Status of Mercury Control Technologies for Coal-Fired Power Plants

By

Ravi K. Srivastava
U.S. Environmental Protection Agency
Office of Research and Development
National Risk Management Research Laboratory

MIT Air Toxics Symposium
August 5, 2004

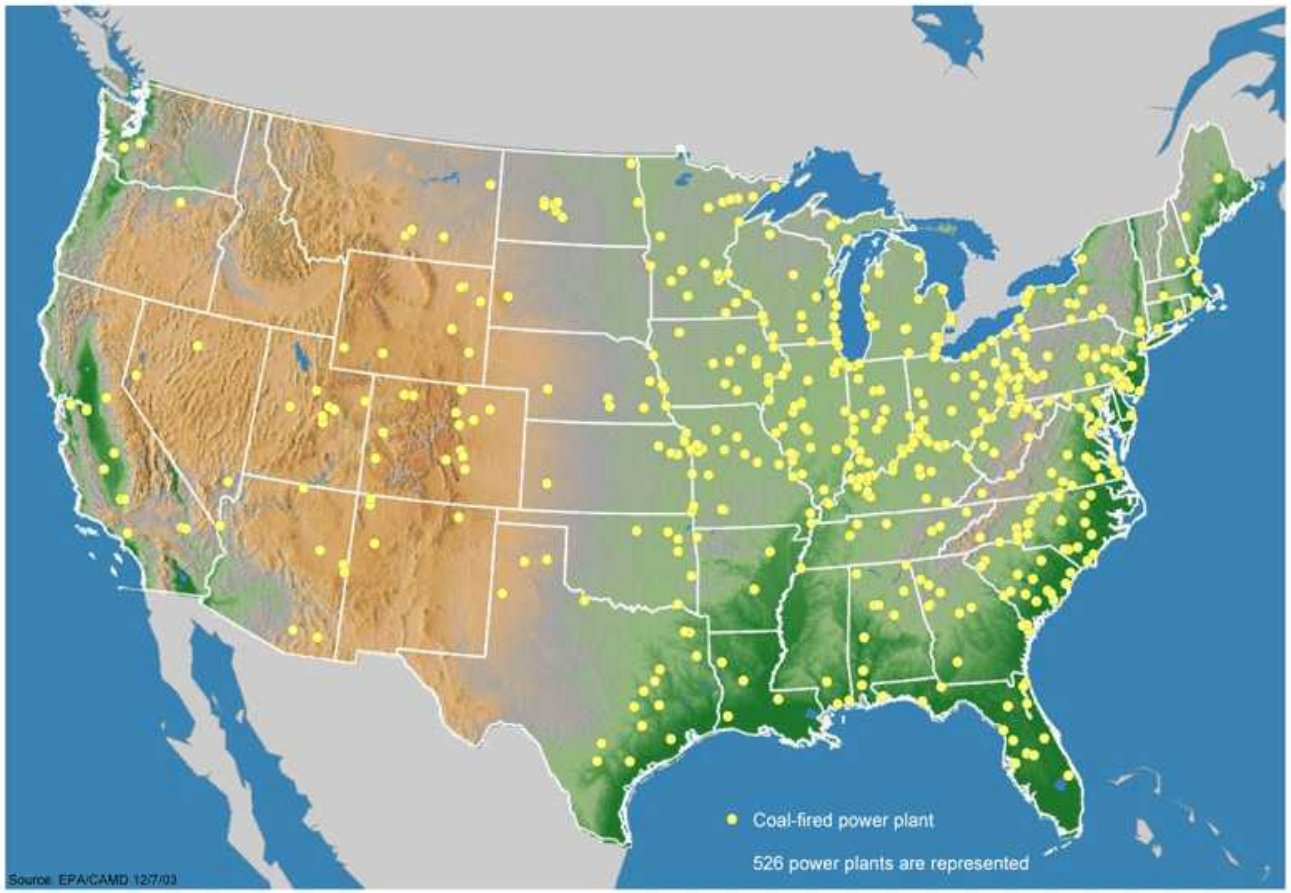
Outline

- Background
  - Mercury (Hg) sources and health impacts
  - Regulatory alternatives
- Mercury speciation and capture
- Mercury control technologies

Background

- Hg known to bioaccumulate in human and animal tissue in its most toxic form: methyl mercury
- Human exposure associated with serious neurological and developmental effects
- EPA regulated municipal waste combustors (MWCs) and medical waste incinerators in 1990s; controlled more than 40 tons
- Coal-fired power plants now major source; 48 tons (1999)
- On January 30, 2004 EPA proposed regulations for power plant Hg control; March 15, 2004 supplemental proposal; presently in comment under review

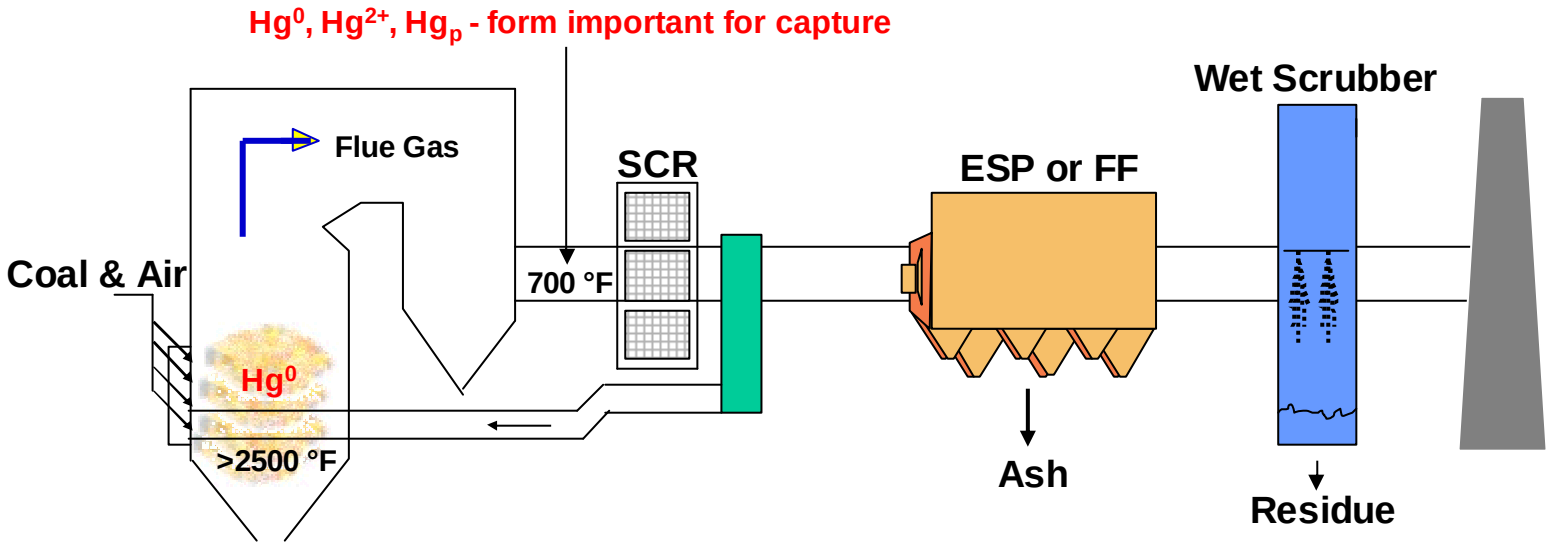
Coal-Fired Power Plants



U.S. Coal-Fired Power Plants

- There are about 530 power plants with 305 GW of capacity that consist of about 1,300 units.
- Coal plants generate the vast majority of power sector emissions:
  - 100% Hg
  - 95% SO_2
  - 90% of NO_X

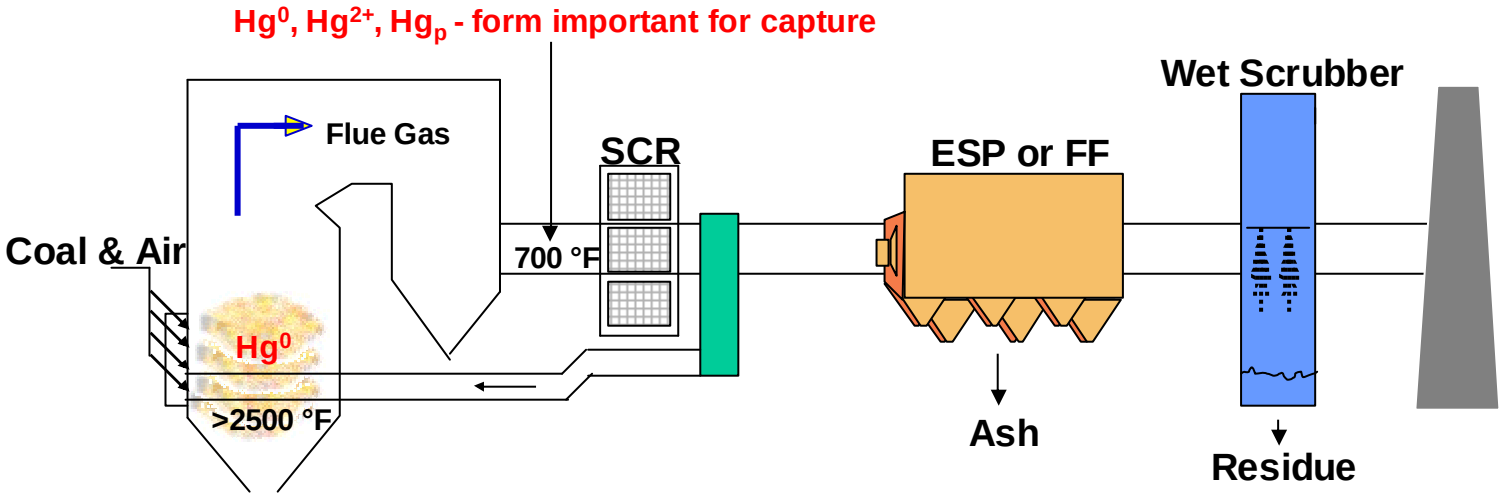
Power Plant Equipment and Mercury



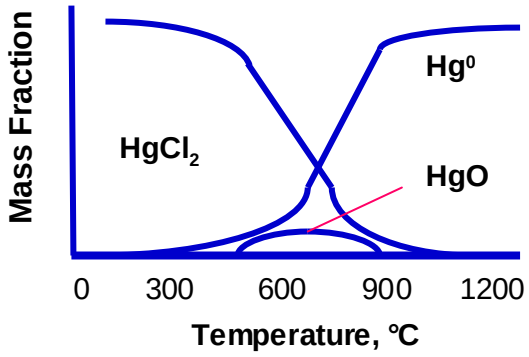
Removal in PM Controls
Mercury adsorbed in fly ash/sorbent, which is captured in ESP or FF; Hg^{2+} compounds are more readily adsorbed than Hg^0

Capture in Wet Scrubbers
Hg^{2+} compounds absorbed in scrubbing solution; Hg^0 is insoluble and cannot be captured; capture enhanced by SCR

Power Plant Equipment and Mercury



Equilibrium Calculations



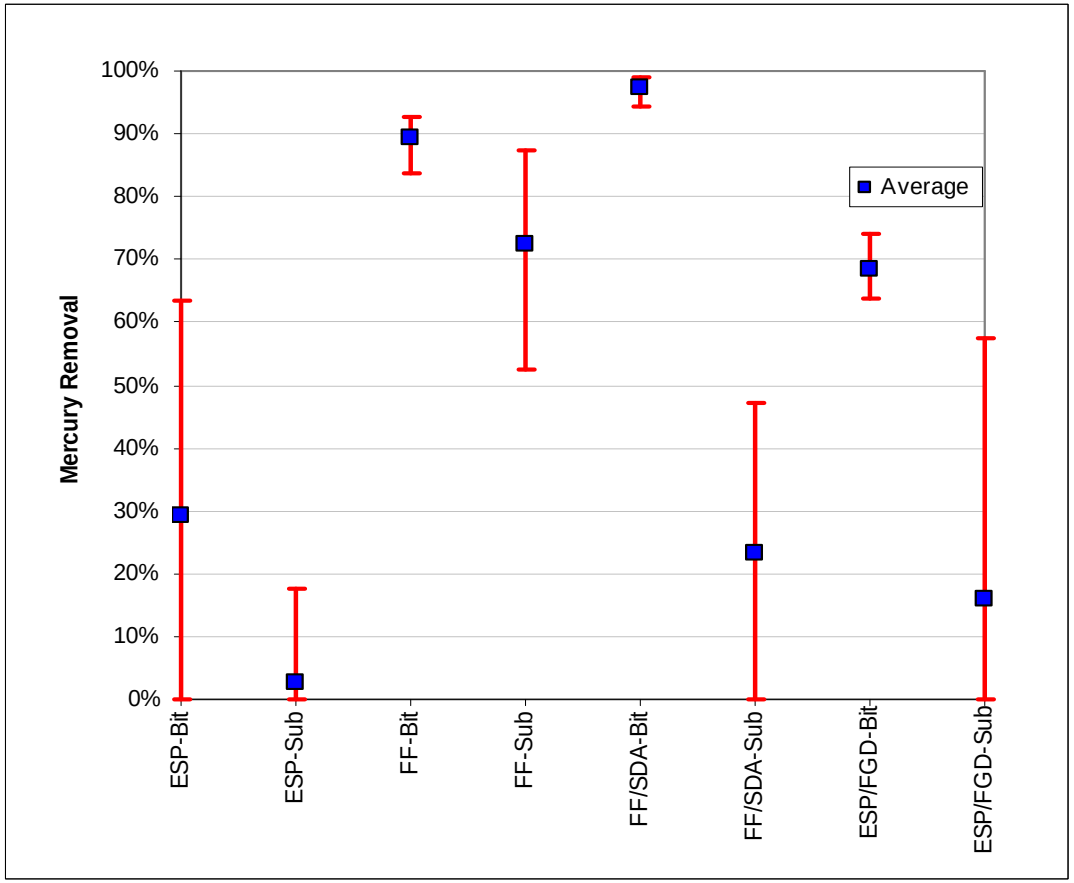
Senior, Boole, Morency, et. al., PSI Final Report, 1997

Mercury speciation is controlled by chemical kinetics

Factors That Influence Mercury Control from Coal-Fired Boilers

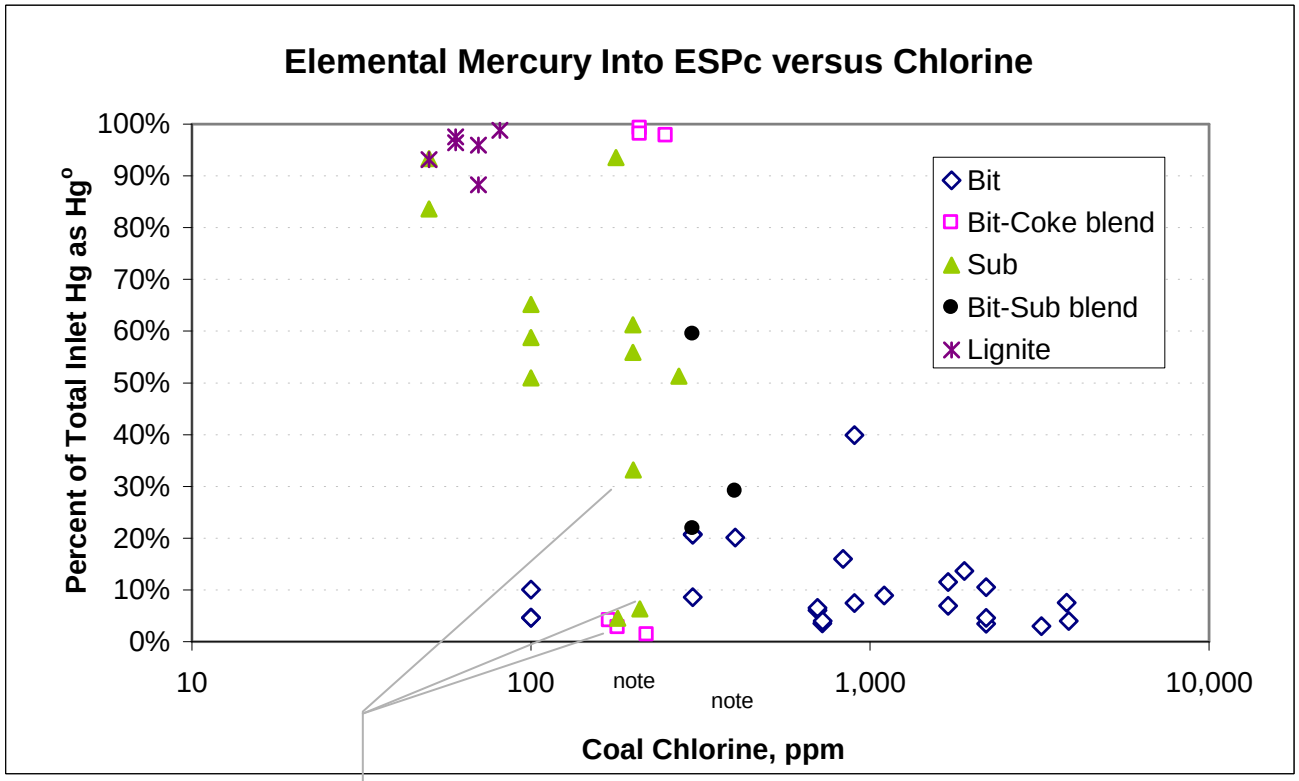
- Coal type
- Time/temperature profile
- Flue gas composition (chlorine) and fly ash characteristics (carbon, calcium, iron, porosity)
- Air pollution controls already in place

ICR Data – Capture in Existing Equipment



- **Higher levels of Hg capture for bituminous coal-fired plants compared to low-rank coal-fired plants**
- **Large ranges of Hg capture observed**
- **Compared to electrostatic precipitators (ESPs), fabric filters (FF) capture higher levels of Hg**
- **Limited data suggested that scrubbers could potentially capture oxidized Hg effectively**

Chlorine vs. Mercury Speciation



ICR data for Hg^0 at ESP inlet

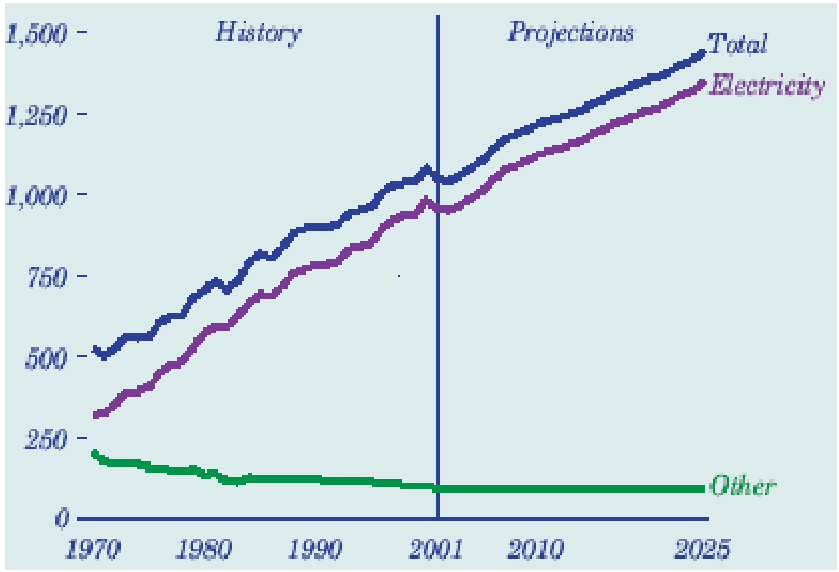
- Hg^0 oxidation appears to be enhanced by chlorine
- Effect of chlorine is significant for all coal types
- Other important factors: temperature, carbon in fly ash

Note: these three subbituminous data points are from a boiler that had recently fired bituminous coal

Looking Ahead - Coal Use

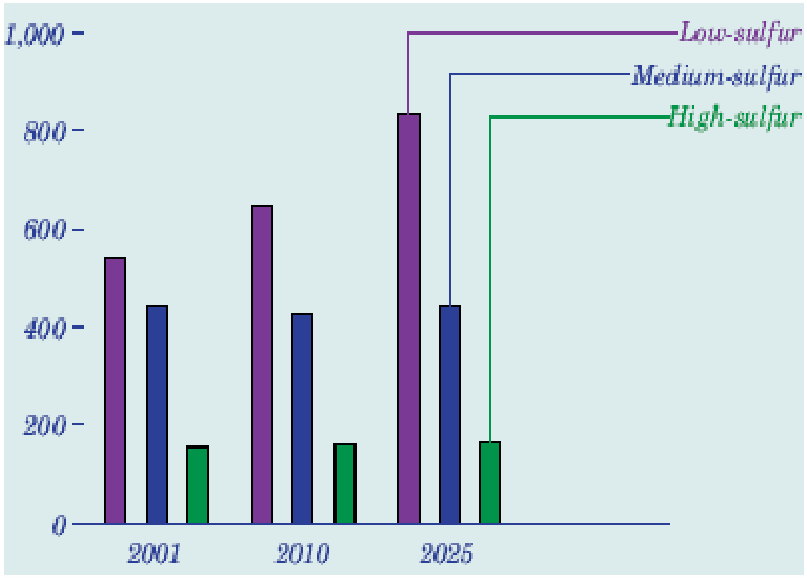
Consumption

(million short tons)



Production

(million short tons)



Consumption of low-sulfur coals in the power generation sector is expected to increase in the future.

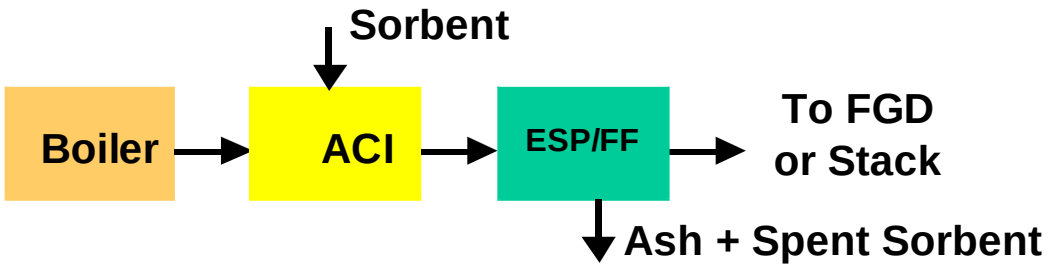
Source: Annual Energy Outlook 2003 with Projections to 2025, DOE/EIA-0383(2003)

Potential Mercury Control Routes

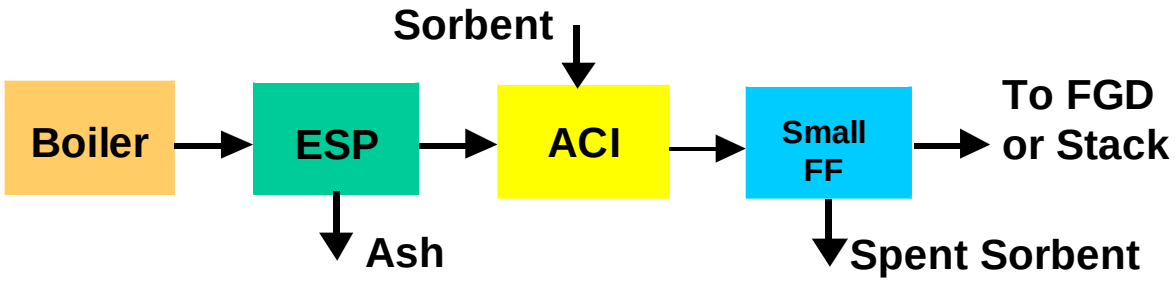
- Emerging add-on Hg controls
  - Activated carbon injection
  - Other sorbents
- Modified (optimized) NO_X, SO_2, and PM controls
- Sorbent injection + optimized NO_X, SO_2, and PM controls

Sorbent Injection

Two approaches:



Or



The extent of capture depends on:

- **Sorbent characteristics (particle size distribution, porosity, capacity at different gas temperatures)**
- **Residence time in the flue gas**
- **Type of PM control (FF vs. ESP)**
- **Concentrations of SO_3 and other contaminants**

Activated Carbon Injection (ACI)

ACI system includes a sorbent storage silo and a sorbent injection system. It may also include an added fabric filter to capture the carbon.

Activated carbon injection system

Activated carbon storage and feed system

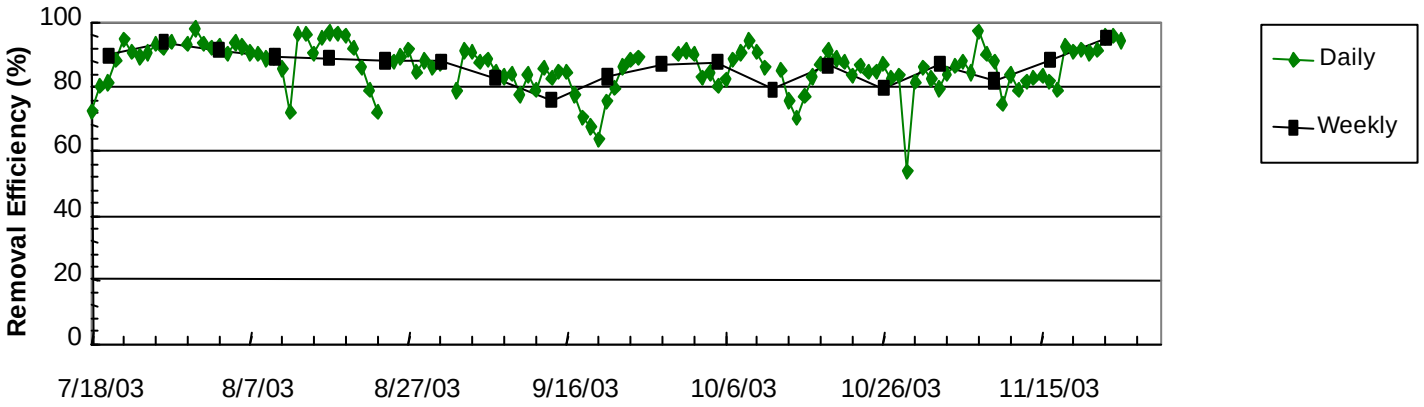
Source: ADA-ES

Initial Short-Term, Full-Scale, ACI Projects

Test Site Information			Mercury Capture, %		
Test Site	**Coal**	**Particulate Control**	**Baseline**	**ACI Test Results**	**Test Duration**
PG&E Brayton Point, Unit 1	Low-sulfur bituminous, Hg = 0.03 ppm, Cl = 2000-4000 ppm	Two ESPs in series	90.8	94.5	ACI for two 5-day periods; 10 lb/mmacf
PG&E Salem Harbor, Unit 1	Low-sulfur bituminous, Hg = 0.03-0.08 ppm, Cl = 206 ppm	ESP	90.8	90	ACI for one 4-day period; 10 lb/mmacf
Wisconsin Electric Pleasant Prairie, Unit 2	Subbituminous, Hg = 0.11 ppm, Cl = 8 ppm	ESP	5.3	66	ACI for one 5-day period; 11.3 lb/mmacf
Alabama Power Gaston, Unit 3	Low-sulfur bituminous, Hg = 0.14 ppm, Cl =169 ppm	ESP + small FF	0	90.6 (78)	ACI for one 9-day period; 1.5 lb/mmacf

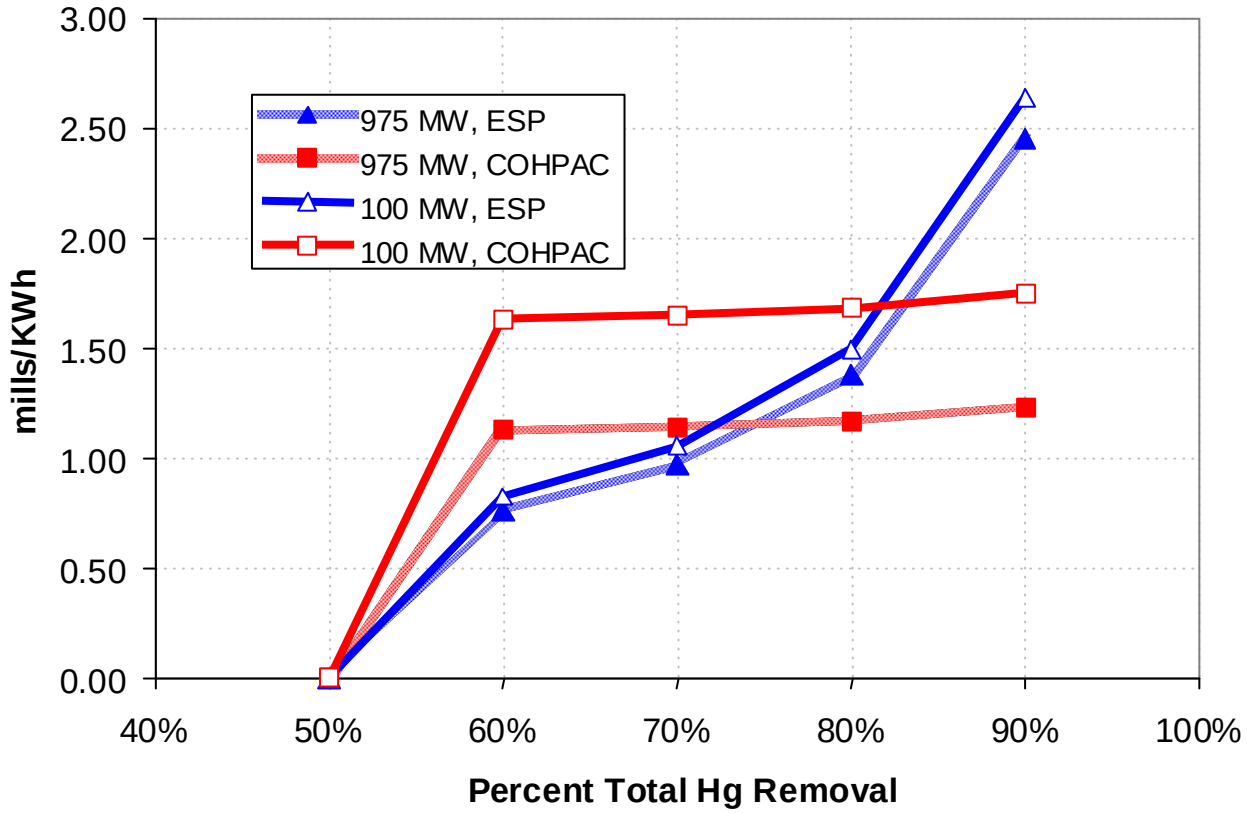
Note: Short-term tests, variability in Hg emissions, impacts on plant operation, unique test conditions, limited capture of Hg for low-rank coal, amount of carbon injected affects the level of capture.

Year-Long TOXECON™ Project
Gaston, Low-Sulfur Bituminous

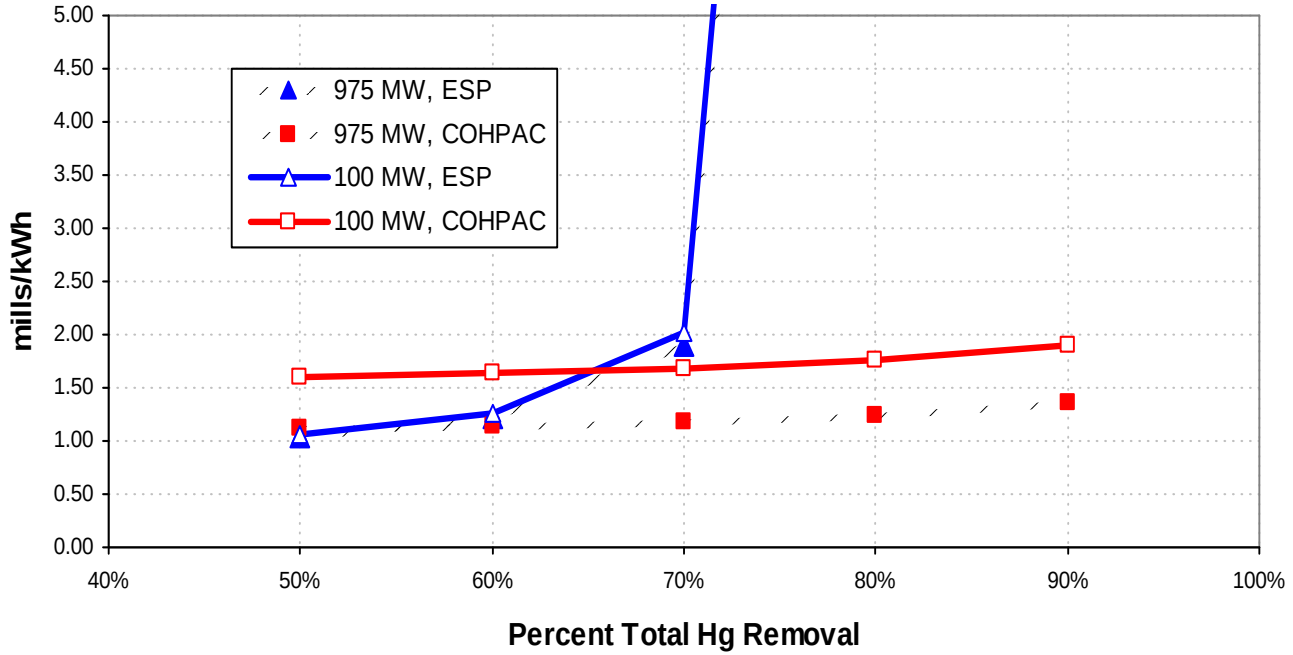


- **Weekly Hg removal between 80- 90%, average 86%, observed over 4 months of continuous operation**
- **Less variability in emissions over longer emissions averaging period**
- **Desirable to have multiple demonstrations with bituminous coals to provide experience base**
- **Similar information is needed for subbituminous coals and lignite**

Estimates of Cost of Control with Carbon Injection (Low-Sulfur Bituminous Coal)



Estimates of Cost of Control with Carbon Injection (Subbituminous Coal)

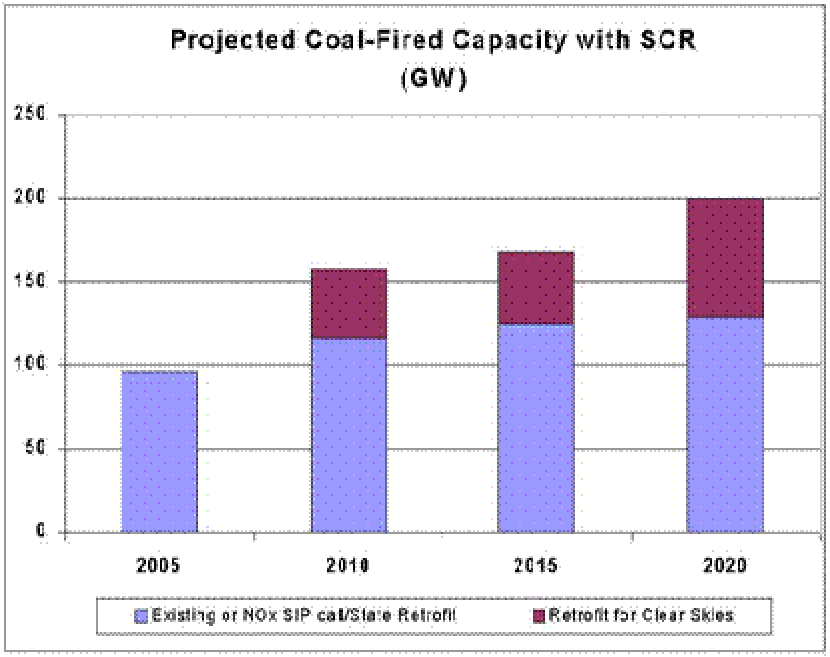


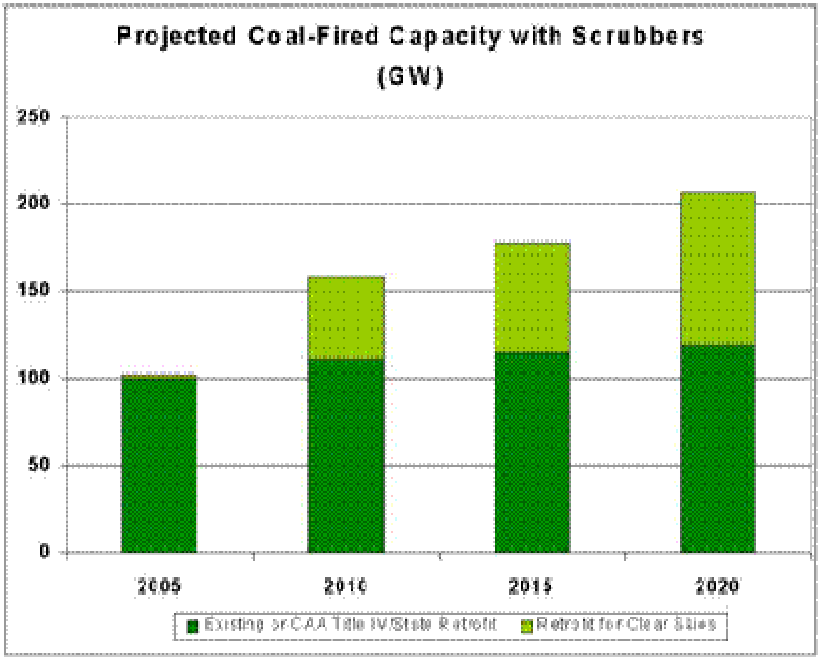
Other Mercury Sorbents

- Amended Silicates
  - Similar cost/performance as PAC is projected
  - Avoids ash disposal issues
  - To be tested by Cinergy at Miami Fort 6 under the DOE program
- Enhanced PAC
  - PAC-based sorbent with higher efficiency due to added chemicals
  - To be tested by Duke Power and DTE Energy under the DOE program
- Mercury Control Absorption Process (MerCAP)
  - Sorbent-coated (gold) metal plates suspended in flue gas
  - Slipstream tests at Great River Power, WEPCO, and Minnesota Power plants
- Sodium Tetrasulfide
  - Commercially used in Europe on waste incinerators
  - Avoids ash disposal issues

Sources: Babcock Power, 2003 Mega Symposium, DOE releases

Looking Ahead – SCR and FGD Projections

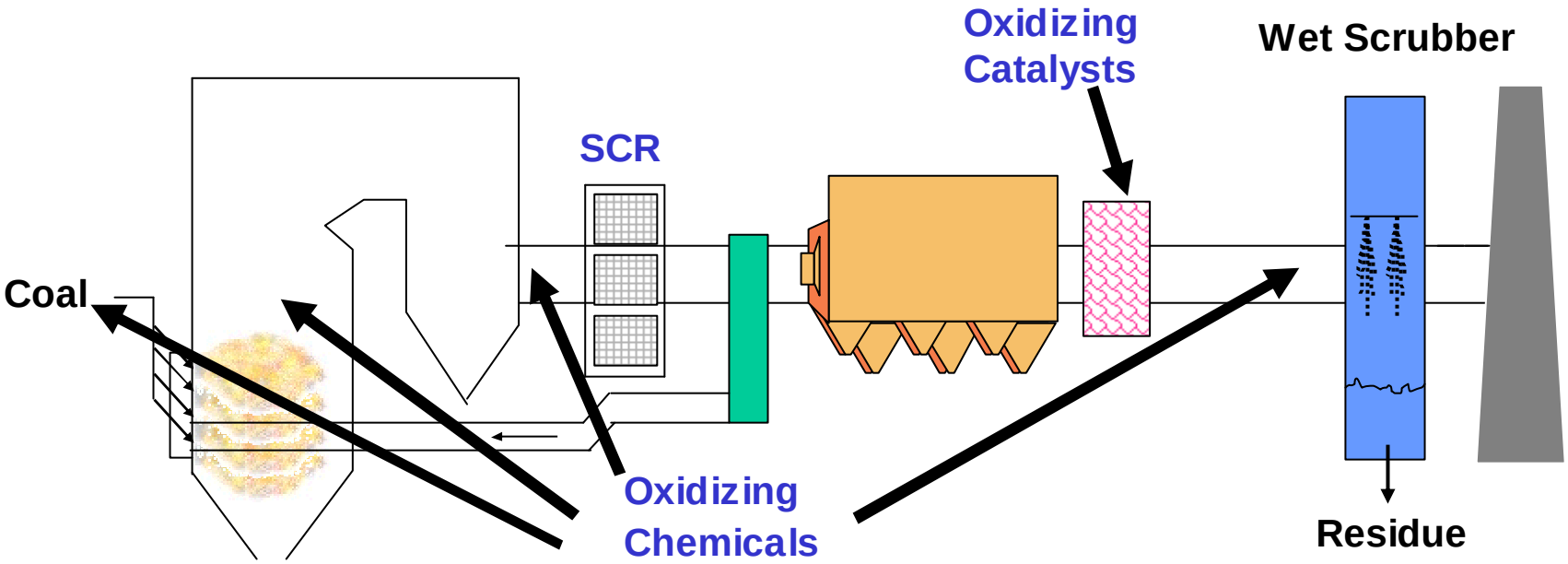




Source: 2003 Technical Support Package for Clear Skies

Enhancing Hg Removal in Wet Scrubbers

Increase the amount of Hg^{2+} in flue gas



SCR – Ongoing full-scale measurements: ~85- 90+% Hg removal for SCR + PM control + wet scrubber with bituminous coals; performance with low-rank coals uncertain. Effects of catalyst volume and aging need investigation. Optimize SCR for Hg capture.

Oxidizing catalysts and chemicals – under development

Ongoing Projects

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

Source: DOE/NETL

Summary & Conclusions

- Hg capture with existing controls depends on coal and technology type.
- More difficult to control Hg from low-rank coal-fired boilers.
- ICR data reflect that some plants already achieve between 85% and 95% control.
- ACI is an emerging Hg control technology.
- Hg control of 90% using ACI with a fabric filter for all coals is potentially achievable by 2010.
- Sorbents other than ACI are under development via EPA's Small Business Innovative Research program and by others.

Summary & Conclusions (continued)

- By 2015, large numbers of SCR and FGD systems are expected to be installed to control NO_X and SO_2, 90% to 95% Hg control is potentially achievable.
- Cost-effective Hg removal via ACI expected to add no more than about 1-3 mills/kWh to the annualized cost of power production.
- Optimization of NO_X and SO_2 controls could potentially reduce this cost substantially.
- ORD and others are investigating the possibility for mercury release from power plant residues.