Improvements in Technologies for Emission Reduction

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Improvements in Technologies:

- Aging Stationary Source Infrastructure
- New Technologies
- Rethinking Smaller Emission Sources

Aging Infrastructure:

- Aging industrial and power sector
- Slow fleet turnover and retrofit technologies more difficult
- Controls for new sources are relatively easy, effective, and expensive

Aging Infrastructure

- Utility boilers - useful operating life?
- Retrofit: putting new equipment on older sources
- 30 years post CAAA: Retrofit 1/2 and 2/3 Coal-fired Power with NO_x and SO_2, respectively
- Time to replace original retrofits (FGD, ESP, RTO, etc.)?
- Capacity expansion at industrial sources
- Don’t fixate on new sources

New Technologies

- New uses for existing technologies
- Doing more with less
- Integrated technologies
- Materials and construction
- Technologies for ‘new’ pollutants

New Uses for Existing Technologies

- ACI/PAC from MSW incineration to power
- Electron beam/plasma from clean rooms to industrial NO_x, SO_2, VOC/HAP & odor
- Catalytic systems – revisit due to higher fuel costs
- PM fine technologies
  - Fabric Filters: 30 years later
  - Electrostatic Precipitators: new & improved

Doing More with Less

- Reagents:
  - Less activated carbon – halogenates
  - Less lime/limestone – enhanced forms
  - Gas and sorbent injection
- FGD & ESP – less energy
- SCR/SNCR – less ammonia slip
- Flowpac/Bubbling Jet Reactor - pumpless
- Industrial catalysts – less fuel
- P^2 for industrials – concentrate & control

Integrated Technologies

- For Power:
  - NO_x + SO_2 + HG + PM + Condensables + CO_2
  - SCR+FGD+ACI+ESP+WESP+Amine Scrubber
- FGD in a bottle/Eurosilo
- Wet ESP integrated into FGD
- SNCR/SCR hybrids
- Mercury/particulate control – Toxecon(s)
- For Petroleum, Pulp & Paper, Cement …

Improvements in Materials and Construction

- Material science
  - Fiberglass reinforced plastics/rubber lined pipes
  - Absorbers: steel alloys, tiles, FRP
  - Steel alloys for advanced high temp/pressure boilers
  - Baghouse fabrics
- Modular construction
- Loose the bypass duct; add quick access stack vent

Technologies for 'New' Pollutants

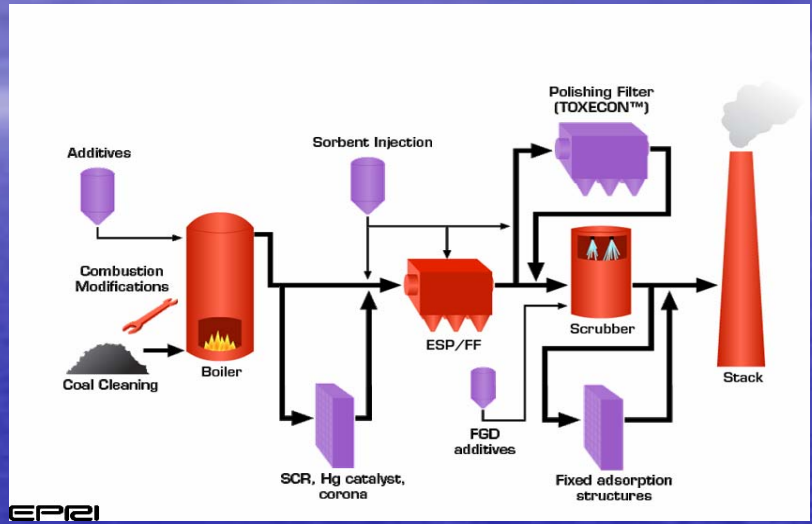
- PM fine tuned
- Mercury
- SO_3
- Condensables – control & measurement
- CO_2

PM Controls

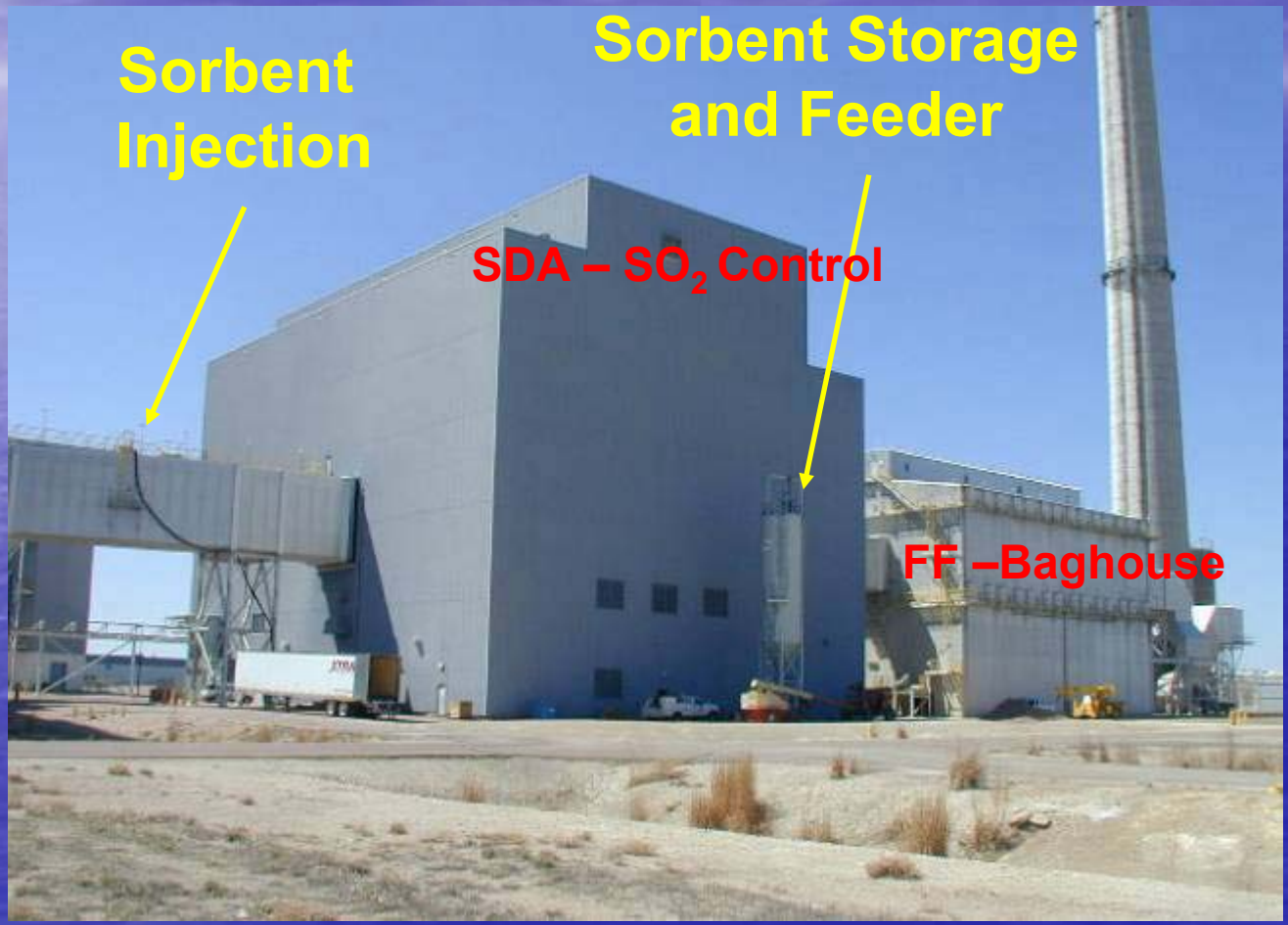
- New life for old controls
  - Advanced electrostatic precipitators
  - Resurgence in fabric filters
  - Condensables/SO_3
- PM for industrial sources
- Role of direct PM for local sources?

Wide Range of HG Control Options

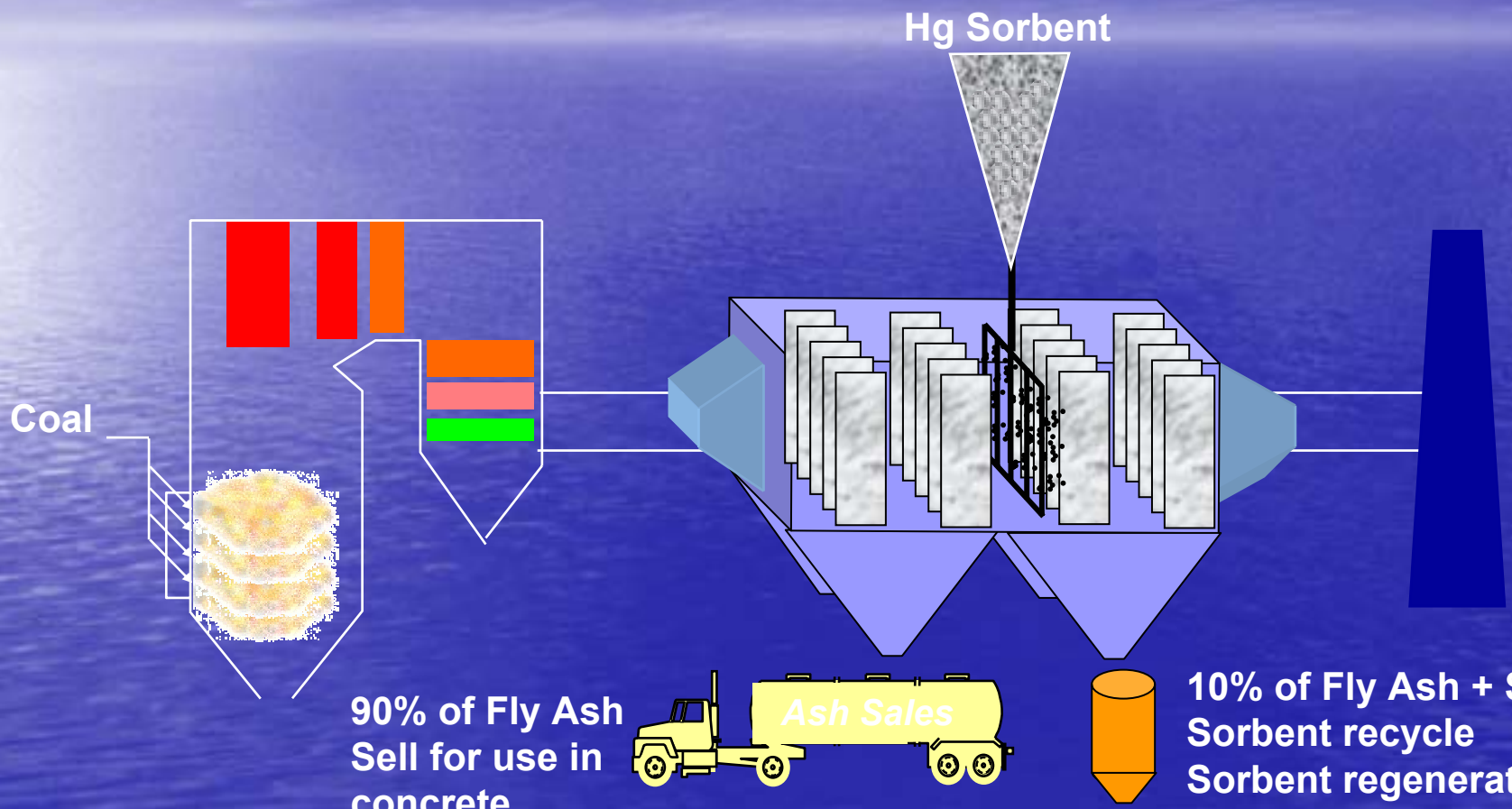
- Co-benefits
  - SCR, FGD, ESP, FF, etc.
  - Multipollutant control technologies
- Enhanced Co-Benefits
  - Chemical Oxidants
  - Oxidation Catalyst
  - High Energy Excitation
  - FGD Sorbents
- Pre-Combustion and Combustion Modifications
  - Coal Cleaning/Beneficiation - K-fuel process
  - Increasing LOI –GE Energy and Lehigh University
- Mercury Specific
  - Activated Carbon Injection (ACI/PAC)
  - TOXECON 1 and 2



Retrofit of ACI on an Existing Plant



EPRI TOXECON 2™ Configuration



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Commercial Mercury Control Technology Bookings

Air pollution control vendors are reporting booking new contracts for mercury control equipment for more than a dozen power plant boilers. The contracts for commercial systems are attributed to federal and state regulations, including new source permit requirements and consent decrees, which specify high levels of mercury capture. Below is a summary of the mercury control equipment that has been procured to date:

	Plant Size (MW)	Location	Prime OEM Contractor	Coal	APC Configuration	Hg Control	New Plant or Retrofit	Regulatory Driver
Unit 1	270	Midwest	Wheelabrator/ NORIT	PRB	TOXECON	ACI	Retrofit	Consent Decree
Unit 2	250	East	Wheelabrator	Bituminous	SDA/FF	ACI	Retrofit	State Regulatory
Unit 3	250	East	Wheelabrator	Bituminous	SDA/FF	ACI	Retrofit	State Regulatory
Unit 4	650	East	Wheelabrator	Bituminous	ESP	ACI	Retrofit	State Regulatory
Unit 5	740	Midwest	B&W	PRB	SDA/FF	Br-ACI	New Plant	New Construction Permit
Unit 6	550	Midwest	B&W	PRB	SDA/FF	Br-ACI	New Plant	New Construction Permit
Unit 7	350	West	B&W	PRB	SDA/FF	Br-ACI	Retrofit	Consent Decree
Unit 8	350	West	B&W	PRB	SDA/FF	Br-ACI	Retrofit	Consent Decree
Unit 9	800	West	B&W	PRB	SDA/FF	Br-ACI	New Plant	New Construction Permit
Unit 10	350	East	ADA-ES	Bituminous	ESP	ACI	Retrofit	Consent Decree
Unit 11	350	East	ADA-ES	Bituminous	ESP	ACI	Retrofit	Consent Decree
Unit 12	204	MidWest	Dustex	PRB	TOXECON	ACI	Retrofit	Consent Decree
Unit 13	375	East	Wheelabrator	Bituminous		ACI	Retrofit	Concent Decree
Unit 14	650	Midwest	Alstom Power	PRB	SDA/FF	Br-ACI	New Plant	New Construction Permit
Unit 15	215	Midwest	Powerspan	Bituminous	Multipollutant	ECO	Retrofit	Construction Permit
Unit 16		Midwest	Mobotec	PRB	ESP	MinPlus	Retrofit	Construction Permit
Unit 17	750	Midwest	Wheelabrator	High Sul. Bit	ESP/WFGD/WESP	ACI	New Plant	Construction Permit
Unit 18	680	South	Alstom Power	PRB	DFGD/FF	Br-ACI	New Plant	Construction Permit
Unit 19	107	East	BPI	Bit./Bio-Mass	FT-SNCR/CDS/FF	ACI	Retrofit	DOE Demo.

CO_2 Capture & Control

- High efficiency generation is only first step in reducing CO_2
- Existing coal-fired power plants: 10-12 % CO_2 by volume
- Already have CO_2 systems – high cost
- Need new retrofittable CO_2 reduction and capture technologies for large existing fleet

General Improvements for Mercury Control

- Techniques to enhance and control mercury oxidation
- Techniques to minimize re-emission
- Potential impacts on by-products
- Less capital intensive techniques
- Cost of mercury removal is coming down

CO_2 Separation & Capture Research & Options *

- "conventional technology" – amine-based scrubbing
- Low-temperature (cryogenic) distillation
- Gas separation membranes – carbon fiber, ceramics and high-temperature polymeric membranes
- Absorbents - carbon or sodium, hydrides and lithium silicates
- Mineralization and biomineralization (carbonate solids)
- Oxygen-enhanced combustion approaches
- Chilled ammonia solvent with associated absorber/regenerator

* *"very little R&D has been devoted to CO_2 capture and separation technologies"*

Rethinking Smaller Sources

- Same issues as for power
  - Older, expanding fleet
  - Don't fixate on new sources
  - Tough to trade
- Lack scalability
- Continuation of MACT process
- ***Need new paradigm for controlling existing industrial sources***
- Look at low capital technologies
- Transferability of control technologies
- Develop market-based approaches

Conclusions

- Huge market and rewards still in cleaning up the existing aging infrastructure
- Low capital cost options increasingly available
- Need new approaches for controlling existing industrial sources

Appendix

- Hybrid SNCR/SCR
- Co-Benefit Plus example
- Multipollutant control option - example
- CO_2 capture & control:
  - Systems
  - What we already know

Integrated Technology: Hybrid SNCR/SCR

- Redesigned SNCR System with In-Duct SCR
- Higher NO_x Reduction and Utilization than SNCR
- Lower Capital Costs than Full-scale SCR
- Greater Operational Flexibility
  - Seasonal NO_x Emission Limits
  - Seasonal and Daily Load Variations
  - Marketplace Variations (Fuel Supply, NO_x Credits)
- Maximum Reduction Achieved (>50%)
  - System Tuned to 2 (low load), 10, or 20 ppm slip
- Hybrid SNCR/SCR Operated for more than 5 years
  - 2 Utility and 3 Industrial Hybrid Applications

Recent Wet FGD Co-Benefit … Plus

Mount Storm Site Test (WV)

- Eastern Bituminous Coal
  - medium sulfur (1.82%)
  - 4,000 tons/day
- 1662 MW (3 units combined)
- Air Pollution Controls
  - SCR – 2 layers
  - ESP
  - wet FGD – forced oxidation limestone

Results of Co-Benefit … Plus

70% mercury removal with only wet FGD
- some mercury re-emission at outlet

80% mercury removal with wet FGD plus additive (w/o SCR)
- additive stopped mercury re-emission
- SO_2 removal by wet FGD system not impacted by additive technology

90% plus mercury removal with wet FGD & SCR
- > 95% of mercury in oxidized state after SCR
- similar results with/without FGD additive (no mercury re-emission to control)

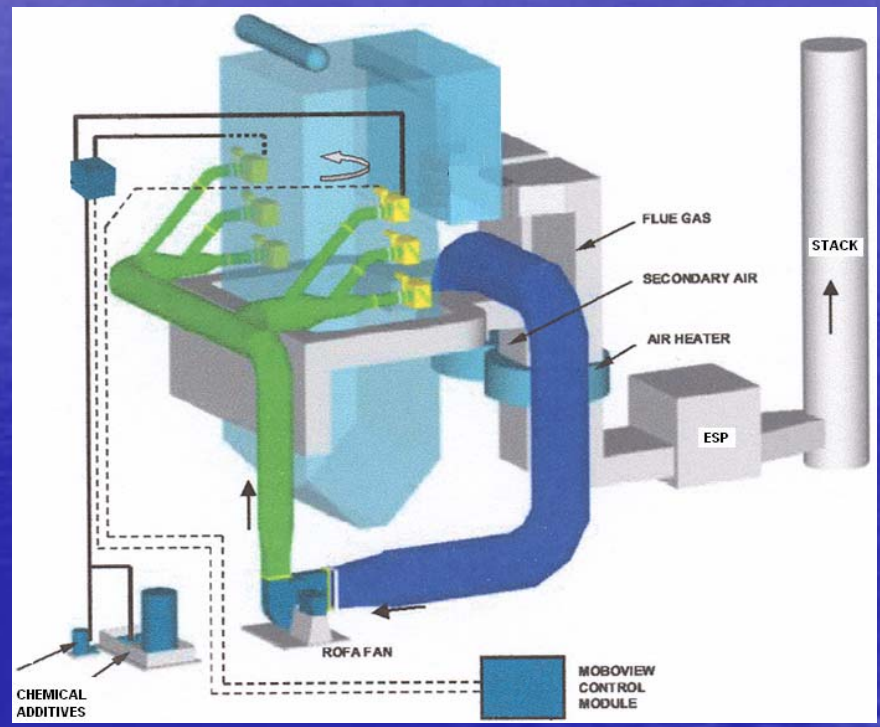
❖ Demonstrated improvements using wet FGD additive process (B&W patented sodium hydrosulfide)
  - Improved removal of mercury w/o SCR in-service
  - Cost-effective incremental mercury removal (w/o activated carbon injection)

Additional Multipollutant Control Options

Mobotec Rofa & Rotamix Technologies

- MINPlus - Sorbent Injection in Boiler
- Scrubber After Boiler

- Performance
  - 60 % NO_x
  - 65 % SO_2
  - Up to 90 % Hg
- Commercial Application
  - Minnesota Power
  - Taconite Harbor Energy Center
  - Startup 2006-2008 timeframe
  - $60 million (includes NO_x control for Laskin Unit 2)



CO_2 Capture & Control - Systems

Post-combustion capture – chemical/physical separation

- Retrofitting/repowering existing power and industrial processes

Oxy-fuel combustion – O_2 injected into combustion chamber

- Produces CO_2 and water; some CO_2 recycled and mixed to absorb heat and control reaction temperature

Pre-combustion – gasification producing synthesis gas of hydrogen and CO_2

- CO_2 separated from hydrogen prior to combustion

CO_2 Capture & Control: What we already know

- Separate and concentrate for sequestration
- Already captured in oil, gas and chemical industries
- Commercial cryogenic and carbon absorbent systems
- Routinely separated and captured as a by-product from industrial processes such as synthetic ammonia production, H_2 production, and limestone calcination
- Recovered from combustion exhaust by using amine absorbers and cryogenic coolers
- Development and cost reduction using oxy-fuel combustion and amine separation