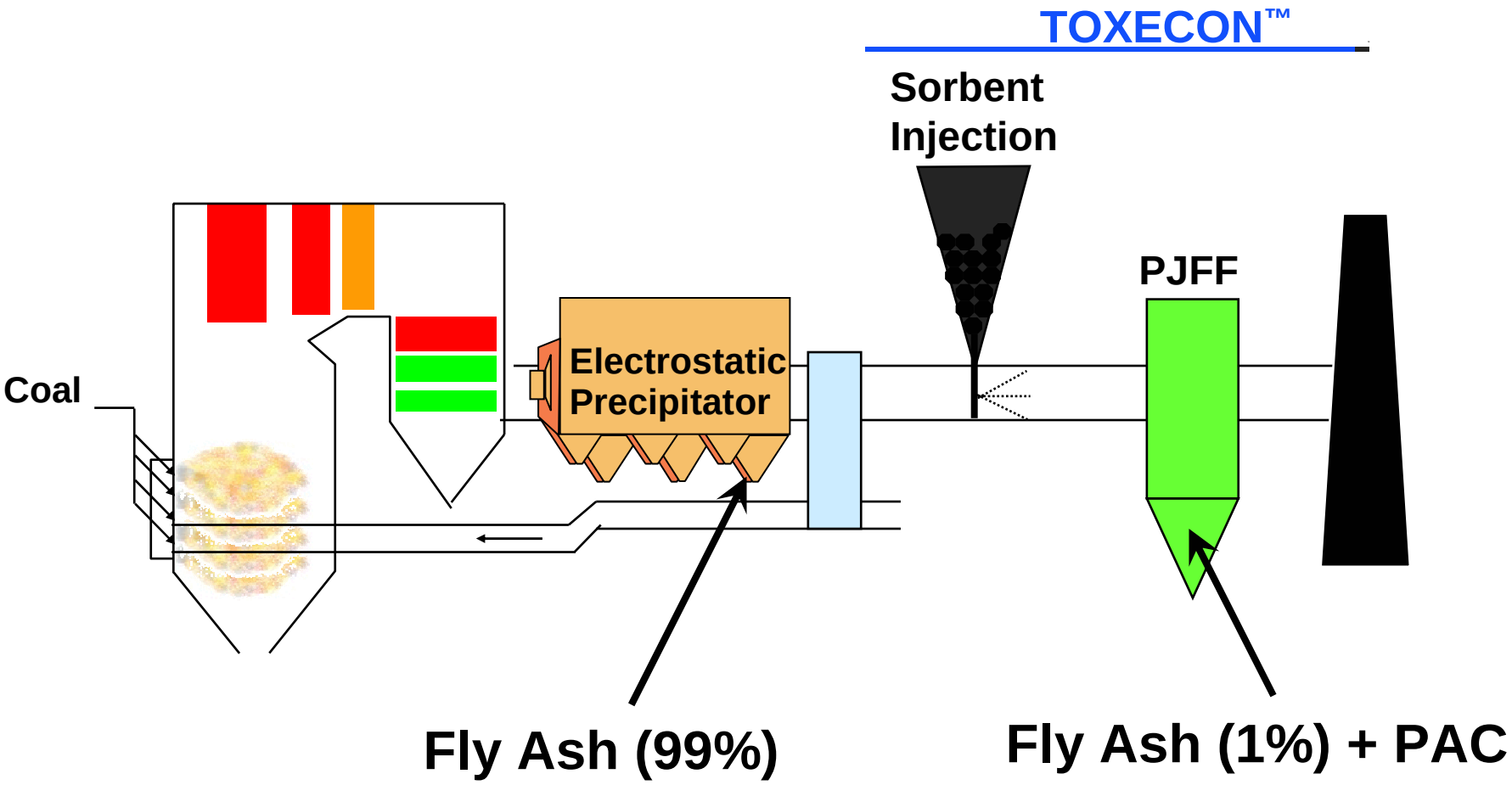


Toxecon™ Retrofit for Mercury and Multi-Pollutant Control – CCPI Demonstration Project

- **Demonstrate:**
  - Multi-pollutant control with PRB coal
    - 90% Hg reduction
    - 70% SO_2 reduction
    - 30% NOx reduction
  - Hg recovery from sorbent
  - Hg CEM performance

We Energies Presque Isle Power Plant

TOXECON™ Configuration

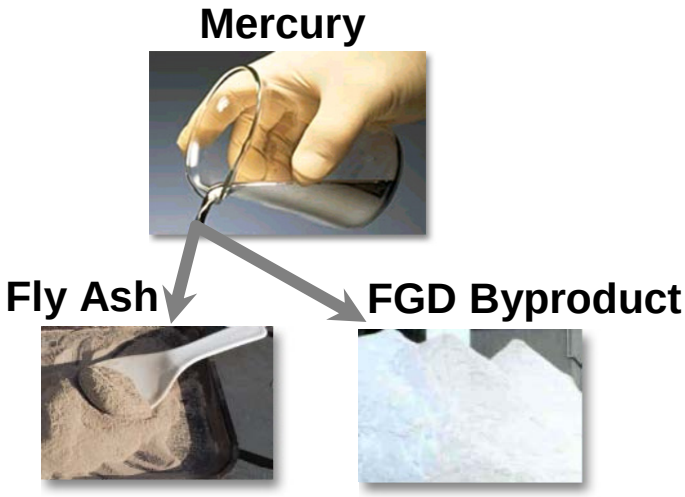


Presentation Outline

- Overview of NETL
- Why mercury control?
- NETL mercury control R&D
- **NETL coal utilization by-products R&D**

Challenges to Increased CUB Utilization

- **Future air pollution regulations, e.g., Clear Skies, Mercury MACT**
  - Increase volume of coal utilization by-products
  - Change characteristics (i.e., quality) of by-products



- **Future solid waste regulations under RCRA?**
  - Limit use applications
  - Regulate coal utilization by-products as hazardous
- **Public perception**

Hazardous Waste Designation of All By-products Could Cost $11 Billion / Year

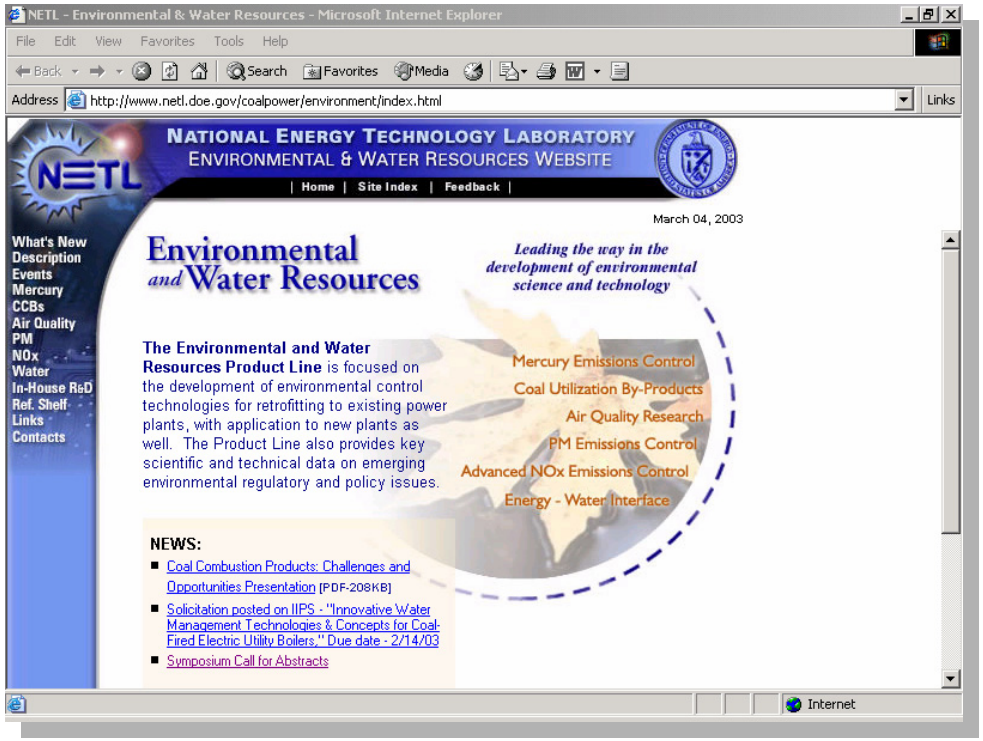
NETL External Projects Addressing the Environmental Characterization of CUBs

- **Fate of mercury from control technology field demonstrations**
  - ADA-ES and Reaction Engineering
  - B&W and McDermott Technology
- **Trace element leaching from CUB disposal and utilization applications**
  - CONSOL Energy
  - University of North Dakota Energy & Environmental Research Center (UNDEERC)
  - Electric Power Research Institute (EPRI)
- **Fate of mercury in synthetic gypsum used for wallboard production**
  - US Gypsum

DOE/NETL Hg Control Technology R&D
Future Plans – 5-Year Horizon

Fiscal Year	Major Activities
2005	•Continue Phase II field testing of 50%-70% Hg control technologies •Continue byproduct characterization •Complete pilot-scale testing of +90% control options •Initiate evaluation of pre-combustion Hg control
2006	•Continue Phase II field testing •Continue byproducts characterization •Initiate Phase III field testing of +90% control technologies
2007	•Complete Phase II field testing •Continue byproducts characterization •Continue Phase III field testing
2008	•Continue byproducts characterization •Continue Phase III field testing
2009	•Continue byproducts characterization •Continue Phase III field testing

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:

www.netl.doe.gov/coalpower/environment