Finally…

...my turn

Energy and Environmental Strategies
Overview

• Key issues regarding control technology options and decisions

• Single and multi-pollutant control technologies

• An “example”
Summary

• Technology choices challenging in light of...
  – Regulatory landscape
  – Technical impacts between technologies
  – Plant economic performance/life
  – “commercial” vs. new technology risk
  – New technology paradigm shift

• Technology options are many...
  – Combined single–pollutant control technologies (e.g. SCR, FGD, ESP, ACI)
  – Multi-pollutant control technologies (e.g. Powerspan, etc.)
  – Generation technologies /fuels (e.g. IGCC, GTCC, etc.)

• Northeast “example”
  – Decision driven by
    • Compliance timing
    • Technology risk profile
    • Plant specific characteristics
Power Plant Emissions

Energy and Environmental Strategies
Flue Gas Path

Energy and Environmental Strategies
Technology challenges…
Impact of SCR on Hg Removal

• Bituminous coals:
  – Significant oxidation for high Cl coals;
  – Oxidation decreases over time;
  – Oxidation reduced by presence of NH$_3$

• PRB coals:
  – Minimal oxidation

• Bottom Line
  – current R&D to provide further knowledge

Energy and Environmental Strategies
Impact of SCR and ACI on flyash

• Ash contamination by
  – NH3
  – AC
  – Hg
  
  Can render it unacceptable for recycling
Impact of Dry FGD on Hg Removal

• Test results show poor Hg removal when AC is added in or downstream of SDA:
  – Removal of SO₃ and HCL limit uptake on carbon particles.

• Ongoing R&D/testing

Energy and Environmental Strategies
Mercury Removal across APCDs

Hg Removal across PCD

ESP
FF
HESP

Hg Removal across FGD

ESP
FF
HESP
WS

Hg Removal across SDA-PCD

ESP
FF

Energy and Environmental Strategies
Uncertainty in mercury measurements

Energy and Environmental Strategies
“New" technology paradigm shift

• In the not so distant past, new technologies came in to the market place mainly with increasingly higher performance attributes (e.g. SCR “better” than SNCR “better” than LNBs)

• Today “commercial” technologies can give us 90+\% reductions on NOx, SO2, PM, (even Hg ???) emissions

• Hence, “new” technologies must find other arguments to compete

• Such “arguments” are more difficult as compliance dates are nearer, environmental regulations are confusing, wholesale power market dynamics are evolving (deregulation…), fuel (gas) options have emerged, new generation technologies (IGCC) become alternatives…

Technology vendors today must not only develop “good” products but also “market” them successfully

Technology “consumers” must be ever more educated to be able to make good technology decisions

Less incentive for technology “push” from environmental community

Energy and Environmental Strategies
Conventional Control Technologies
NOx Control Technologies

• Combustion modifications
  – LNBs, OFA, FGR, Reburn
    • >250GW
    • 20% - 70%

• Post-combustion
  – SNCR
    • 10-12GW
    • 20% - 50%
  – SCR
    • ~110GW
    • 80% - 95%
## SO2 Technologies
**Capacity (MWe) Equipped with FGD**

*source - EPA*

<table>
<thead>
<tr>
<th>Technology</th>
<th>United States</th>
<th>Abroad</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet</td>
<td>82,092</td>
<td>114,800</td>
<td>196,892</td>
</tr>
<tr>
<td>Dry</td>
<td>14,081</td>
<td>10,654</td>
<td>24,735</td>
</tr>
<tr>
<td>Regenerable</td>
<td>2,798</td>
<td>2,394</td>
<td>5,192</td>
</tr>
<tr>
<td><strong>Total FGD</strong></td>
<td><strong>98,971</strong></td>
<td><strong>127,848</strong></td>
<td><strong>226,819</strong></td>
</tr>
</tbody>
</table>
FGD Performance

source - EPA

Energy and Environmental Strategies
PM Control Technologies for Power Plants

• Electrostatic precipitators (ESPs)
  – 72% of U.S. coal-fired boilers, total PM up to 99.9%, fine PM 80-95%

• Baghouses
  – 14% of U.S. coal-fired boilers, total PM up to 99.9%, fine PM 99-99.8%

• PM scrubbers
  – 2% of U.S. coal-fired boilers, total PM 95-99%, fine PM 30-85%

• Cyclones

Energy and Environmental Strategies
<table>
<thead>
<tr>
<th>Control Technology</th>
<th>Effect on Oxidized Hg</th>
<th>Effect on Elemental Hg</th>
<th>Effect on Particulate Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESP</td>
<td>Little if any</td>
<td>Little, if any</td>
<td>Efficient removal</td>
</tr>
<tr>
<td>Fabric Filter</td>
<td>Adsorption on fly ash (western fuel)</td>
<td>Adsorption on fly ash (high LOI ash)</td>
<td>Efficient removal</td>
</tr>
<tr>
<td></td>
<td>Decrease due to oxidation in some cases</td>
<td>Decrease due to oxidation in some cases</td>
<td></td>
</tr>
<tr>
<td>Flue Gas Desulfurization</td>
<td>Efficient removal</td>
<td>Little if any removal</td>
<td>No effect</td>
</tr>
<tr>
<td></td>
<td>Increase due to oxidation Increase due to oxidation</td>
<td>Decrease due to oxidation Increase in some cases</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase due to reduction of adsorbed oxidized mercury</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCR</td>
<td>Increase due to oxidation</td>
<td>Decrease due to oxidation</td>
<td>Increase in some cases</td>
</tr>
<tr>
<td>SNCR</td>
<td>No effect</td>
<td>No effect</td>
<td>No effect</td>
</tr>
</tbody>
</table>
Mercury-specific control Technologies

DOE Demonstration Projects

• Plants without “wet scrubbers”
  – Dry Sorbent Injection (e.g. ACI)

• Plants with “wet scrubbers”
  – Hg oxidation before FGD

Energy and Environmental Strategies
Sorbent Injection System
Mercury Removal Trends with ACI

Source: ADA Environmental Solutions (2003)

Energy and Environmental Strategies
Emerging Technologies

- Reduce costs
- Increase performance
- Increase flexibility

Energy and Environmental Strategies
## Selected Advanced/Emerging Technologies

**WGI-EPRI – AQIV 2003**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Process Description</th>
<th>Commercial status</th>
<th>Controlled pollutants</th>
<th>Removal efficiency</th>
<th>Published costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECO Powespan</td>
<td>Electro-Catalytic Oxidation followed by scrubber and wet ESP</td>
<td>Pilot and demonstration tests completed 50MW unit under construction</td>
<td>NOx</td>
<td>55-80</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SO2</td>
<td>46</td>
<td>$150-200/kw</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hg</td>
<td>&gt;60</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>metals</td>
<td>&gt;90</td>
<td></td>
</tr>
<tr>
<td>LoTOx</td>
<td>Ozone injection for NOx and Hg oxidation and removal by wet scrubber</td>
<td>Completed 25MW demo - NOx only</td>
<td>NOx</td>
<td>90-95</td>
<td>NA</td>
</tr>
<tr>
<td>BOC Gases</td>
<td></td>
<td></td>
<td>Hg</td>
<td>90+</td>
<td></td>
</tr>
<tr>
<td>Pahlman Process</td>
<td>Dry injection of Pahlmalite sorbent</td>
<td>Pilot work ongoing NOx-SO2 demonstrated separately</td>
<td>NOx</td>
<td>95+</td>
<td>$150/kw</td>
</tr>
<tr>
<td>Enviroscrub</td>
<td></td>
<td></td>
<td>SO2</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>AIRborne B&amp;W</td>
<td>Dry sodium injection or wet sodium scrubbing with multiple options for fertilizer products</td>
<td>CCPI project - 525 MW start-up 2007</td>
<td>NOx</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>AIRborne Technologies</td>
<td></td>
<td></td>
<td>SO2</td>
<td>85-95</td>
<td>$170/kw</td>
</tr>
<tr>
<td>K-fuel</td>
<td>High energy fuel from Testy burns completed K-fuel in WY</td>
<td>NOx</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kx</td>
<td>Low quality coal feed stocks</td>
<td>SO2</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hg</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Mitsui-BF process</td>
<td>Carbon bed absorption with regeneration overseas NH3 injection for NOx control</td>
<td>Several installation NOx</td>
<td>NOx</td>
<td>60-80</td>
<td>$110-140/kw</td>
</tr>
<tr>
<td>Marsulex</td>
<td></td>
<td></td>
<td>SO2</td>
<td>80-93</td>
<td></td>
</tr>
<tr>
<td>GSA</td>
<td>OFB Absorber with lime injection</td>
<td>Commercial largest unit to date is 125MW</td>
<td>SO2</td>
<td>&gt;95</td>
<td>$150/kw</td>
</tr>
<tr>
<td>FL Smith/Airtech</td>
<td></td>
<td></td>
<td>SO3</td>
<td>&gt;95</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hg</td>
<td>60-90</td>
<td></td>
</tr>
</tbody>
</table>

**Energy and Environmental Strategies**
NOx-SO2-Hg
Electro-Catalytic Oxidation™ (ECO)

- Process
  - Barrier discharge reactor oxidizes gaseous pollutants
  - Products of the oxidation are captured in ammonia scrubber and wet ESP
  - Ammonium nitrate and sulfate (fertilizers) byproducts

- Status
  - Pilot scale test at approximately 2-4 MW equivalent
  - Projected reductions: 90, 98+, 80-90, and 95% of NOx, SO2, Hg, and fine PM
  - DOE-sponsored testing to evaluate mercury removal performance

Energy and Environmental Strategies
K-Fuel®

- K-fuel is a beneficiated coal derived from western subbituminous coals that is lower in ash, higher in BTU value, and produces lower pollutant emissions than parent coals.

- Test burns at the SRI - significant reductions in NOx and SO2

- First commercial plant being built at the Black Thunder mine in Wright, Wyoming; completion by 2004; capable of producing more than 700,000 tons per year of K-Fuel

Energy and Environmental Strategies
An example

Compliance with regulations in the Northeast
Background

- Environmental requirements for coal-fired plants (state regulations – post OTC NOx budget, title IV)
  - Multi–pollutant
  - 2006 compliance
    - Must minimize R&D risks

- The Station
  - Real Estate constraints
    - Configuration options reduced
Environmental Requirements

• The regulations
  – Multi-pollutant controls
  – Compliance 2006

• NOx - 1.5 lb/MWh (~55% reduction from SNCR)
  (~75% reduction from LNBs)

• SO2 - 3.0 lb/MWh (~75% reduction)

• CO2 - 1800 lb/MWh

• Hg - 85% - 95% (two phases)
Other Environmental “Forces”

• Strong anti-coal pressure

• Solid waste disposal
  – Few options
  – High cost

• **Bottom line…**
  – Low emission (high reductions) targets
  – Short time frames
  – Multi pollutant considerations
  – Still some uncertainty

Energy and Environmental Strategies
The Station

• 4 units - ~750MW
  – Units 1,2 - ~80MW coal
  – Unit 3 – 150MW coal
  – Unit 4 – 450MW oil

• Coal units
  – Low sulfur (<1%) coals
  – Wall-fired boilers
  – Low NOx burners
  – OFA (unit 3)
  – SNCR

Energy and Environmental Strategies
The Station (cont’d)

- Large ESPs (>450 SCA)
- Other performance information
  - NOx: 0.45-0.55 lb/Mbtu (w/o SNCR)
  - SO2: <1.2 lb/Mbtu
  - Hg: 80-90% capture (baseline)
    - ICR phase III participant
    - MA Hg test program (2000-2002)
    - DOE Hg control full-scale demo
  - Carbon-in-ash: 20-30%
The Station (cont’d)

Summary…

• Older vintage, small units, space-constrained plant
  – Some technical options not viable/economic
• “Neighborhood” challenging for power plant
  – technical choices must be “compatible” w/ political realities
• Baseline emissions low
  – Important consideration for overall compliance strategy

Energy and Environmental Strategies
Options

- Conventional, individual unit technologies
  - SCR
  - FGD (wet or dry)
  - Hg Sorbent injection

- New multi-pollutant technologies
  - Powerspan
  - Airborne
  - Enviroscrub

- “Hybrid” innovative application of commercial technologies
Options (cont’d)

• Conventional, individual unit controls
  – Space constraints
  – High cost

• New multi-pollutant technologies
  – Technology risk
  – Uncertain cost

• Innovative application of commercial technologies
  – Lower technical risk
  – Lower cost (~$35M) savings
Proposed Project

• **Emission Control Technologies**
  – NO\textsubscript{x} control using clean-side SCR
  – SO\textsubscript{2} control using SDA
  – PM control using existing ESPs and new FF
  – Acid gas control using the SDA and new FF
  – Mercury control using the SDA/FF (ACI if necessary)

• **Multi-pollutant Control**
  – Single pollution control train for multiple emissions from three three coal units

• **Byproduct Utilization, Treatment and Disposal**
  – Fly ash beneficiation with integrated mercury control technology
  – The FF may allow possible reuse of SDA byproducts

Energy and Environmental Strategies
Summary

- Project approach utilizes combination of innovative application with proven, low risk technologies
- Overall emissions reductions capabilities beyond MA requirements
- Cost savings of ~$35M vs. conventional deployment of NOx, SO2 controls
- Ash beneficiation carries large incentive (high disposal costs in the Northeast)
Thank you!
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Energy and Environmental Strategies